Trey: Hello everyone, and thank you all for this. Today's webinar, "What's the Difference?" Nylon 6 versus Nylon 66 is presented by PolyOne. Your presenters today are Mark Elkovitch and Renlong Gao. Mark Elkovitch is currently the Senior Technology Manager at PolyOne Corporation where his focus is on the development of Continuous Fiber Thermoplastic Composites, and he joined PolyOne in January of last year. Mark earned his Bachelor of Science degree in Chemical Engineering in 1995, and his Ph.D. in 2001, both from Ohio State University.

Joining Mark is Renlong Gao. Renlong is a polymer scientist with experience developing innovative thermoplastic and thermostat materials. In his current role as lead R&D chemist for Specialty Engineered Materials business at PolyOne, he is responsible for growing the Nylon-based product platform to deliver cutting-edge material technology to customers.

My name is Trey [inaudible 00:00:58] with UL, and I'll be moderating today's event. You can send us your questions by typing them in the question box located on your screen and our panelist 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 the UL Prospector Knowledge Center. With that, I'd like to turn the presentation over to Mark. Mark?

Mark: Hello, everyone. Thank you for joining me and Renlong today, for we hope it will be an informative and enlightening discussion of Nylon 6 and Nylon 66. Together, we'll explore these two most popular grades of Nylon which are also called PA6 and PA66 to help you understand the difference between them and how you can determine which is the best material for your application.

Before we get started, we want to let you know that you'll be receiving the slides from this webinar from UL Prospector and a follow-up email. Now on to the agenda. We'd like to begin today by providing a little background on Nylon then we'll move into Nylon performance and use, the processing of Nylon 6 and Nylon 66, the applications where you're most likely to find these materials use, and how to decide which one to select. After that, we'll be happy to take your questions. So let's get started.

Renlong: Nylon is a thermoplastic that can be processed to create flexible fabrics, rigid shapes, and malleable films. Typically, this material is used to replace metal for lightweight in resins. Glass-filled Nylon, for example, has been used for years in metal replacement application and is still popular today. It can actually provide a higher strength to weight ratio than most metals. This is possible because Nylon is a semi-crystalline polymer which contain both amorphous and a semicrystalline regions. This means that this molecular chain is folded together and forms outer regions called lamellae, which in turn create larger spheroidal structures known as spherulites. These lamellae and the spherulites are what give Nylon the ability to form into flexible, malleable, and rigid products.

Mark: The person who first introduced this amazing polymer in the U.S. was a chemist named Wallace Carothers. In 1935, Carothers and his team at the DuPont experimental station in Wilmington, Delaware, introduced the 66 grade. Soon thereafter, Nylon 6 was developed in Germany. The timing for both could not have been better. With the outbreak of World War 2, the demand for Nylon and fiber applications rose exponentially. Why? Because engineers saw it as a replacement for parachute silk which are becoming increasingly scarce. This synthetic material was eventually recognized as extremely useful, enabled to be molded into strong, rigid, or flexible components for transportation, shooting sports, sporting goods, industrial, and electrical and electronic applications.

Renlong: Today, over [inaudible 00:04:30] years up to the discovery, Nylon uses has really skyrocketed. BCC Research asked me that the world consumption of Nylon not including Nylon fiber is about £7 billion per year. In many cases, fiber fillers are often used to reinforce Nylon providing the considerable stiffness and strength that is needed for many demanding applications. These fiber reinforced polymer formulations are what we've been focused on today.

In nearly every industry, fiber reinforced Nylon formulation are used as metal replacement material. Automotive manufacturers routinely uses Nylon for its ability to provide a higher strength to ratio than most metals. In fact, without the use of Nylon, it will be incredibly difficult for automotive companies to build cars that offer better mileage while still providing the safety we have all the come to expect. The addition to Nylon 6 and Nylon 66 you may have encounter formulations such as Nylon 6/10, 6/11, and a 6/12. One thing to keep in mind is that the high number do not necessarily indicate increased performance, instead, it's simply described the chemical structure of the polymer chain.

Mark: Both Nylon 6 and 66 materials are easy to process, provide incredible strength, they're very tough. While they're very similar, each offers separate and distinct benefits. Nylon 6 is made from a caprolactam monomer having six carbon atoms. It is known for its lustrous surface finish as well as its high impact strength and stress resistance effectively combining aesthetics with performance. Fiber-filled Nylon 6 is processed easily using extrusion or injection molding machinery. It processes at a lower temperature and is less crystalline than Nylon 66.

A 30% glass-filled Nylon 6 will melt at approximately 220 degrees C and will also exhibit lower mold shrinkage, a common benefit with crystalline and semicrystalline materials. Lower mold shrinkage has reliability and consistency to final part dimensions. Unlike Nylon 6, Nylon 66 is comprised of two monomers, Hexamethylenediamine, and adipic acid, each providing six carbon atoms hence the 66 name. The material is more crystalline in nature than Nylon 6 which improves stiffness and tensile and flexural modulus.

Fiber-filled Nylon 66 can easily be extruded or injection molded and it has a melting point of approximately 262 degrees C, which is about 40 degrees higher than Nylon 6. This causes it to be slightly more challenging to process. Additionally, Nylon 66 makes a bit greater mold shrinkage when compared to Nylon 6 because it's more crystalline. To combat this, dimensions for extrusion dies and injection molds should be proportionately increased to account for the material shape change after processing.

In general, Nylon is a moisture sensitive material and will naturally absorb humidity from air. Nylon 6 will absorb slightly more moisture than Nylon 66. Because both materials absorb water, they require a prescribed drying step before they're molded or extruded. And this thing occurs when you allow a molded or extruded part to rest in an ambient environment with normal humidity levels. As the part absorbs waters, the ductility and impact resistance can be improved by up to a factor of 10, but strength and stiffness are reduced.

When you're researching Nylon types you will see D-A-M listed next to properties. And that acronym stands for dry as molded. Note that these are the properties you can achieve before any type of conditioning. Nylon 66 naturally absorbs less moisture than Nylon 6. But what is still relatively moisture sensitive compared to polycarbonate, for example. As with Nylon 6, drying before molding is necessary to achieve dry as molded properties.

Again, as the material rest in an environment with normal humidity levels, the ductility and impact performance can be improved up to a factor of 10. However, as with Nylon 6, strength and stiffness are reduced, so there is a tradeoff. With those conditions in mind, let's explore the applications ideal for each.

Renlong: While you're looking for a lightweight material designed to withstand high impact and high stress, Nylon 6 actually is what you want, often used in automotive, industrial, and military markets. Engineered Nylon 6 application including gears, automotive engine compartment and the semi-structural parts, firearm components, and kitchen utensils.

Mark: So one of the benefits of using Nylon 6. Generally, products made from this material have a lustrous finish, are easily blended with additives and have durable color, especially those created from fiber-filled grades. Nylon 6 also withstands high impact and stress and it stands up to high carbons very well allowing it to be positioned in automotive applications. Look to Nylon 6 for applications such as gears and semi-structural automotive components that can take advantage of this grade's wear resistance and lubricity. And don't forget military and industrial components which are a great mask to exploit the material's, high impact and stress resistance.

Renlong: Nylon 6 does have some drawbacks though because it has a slightly higher order absorption rate. And because it has a lower heat deflection temperature than Nylon 66 it's better suited for applications that are not regularly exposed to water at higher temperatures. Also Nylon 6 exhibits poor resistant to acid. In fact, that you generally want to avoid Nylon 6 materials for applications that requires sustained performance in harsh environments.

Mark: We've found a great example of an application that takes advantage of the strength and lightweight of Nylon 6. One of our automotive OEM customers used it to replace sheet metal in a seat fastening plate. This rectangular piece mounted onto the driver in front passenger seats functions as the attachment point for power steering positioning, heating, and electronics. It's a very complex part with multiple openings and an irregular shape. The OEM found that the sheet metal was restricting design flexibility and heating into productivity because each of their automotive manufacturing customers were requesting custom attachment configurations for the partner. At the same time, the manufacturers were clamoring for lighter parts.

The OEM needed something that offers high strength and stiffness, impact resistance, moderate temperature resistance, and low warpage. What they used was a Nylon 6 compound with 30% glass fiber reinforcement. The material met all OEM requirements and it allowed greater design freedom because the parts were injection molded rather than stents. It also enabled them to duplicate key performance attributes while gaining new benefits in the areas of costs, savings, and weight reduction.

Now, for the other side of the fence. When you're looking for a material that will stand the test of time for products, subjected to high temperatures and hydrocarbon exposure, look no further than Nylon 66. Often used for friction bearings, bolts, and fasteners, radiator caps, battery modules, tire ropes, and other general purpose uses. Nylon 66 is a high performer. You may wonder why battery modules are listed because Nylon, in general, is not resistant to acids and basis. While Nylon 66 should not be positioned for parts that make contact with battery acid, it is very suitable for brackets and support parts such as clamps and clips that are near the battery module because it has very good electrical insulation properties.

Renlong: This Nylon 66 material exhibits a higher heat deflection temperatures and a lower moisture absorption rate than Nylon 6, which translate into a poor performance in high-temperature water, for example, in radiator caps. Additionally, it's in poor stiffness, tensile modulus and the flexural modulus are deal for applications that need or were paid a long-term performance. Nylon 66 is also well suited for applications that need to be impermeable such as engine housings.

Nylon 66 does have some drawbacks, however. For example, it has a naturally reddish brown tint that makes it slightly more difficult to color. And then with careful color design car change in Nylon 66 pattern may occur once they're exposed to, of course, but you can prevent this with a proper stabilization keeping in mind that you're not going to get the lustrous service finish you would get with Nylon 6 however. Turning into the automotive industry, let's look at the example of Nylon 66. They're used to solve our difficult problems.

Recently, a leading global OEM plastics parts manufacturer had begun producing safety belt guides for a sport utility vehicle. The guides which direct the safety belt from the ceiling to the seatback were produced using insert molding. In this process, a metal insert is placed into the mold before a thermoplastic material is injected around it. For the safety belt guide, the insert consisted of a large metal loop with an anchor point for assembly.

The manufacturer found that as the parts cooled after molding, they developed cracks at the top of the loop that made the guides unusable. The effects were attributed to the metal loop which dissipated heat much faster than the thermoplastic material and accelerated expansion and contraction in the part. As a result, scrap rates on the part were approaching 80%. And to make matters worse, scrap parts could not be economically reground and reused because the guides contained a combination of metal and plastic.

Using a Nylon 66 compound eliminated the cracking problem and harmonizes the surface appearance to other interior components. The specialty compound met or exceeded application requirements that included high flow for easier processing, excellent impact resistance, high-quality service appearance, and with the help of color stabilization, long-term aging and color retention. In the end, the OEM was able to reduce its scrap rates from 80% to nearly zero maintaining its supply position and reputation with its automotive OEM customer and improve the surface appearance of the safety belt guides.

So how do you make the decision to use 6 or 66? There's both an art and a science to this. With design flexibility...well, design flexibility is given for both materials consider your applications need in terms of processing, aesthetic appearance, and mechanical properties first. Then map them to the comparison points we've given you here to find the best fit. Before we open the floor to questions, I'd like to take a moment to provide some background on PolyOne.

If you're not familiar with us, we're based in Avon Lake, Ohio just west of Cleveland. With facilities around the world, we provide manufacturers and processors across nearly every industry, the specialty polymers, colorants and additives, polymer sheet, and services such as polymer distribution and design. Thanks for your patience and now we'll get set for questions and answers. My colleague, Paul Hans, will be moderating the questions. Paul is a senior product scientist with a Specialty Engineered Materials group. Troy, are we all set for Q&A now?

Troy: Yes, we are Mark. We'll give you guys just a few moments to review. A lot of great questions that have already come in this far. Just to remind you, to everybody online, we are moving into our question and answer session at this time. You can submit questions by typing them in the question box that's located on your screen and our panelist will get to those questions. Already a lot has come in so far. So, please, do continue to send those in.

Questions regarding, "Where can they get a copy of the presentation? Where can they get a copy of the slides?" We will be sending you guys a link to that via email so you'd be checking your email for that in a few days. But we have had a lot of great questions, again, coming thus far so well go ahead and get those kicked off. Whenever you guys are ready feel free to take it away.

Paul: Okay, thank you, Troy. And guys as Troy said please let's continue having some questions send in here, so here's the first one. Why is the surface appearance of glass-filled PA6 much better than that of PA66? Mark, would you like to get that one or...?

Mark: Yeah, sure, I'll answer that question. Nylon 6 will tend to have a better surface appearance than Nylon 66 because Nylon 6 actually crystallizes much slower than Nylon 66 does. So when you think about an injection molding application, let's say a glass-filled PA6, say 30%, 40%, 50% glass-filled, what happens is when the injection molder forces the packs to part out because Nylon 6 will actually crystallize so much slower, it will actually force more polymer to the surface giving you a real resin rich surface. Nylon 66 won't do that as well as 6 because it crystallizes much faster. So during the packing process, more glass fibers will actually end up on the surface. So if you have a 30%, 40%, 50%, whatever glass fiber part, a Nylon 6 part will typically look a little bit more lustrous than a Nylon 66 part will.

Paul: Okay, super. And here's another one, "What can I do to maximize the performance of Nylon?" Renlong?

Renlong: All right. So, in order to maximize the property with Nylon really, we have to consider the entire process for our material corporation, processing and also the full treatment. I'm using injection molding here as example. For example, you want to dry your material very properly, meaning you're not over drying the materials, you get a too much viscosity from the material, but also the one have too much moisture in the Nylon material. And also consider on the processing how to think, you know, the rights...who designed the right temperature profile and also the right tooling design. Talking about the post-treatment of course regarding the storage of the parts or the post-conditioning of the parts, how to be handled in a proper way.

Paul: Okay, super. So here's another one, "Which Nylons, 6 or 66, is easier to color?

Mark: Yeah, Paul, that's a good question. We'll do get that question a lot. And in general, Nylon 6 is a little easier to color than 66, a part of that has to do with the lower temperature for Nylon 6 versus 66. Remember, we talked earlier in the presentation that Nylon 6 has about 40 degrees lower melt temperature than Nylon 66. So that opens it up to more color additives that can be compounded in or processed into the extrusion or molding process compared to 66. So, therefore, that's part of the reason that Nylon 6 is generally gonna be a little bit easier to color than 66.

Renlong: Yeah, just to add something onto Mark's comments, as we mentioned in the presentation, Nylon 6 is gonna have some reddish brown tint color with it, so it make a little bit challenging for Nylon 66 to color in comparison to a Nylon 6.

Paul: Okay, thanks, guys. "Do you think carbon black is enough to satisfy a UV-resistant specification or should we go for an additive?" Mark?

Mark: You know, in general, carbon black is a very good UV additive. It absorbs UV very well both with Nylon 6 and 66. The key thing when you use carbon black as a UV additive is you got to put a little bit more...actually quite a bit more of it in there to provide the UV stability as opposed to if you just put in carbon black in there for colorant. So you just got to increase the loading a little bit and you should be fine for UV resistance.

Paul: Okay. "Can you discuss friction welding of the two materials?"

Mark: So, friction welding of the two materials in this particular case it...Nylon 6 will friction-weld better than Nylon 66 because of the lower temperature. So, when you have applications that you could choose between Nylon 6 or 66, Nylon 6 will perform slightly better in friction welding just due to the lower temperature.

Paul: Okay. "How about...how is impact strength affected by lower temperatures?"

Renlong: Well, I'll take that one. So generally, you know, low temperature make the material more rigid and also a lot of them more brittle. So in general, the impact...talking about, you know, for example, notch [inaudible 00:24:31] notched impact they will become lower than the room temperature. It depends on how long ago. I think it can get ahead pretty big by the low temperature.

Paul: Okay. How about...let's see, how about zinc chloride resistivity for Polyamide 6 and 66?

Mark: Thanks, that's one where you have typical automotive applications and in general, in this particular case, Nylon 66 will have better resistance to zinc chloride, calcium chloride, those types of materials than Nylon 6 will. In general, if you want even higher performance with Nylon 6 and 66, you'd actually be better off going to a more moisture resistant Nylon like a Nylon 6/12. Those materials are gonna be positioned into those types of applications a little bit more frequently. Unfortunately, Nylon 6/12 is quite a bit more expensive than Nylon 6 or 66, so there's your tradeoff for that one. But in general, Nylon 66 will have better performance against zinc chloride, calcium chloride, than Nylon 6 will.

Paul: Okay. How about...let's see, we have one on antistatic characteristics, which material has antistatic characteristics? I'm assuming 6 or 66, we'd like to use in potential explosive environments ATEX/IECex certification?

Mark: I can check.

Paul: Do you guys have any experience on that?

Renlong: I think Mark mentioned in the presentation that both 66 has a pretty good insulation properties, right? So in order to get a nice antistatic application, we do have to do some kind of formulation making more like engineered material.

Paul: Yeah, I would agree with you there, yeah.

Mark: One of the questions that we're getting quite a few up here is the pricing, and, of course, you know, we can't answer like specific pricing but in general, Nylon 66 will have a slightly higher price than Nylon 6 will. Of course, it's all market dependent. But in general, Nylon 66 will have a slight premium in the market to Nylon 6. So those are your two big Nylons. And then as you get into 6/10 and 6/12 those will be substantially higher. But in general, Nylon 66 will have a slight premium over Nylon 6.

Paul: Okay. Hold on a little bit, "Creep, is there any difference regarding creep behavior? Which one is better, 6 or 66?" Do you have enough data on that one?

Renlong: I think for the creep application and often case, we use fiber reinforcement...

Mark: Yeah.

Renlong: And so again talking about the creep and their load at different temperatures 66 glass-filled material typically has RHD/10 a better thermoplastics. So they will maintain the dimension a little better than 6.

Paul: So from the creep standpoint, given similar temperature...

Renlong: Yeah, 66 would be probably better.

Paul: ...would probably be a little better off going to 66.

Renlong: Yeah.

Paul: "What is the difference in dimensional expansion with water absorption between Nylon 6 and Nylon 66?"

Mark: In this case, because Nylon 6 will absorb a little bit more water than Nylon 66 will, Nylon 6 parts will expand or grow a little bit more than Nylon 66 will. So it's really kind of directly proportional to how much moisture it absorbs but in general, Nylon 6 will take in a little bit more water, therefore, it will expand slightly more than Nylon 66 will.

Paul: Okay. "Is Nylon 66 flame retardant?"

Renlong: Well, I guess it depends on the radiant, right? So I think it kind of has a HB rating...UL HB rating or regarding, others it depends on the dimension of the parts and also it depends on what level of flame we're trying to look at. I think honestly, it depends on the application.

Paul: Yeah. And there's also gonna be pretty dependent on the formulation. So, for instance, some unfilled Nylon at say, you know, moderate thickness, 125.

Renlong: Yeah.

Paul: Those can be like B2 with not having to put up much...

Renlong: Flame retardant.

Paul: ...flame retardant that if you put glass-fiber into it that changes the landscape. So that's a very interesting question. It's very dependent on...

Mark: For glass-filled materials both Nylon 6 and 66 they both can be flame retardant. They both can be either non-halogen or halogen flame retardant. It just depends on the formulation. The more the formulation changes the more consideration you'll have to have there. But both are widely used in the market for both non-halogenated and halogenated flame retardancy and it just depends on the application but both are suitable for flame retardant applications.

Paul: So, both 6 and 66 have certain options out there that are V0 like, a UL94 V0.

Mark: Yup, yeah. They both can be V0, both unfilled and glass-filled and they both can be V0 down to very thin thicknesses, down to 0.8 millimeters or less on glass-filled or unfilled and they both can be done that thin of a thickness both halogenated and non-halogenated flame retardants.

Paul: Okay. There's another one, is Nylon 6 easier to foam with the foaming agent than Nylon 66? I have an opinion but...

Mark: Oh, I have actually never done applications like that but I would tend to lean towards Nylon 6 because of the lower melt temperature. I think you're gonna have some processing additives, blowing agents, what have you, that would be better suited for the lower processing temperature of Nylon 6 versus 66.

Paul: Yeah, that's my opinion, my experience. It depends on the...every blowing agent has a different kickoff temperature. And I don't know many of that kickoffs in the 66 rating, but I haven't done a lot of them probably.

Mark: And the other thing that we're getting while we're looking at the equations come in here are general about applications versus 66 versus 6. And so, you know, what...I've got a lot in here that, "What are some large applications for 66?" Well, on an injection molded perspective if you look at injected molded parts, engineers, fasteners, also know this, cable ties, are one in which that is predominant Nylon 66 relative to Nylon 6. So all of these that you know the cable ties that you buy at Home Depot and Lowe's, those are normally gonna be Nylon 66.

And the reason for that is because Nylon 66 will set up and freeze, crystallize way faster than Nylon 6 does. So when you're molding a lot of cable ties engineered fasteners all at once Nylon 66 will actually allow you to cycle through...use very short cycled times for your cable ties relative to Nylon 6. And so those are some...that's one application where it's heavily dominant in Nylon 66.

On the other hand, Nylon 6, you know, you'll have a lot of injection molded parts that are what we called like good surfaces that also, like, tool...like, hand tools. So, you know, the parts that you go into, again, Lowe's and Home Depot, your nice yellow powered drills, saws, things like that, well, those are gonna be a situation where those are predominantly Nylon 6 because of the good surfaces that acts with glass-filled materials.

Also for Nylon 66 they're gonna be both 6 and 66 are found under the hood but there's specific parts that Nylon 66 plays where Nylon 6 cannot. A radiator end tank is one of those, that's an application in which you have chemical resistance against the ethylene glycol-water mixture. Nylon 66 does much better in that application than Nylon 6 does. And so, there's just a few examples as we've gotten questions quite a bit coming in on that of where some of the differences are. So, I hope that gives you a flavor of what we're talking about.

Paul: And so, here's one another surface, well, and it says, "Will a nucleated 6...will a nucleated PA6 generally have a lower quality surface appearance than a non-nucleated?" So, and this is Paul. I have done some nucleation in Nylon 6 and I've not necessarily seen that being an issue but I guess it's probably nucleant-dependent and how much would go in. But in general, as the guys have already said, that even with the 33%, 30%, 40% glass-filled material the 6 will give you a better surface than a 66 in general. Processing can affect that but...

Mark: I know Nylon 66 is nucleated when it's on...it's more popular to see that unfilled. You know, again, going back to engineered fasteners, cable ties, even clips are very common for Nylon 66, those are...even Nylon 66 will sometimes use nucleants to really speed the process up. So on an unfilled part, I would say that the surface appearance is probably gonna be the same. On a glass-filled part, I have rarely seen cases in which you would add a nucleant to like a glass or filler-filled material because the glass are the filler, access are really good nucleant anyways. So I think it would only apply to unfilled, and for unfilled that wouldn't make that much of a difference on surface terms.

Paul: Okay. Question, "What is the maximum recommended moisture content percentage before processing?"

Renlong: I guess that depends on if it's filled or it's unfilled. I think, typically, for unfilled Nylon 66, the recommended moisture is something below 0.18. And for some filled, like for example, 40% or 30% glass-filled on Nylon...even at Nylon 6 and 6 and the moisture definitely want to get below something between one to about 0.06. So, we have a lot of moisture to help to reduce friction between the Nylon chain armors but also make sure it's dry, that there's no hydrolysis happen during the molding process.

Mark: And the other thing that I'd like to mention on this is that getting the moisture level correct in Nylon 6 and 66 is critical in extrusion injection molding. So certainly getting it below the certain level it is good but you don't wanna over dry Nylon 6 or 66 in a molding process. I'm a little more familiar with Nylon 66 and that's because it's a condensation polymerization. If you're removing water, you're building molecular weight.

Renlong: Yeah.

Mark: So if you over dry Nylon 66 you could drive molecular weight higher. The other thing is, is to...from an injection molded standpoint, it will be much more difficult to injection mold like bone dry Nylon 6 or 66 than if it has just a little bit of moisture in there. That's why the recommended molding conditions are on the datasheets and you really should try to stick to below the maximum but above the minimum. And that will give you the optimum characteristics for both your molding process for both of your part performance afterwards as well.

Paul: Yeah. So basically the water is acting as a plasticizer.

Mark: Yeah, and it helps though.

Paul: Through hydrogen bonding and all that good stuff. These are the process questions, "What are the differences between PA6 and PA66 in processing methods other than injection molding, i. e. extrusion, low molding, etc.?" So, I mean, I can get the thought process going a little bit the...I have worked on some extrusion in calendaring type applications wherein I've used higher viscosity Nylons in order to handle all the needs of that particular method. So like many resins, you can buy a variety of molecular weights depending on what you're trying to do.

Mark: So for applications such as extrusion or blow molding it actually comes down to it's not just melt viscosity that's important it's actually the melt strength of the material. So when you talk about like a blow molding application in which you're kind of suspending a paraffin before you blow it into a part just because the material could have high melt viscosity doesn't necessarily mean it has high melt strength. And so that's a...you know, and a lot of times there are additives that can be used to drive up melt strength and impact modifier as a common way of doing that.

But you wanna drive up melt strength in extrusion and that low molding applications, and both Nylon 6 and 66 can do that. Nylon 6 would probably be more frequently used in those types of applications mainly because of the lower process temperature and it's got a little bit wider of a process window than Nylon 66 does because it's 40 degrees lower melt temperature.

Paul: Okay. We have two questions, very similar, "Do blends of Nylon 6 and Nylon 66 makes sense?" And the second, "Is there any advantage in blending 6 and 66?"

Mark: That's a good question. You know, blending 6 and 66 are very common. You know, sometimes...when we talked earlier about getting a good surface appearance for Nylon 6 that's actually quite common to blend it to kind of get a tradeoff of the really good appearance of Nylon 6 versus the higher temperature performance of 66. So it's very common to blend Nylon 6 and Nylon 66 together.

Paul: Yeah, and also by doing so, you can adjust the crystallization be here of both Nylon 6 and 66, you know, in the polymer...in the blend. So by doing so, you can actually modify the properties, for example, impact or tensile or other mechanic properties.

Man 1: Okay. Another, here's the question on flame retardants, "Again, could you please comment on the effective flame retardants?" So, I'm guessing other than the fact that you're trying to...

Mark: Well, one of these...so let us do a couple of different scenarios there. So if we talk about a glass-filled Nylon 6 or Nylon 66, you'll have to add additives in there that are typically going to decrease your mechanical properties such as impacts, right? So for example, if you want to have a 30% glass-filled Nylon 6 or 66 material, you have to put in a good amount of non-halogen or a halogenated flame retardant. Both of those are going to decrease the mechanical properties, especially impact resistance of either Nylon. From an unfilled perspective, the mechanical properties are not affected as badly but either way, when you add a flame retardant into Nylon 6 or 66 glass-filled or unfilled, the mechanical properties will be affected.

Paul: Okay, here's an application crunch. "Do I need to be concerned about moisture absorption in an automotive audio panel application? Which material would be better in this application?"

Mark: So that's an application where the material will go through a painting process. And so, when you mold an automotive body panel and then it gets painted, if you have moisture in the part it will bubble to the surface. And it will adversely affect the paint quality. So when you mold an automotive body panel out of Nylon 6 or 66, you have to take good care to get rid of as much moisture as you can after the part is molded. So certainly, the part will come out dry a molded but if it sits around it will have to be conditioned or dried to remove all the moisture before the paint is applied or you'll get bubbling on the surface there, but it can be done.

Paul: How about in terms of like, I'm just thinking...let's say you have it painted, it paints nice class and all that good stuff, how about moisture growth?

Mark: Yeah, I mean the panel itself will absorb...you know, if the panel is fully painted it won't, but typically the back side may not be. So you'll still have some moisture growth there. That's more gonna be dependent on how the part is fastened to the automobile. They'll have to account for the moisture growth but it's very well documented with the moisture growth of these types of products are or it can be measured very easily. So it's easy to take that inward now.

Renlong: Yeah, just think about the fact that actually the Nylon 66 with a moisture but take time for the...and being conditioned and humidity it take months and then sometime...and then a year to really reach their equilibrium, right? During the cycles, summer or winter time that more like...you know the moisture is breath in, breath out during the process.

Paul: Okay. "Can we use a...?" A process question, "Can we use the same tool for both Nylon 6 and 66? How will it affect the warpage and shrinkage on the part?" Have you got any answers with you guys?

Mark: So in general, Nylon 66 will have a slightly more mold shrinkage than 6 will, but there's probably applications out there that don't have dimensional tolerance, it's so tight that you'd have to retool. So can the same tool be used? It's obviously gonna be application dependent. And so, I would suggest that there are probably many applications out there in which you can use the same tool for Nylon 6 versus 66. Those in which you would...where the mold shrinkage is the difference between 6 and 66 is too great. You'd either need to adjust the formulations to account for that or you need to adjust the tools to account for that.

Paul: Okay. This is a...you'll see a compounding question. "Can Nylon 6 be processed in the same extrusion equipment that's used for Nylon 66? Or do we have to have different screws, barrels, or machine characteristics?" So basically, I guess that's gonna be dependent on what type of equipment we're talking about. If we're talking about twin screw compounders, they're very versatile. If we're talking about doing highly filled materials you know that specific to the equipment you'd wanna definitely have the right metallurgy in place for both screw and elements and barrels.

Mark: But in general, twin screw, single screw, they both can be used with similar setups for both compounding of 6 and 66. Of course, it's application and product dependent, but in general and I'd say that covers more than half of the products out there. You could use the same twin screw, the same single screw that you could for 6 and 66 and you'd be better...you'd be just fine with either material.

Paul: Okay. Just going through the questions here. "What is the best material for underwater applications?" Uhu.

Mark: Yeah. So for underwater applications, both Nylon 6 and 66 will take up a lot of water. And so, you know, certainly temperature-dependent as well, but in general if you're going to an underwater application even though 66 will take up less water than 6 neither one is really perfectly designed for underwater applications. Of course, it depends on the material application characteristic. There are other Nylons out there that are much less moisture sensitive than Nylon 66, Nylon 6/12, Nylon 11, Nylon 12, all take up much lower amount of water than 6 or 66 does and those applications, those materials will typically find themselves into underwater applications. But again, it's, you know, it's gonna be application dependent.

Renlong: If we really want to stay with Nylon 6 and 66 there are some formulation technique that we can use to minimize the water absorption, try to, you know, better return the properties.

Paul: Okay. Here's one that. Our application is outdoors that we can see UV wherein freezing conditions to high-temperature environments which the upper limit depends on location, which would be best for all of these conditions? So another...it depends, isn't it?

Mark: Well, I think they both can be. I mean this is an additive kind of compounding situation so both 6 and 66 if it's gonna be put into an application, are going to have stabilizers that are compounded into them. So, on the application, you know, it may depend on a whole bunch of other things. If the temperature requirements are high then you would probably want to have Nylon 66 over 6. If you really need a high surface static outdoor part that's really nice and shiny after molding then Nylon 6 maybe a better way to go. But either way, you'll have to compound in additives that will stabilize them against the elements.

Paul: Okay. "Is PA6 miscible than PA66?" And Renlong, you just did a little study in this, miscibility of 6 and 66?

Renlong: Yeah, I think it depends on the percentage you are using and also it depends on the screw design you're using. They are miscible but not at any ratios. So you just have to be really careful about what you use and how much you use in the formulation and then work from there.

Paul: Okay. I think we have time for maybe two more questions and then were gonna have to end. So let's see. "What is the main difference between amorphous Nylon and Nylon 6 and 66?"

Mark: So the most common amorphous Nylon out there is Nylon 6860. So, that's a...it's a more expensive Nylon, it's a specialty Nylon, it's not made from either the same monomers that is with 6 or 66. You know, it's common, it's...because it's amorphous it's translucent and it will have a light texture on it. But you know, it's used a lot in packaging applications. You know, that's a Nylon that can be compounded just like 6 or 66. It looks like there was a question on the UV stability of those. Again, you would have to compound in a UV stabilizer to those types of materials. And so, a transparent Nylon, amorphous Nylon is gonna be, you know, more expensive than a 6 or a 66.

Paul: Okay. One last one is, "Do you find that treated glass fiber bonds better to PA6 or PA66? Or do you find that it's not the same?" Particularly the glass fibers, and you know from my experience you never know exactly...there are couple of agents that are put on this surface of the fiber because that's proprietary to the fiber manufacturer but they tend to be of a certain class and it seems for the Nylons they tend to be year things.

Mark: Yeah, I couldn't imagine that they would be much different between a 6 and a 66. One that works for one is gonna work to the other one. You're not gonna have...you're not typically, you know, gonna have one glass fiber for Nylon 6 and another glass fiber for 66 or any other glass, or any other Nylon for that matter. It's gonna be the same.

Paul: Thinking from the chemical of the structural 66 they are similar, right? In terms of the carbon air or age, ratio, or everything, they're just quite similar. So, it should be...very a little difference if there's any.

Mark: Yeah.

Troy: Okay. Great questions guys, great questions. So we're at the end of the hour. We wanna thank you all so much. If you have any further questions or if your questions were not answered during this session we got a ton of questions today. So, you can send an email to nylon@polyone.com or visit our website where you can access product information and all our Nylon compounds including literature and, of course, datasheets provided by UL Prospector. Thank you, guys, very much for your attention today.

Trey: All right, it's a big thank you to Mark and Paul and Renlong for that really great and informative presentation. Just a reminder to everybody, we still had some questions about, "Where can I 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'd be checking your email for that. We also do encourage you to do check out some of the other PolyOne webinars on the UL Prospector Knowledge Center, just some great information, great presentations there. A big thank you to everybody for attending and we encourage you guys, have a great rest of the day. Thanks a lot.