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Enhancing the Properties of Polyolefins to Accelerate Market Adoption

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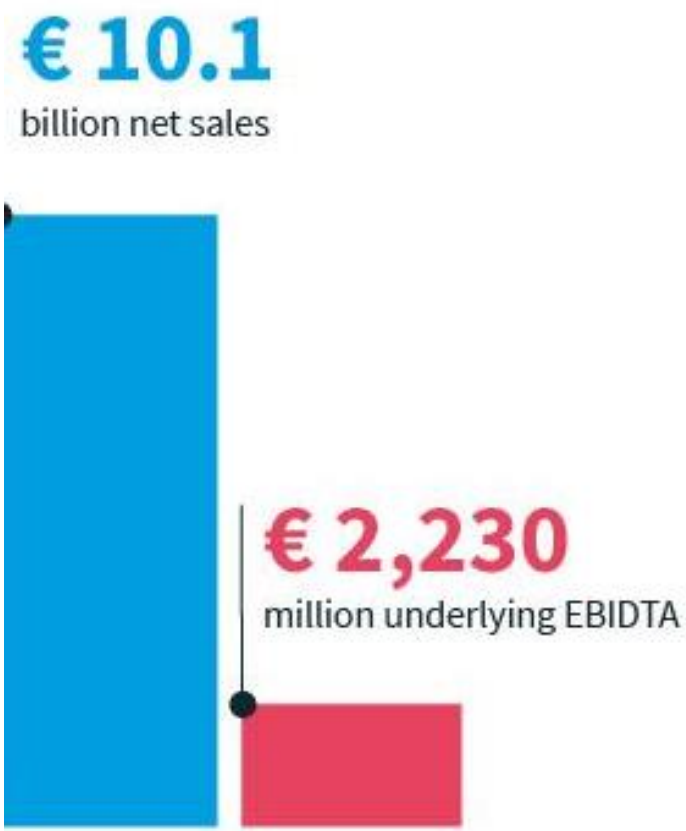
Outline

- Introduction to **Solvay** _ *Asking More from Chemistry®*
- Advanced UV Stabilization Technologies for
  - TPO Sheet Roofing - Introduction of ***CYASORB CYNERGY SOLUTIONS® B878T Stabilizer***
    - *Roofing Industry Trends*
    - *Performance Data*
    - *Key Features and Benefits*
  - Injection and Blow Molded Durable Applications - Introduction of ***CYASORB CYNERGY SOLUTIONS® M528 Stabilizer***
    - *Emerging Needs for Resin Producers and Masterbatchers*
    - *Performance Data*
    - *Key Features and Benefits*
- Conclusions

WE ARE
AN ADVANCED MATERIALS AND SPECIALTY CHEMICALS COMPANY



135
SITES
and presence in
61 COUNTRIES

26,800
EMPLOYEES

21
MAJOR GLOBAL
R&I CENTERS

2017 key figures

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About Solvay Polymer Additives

Inspired by your challenges. Driven by *sustainability*

- Recognized as the **global technology leader in UV stabilization technology** with more than 60 years of experience
- Committed to help preserve the planet against global environmental issues through **sustainable product development**
- **Creating more value** for key markets and customers
  - Engage with stakeholders across the value chain
  - Anticipate emerging trends
  - Innovate to deliver on unmet needs
- Delivering solutions that meet customers' most demanding stabilization requirements through **formulation and application expertise**

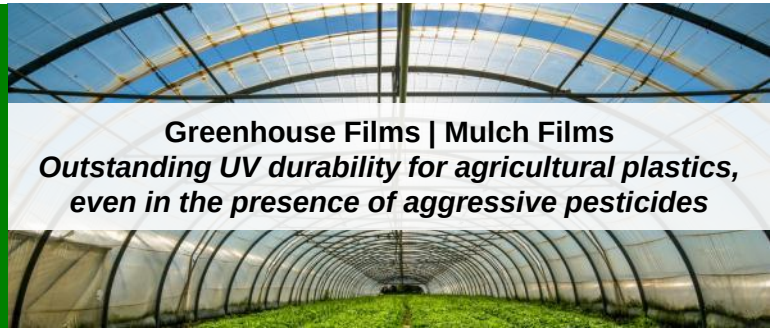
Demonstrated commitment to the future growth of the polyolefin industry by **doubling capacity for HMW Hindered Amine Light Stabilizer (HALS)** production in the US

Polymer Additives | Global Markets

AUTOMOTIVE

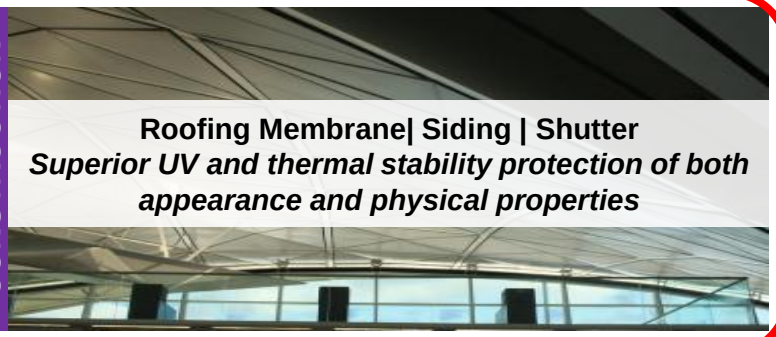
Automotive Exterior | Automotive Interior
Stabilizer providing exceptional durability and high performance

AGRICULTURE



Greenhouse Films | Mulch Films
Outstanding UV durability for agricultural plastics, even in the presence of aggressive pesticides

BUILDING AND CONSTRUCTION



Roofing Membrane| Siding | Shutter
Superior UV and thermal stability protection of both appearance and physical properties

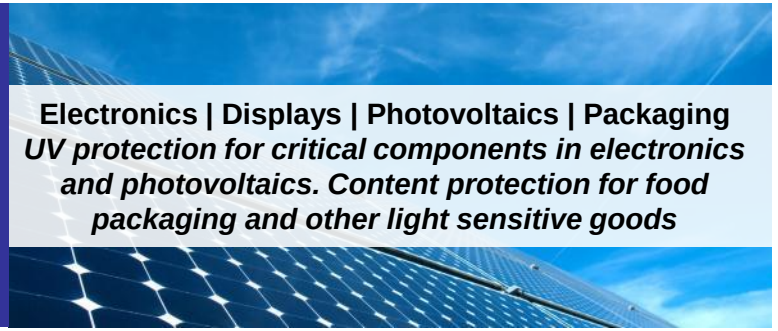
MOLDING

Bins | Table/Chairs | Pallets | Electronic Parts
Outstanding durability for outdoor applications

ROTOMOLDING

Tanks | Containers | Toys | Sport Equipment
Outstanding durability for outdoor applications

SPECIALTY FILMS



Electronics | Displays | Photovoltaics | Packaging
UV protection for critical components in electronics and photovoltaics. Content protection for food packaging and other light sensitive goods

Building & Construction
Roofing Industry Trends

- Thermoplastic polyolefin (TPO) roofing membranes: the fastest growing commercial roofing products and have gained broad industry acceptance
  - Less environmental impact; do not contain plasticizers, chlorine or heavy metals; recyclable
  - Intrinsically flexible even at low temperature
  - Light weight
  - UV durability, thermal resistance, flame retardancy
  - Ease of installation - heat weldable
  - Energy efficiency - reflective white/light colored roofing membranes

- Product differentiation desired in the competitive roofing market

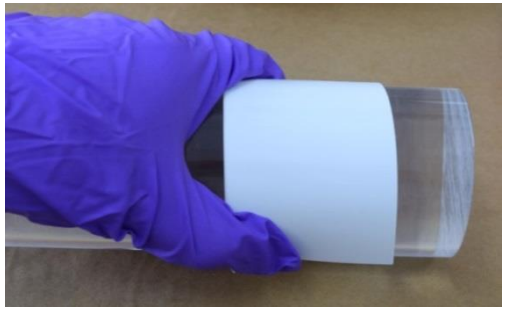
- Higher performance requirements
  - Increase in UV weathering performance specification
    - **5,040 kJ/m²** (**2003**; ASTM D6878) -> **10,080 kJ/m²** (**2006**; ASTM D6878) -> **>30,240 kJ/m²** (**+2017**; industry differentiation trend)
    - Higher performing stabilizer solutions needed to meet/exceed specification
  - Increase in thermal performance specification
    - **4 weeks @ 240°F** (**2003**, ASTM D6878) -> **32 weeks @ 240°F** (**2011**, ASTM D6878) -> **8 weeks @ 275°F** (**2017**, ASTM D6878) offered as alternative
    - Higher performing stabilizer solutions needed to meet/exceed specification

New stabilizer solutions are needed to meet evolving demanding weathering and thermal stabilization to extend the lifetime of roofing systems

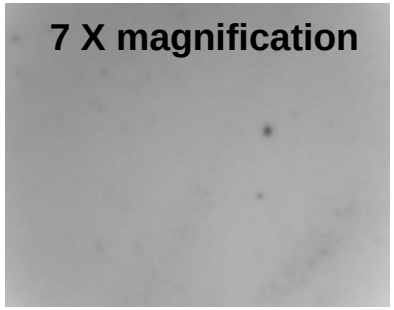
Thermoplastic Polyolefin-based Sheet Roofing
Standards & Specifications

ASTM D6878 -17 Standard for Thermoplastic Based Sheet Roofing (2017)

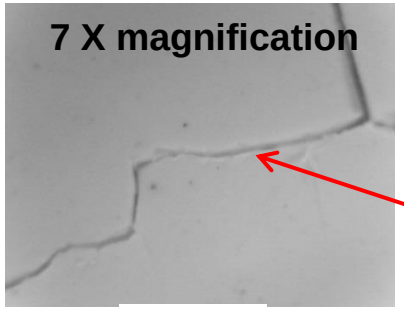
Test	ASTM Test Method	Test Condition	Passing Requirement
Heating Ageing	ASTM D573	• 5,376 hours (32 weeks) at 240°F (116°C) *or* • 1,344 hours (8 weeks) at 275°F (135°C)	• 3” Mandrel Bend Test No cracks/crazing inspected at 7X magnification • Weight loss < 1.5%
Weathering Resistance	ASTM G155	• 10,080 kJ/m^2 at 340 nm and 80°C BPT, 50°C air temperature • Water spray cycle = 102 min. light & 18 min. light + water	• 3” Mandrel Bend Test No cracks/crazing inspected at 7X magnification



Mandrel Bend Test (3” diameter)



Passed



Failed

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UV Weathering Performance

Mandrel Bend Test

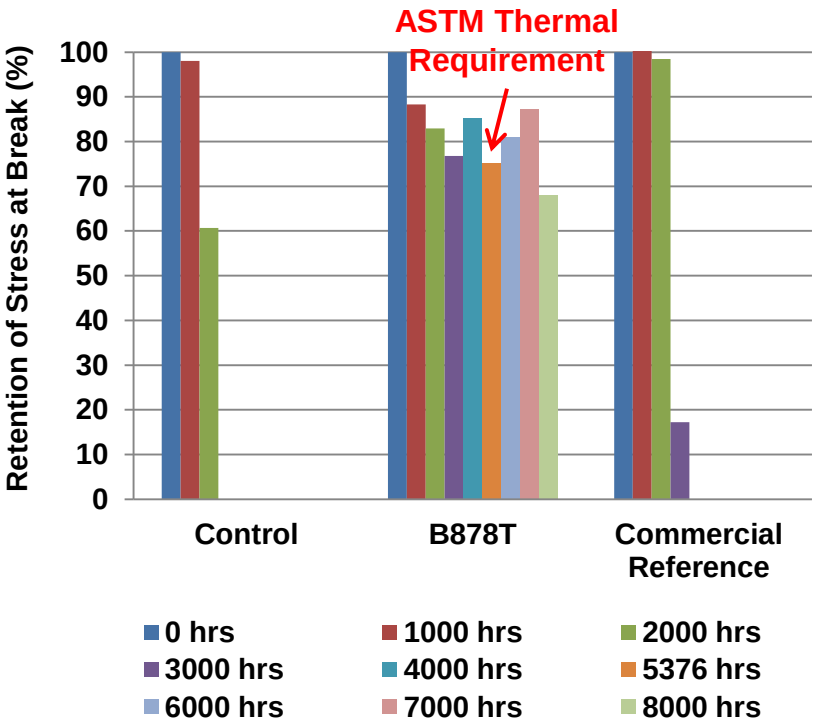
		ASTM D6878 UV Requirement ↓		Industry Trend ↓		Solvay Innovation B878T ↓
kJ/m²	**5,040**	**10,080**	**20,160**	**30,240**	**35,280**	**50,400**
Control (No UV)	**Failed**					
B878T	**Passed**	**Passed**	**Passed**	**Passed**	**Passed**	**Passed**
Commercial Reference	**Passed**	**Passed**	**Passed**	**Failed**		

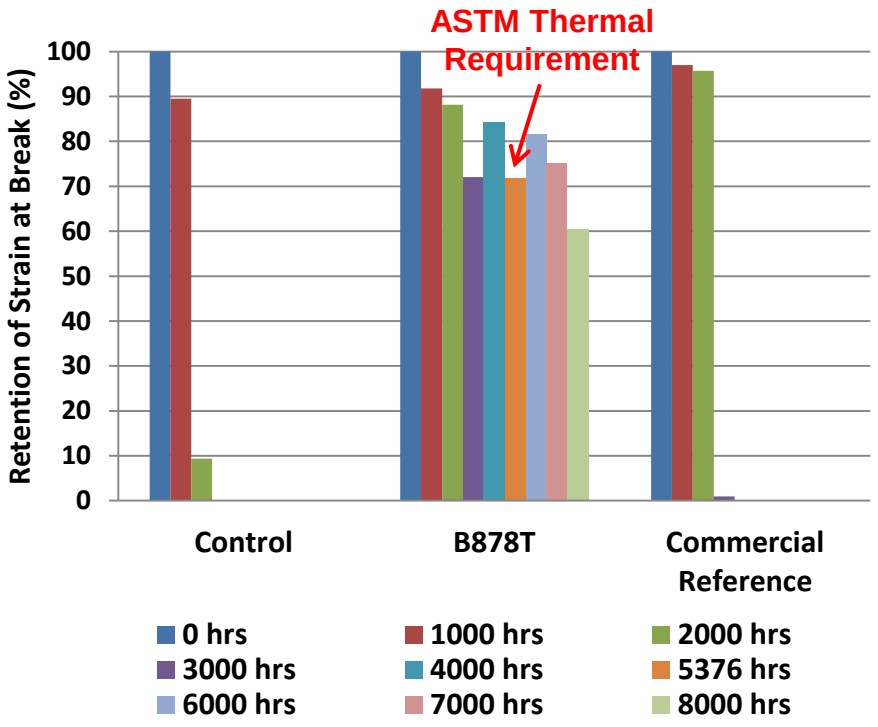
B878T provides outstanding UV weathering performance, far surpassing the ASTM D6878 UV weathering requirement for TPO sheet roofing

27 mil (~0.69 mm) TPO sheet for single ply roofing membrane

Heat Ageing Performance (240°F/116°C)

Outstanding Physical Property Retention with B878T





B878T provides excellent physical property retention after 8,000 hours of 116°C thermal ageing, surpassing the ASTM D6878 heat ageing performance requirement

Heat Ageing Performance (240°F/116°C)

Mandrel Bend Test

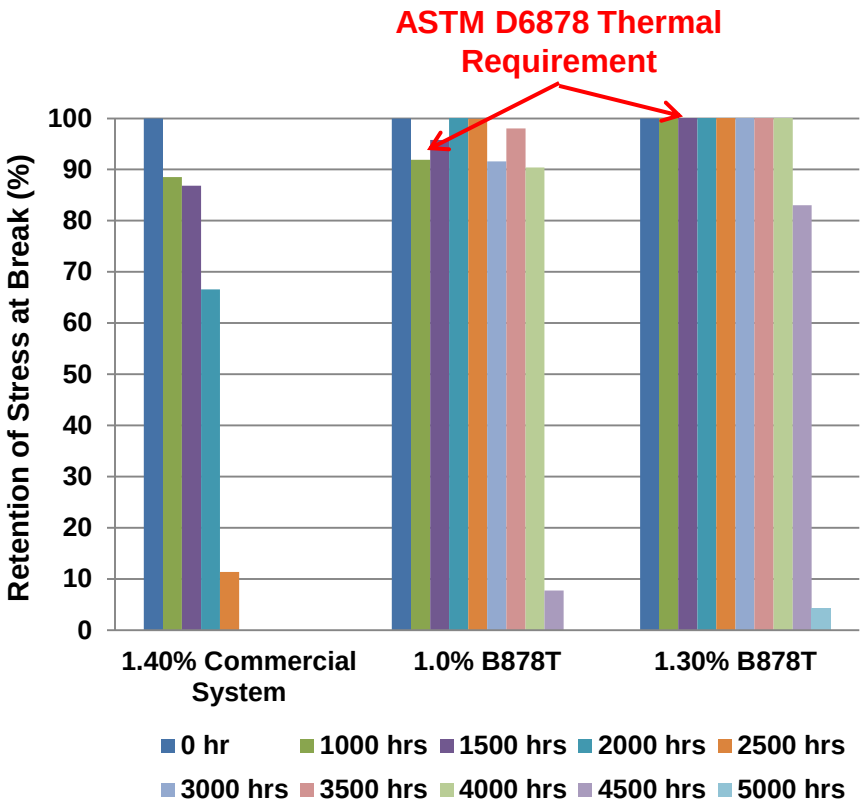
ASTM D6878 Thermal Requirement ↓

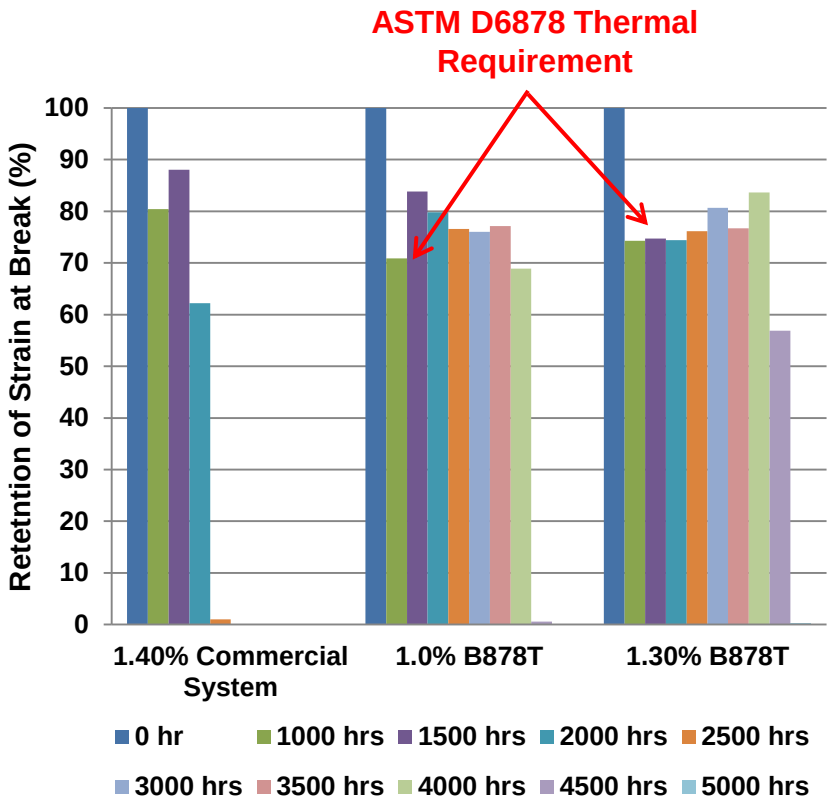
Hours	1,000	2,000	3,000	5,376	6,500	7,500	8,000
Control	Passed	Failed					
B878T	Passed	Passed	Passed	Passed	Passed	Passed	Failed
Commercial Reference	Passed	Passed	Failed				

B878T provides unprecedented thermal stabilization performance, far exceeding the ASTM D6878 heat ageing requirement for TPO sheet roofing

Heat Ageing Performance (280°F/138°C)

Excellent Physical Property Retention with B878T





B878T provides much better thermal stabilization at 138°C compared to the commercial state-of-the-art stabilizer system

Ultra Accelerated - EMMAQUA

Test Type: EMMAQUA

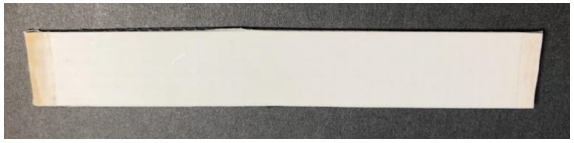
Test Location: New River, Arizona

Test Method: ASTM G90 -17

Exposure Type: SPRAY CYCLE 1 (EMMAQUA, day spray with night time wetting). The specimens are mounted unbacked in an aluminum frame, with the uncoded side facing the sun. The specimens are exposed on an Ultra Accelerated device.

Radiant Energy (295-385 nm); MJ/m²	1,550	3,100	4,650	6,200	7,750	9,300
Miami 5° South (**Years**)	5	10	15	20	25	30
B878T	**Passed**	**Passed**	**Passed**	*Weathering Continues*		

Photo of weathered TPO roofing membrane (2 cm x 15 cm x 1.26 mm) (*After* 4,650 MJ/m² radiant exposure)



Experimental Observation

No cracks/crazing observed at 7X magnification in the 3" Mandrel Bend Test after exposed to 4,650 MJ/m² radiant energy in a UA-EMMAQUA Test in Arizona.

B878T demonstrates to exceed 4,650 MJ/m² radiant exposure (~15 Years Miami exposure) in the UA-EMMAQUA testing

ASTM G90-17: Standard Practice for Performing Accelerated Outdoor Weathering of Materials Using Concentrated Natural Sunlight

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CYASORB CYNERGY SOLUTIONS® B878T Stabilizer

Key Features & Benefits

- Exceptional long-term UV and thermal protection to polyolefins used in outdoor roofing application
  - Outstanding surface protection and crack resistance upon UV exposure
  - Excellent thermal protection at elevated temperatures

- Single stabilizer solution for both UV and thermal
- stabilization

- Produced with the **CYFLOW™ Technology**
  - Dust free for safe handling and feeding
  - Low agglomeration potential resulting in excellent storage stability and product feedability

B878T allows building & construction products to meet challenging extreme UV and thermal performance requirements

Polymer Additives | Global Markets

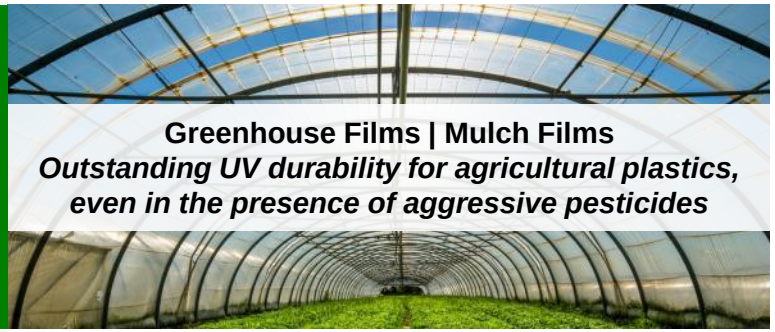
AUTOMOTIVE

Automotive Exterior | Automotive Interior
Stabilizer providing exceptional durability and high performance

MOLDING

Bins | Table/Chairs | Pallets | Electronic Parts
Outstanding durability for outdoor applications

AGRICULTURE

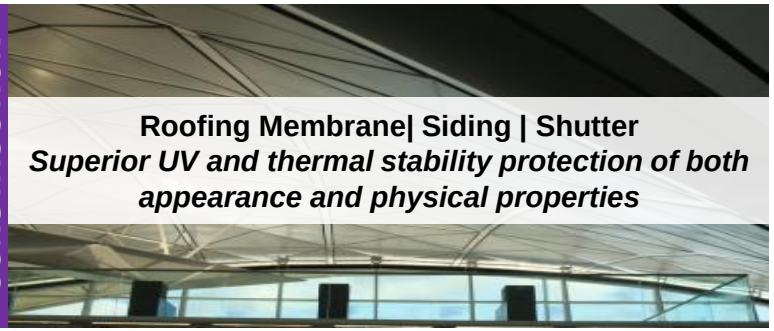


Greenhouse Films | Mulch Films
Outstanding UV durability for agricultural plastics, even in the presence of aggressive pesticides

ROTOMOLDING

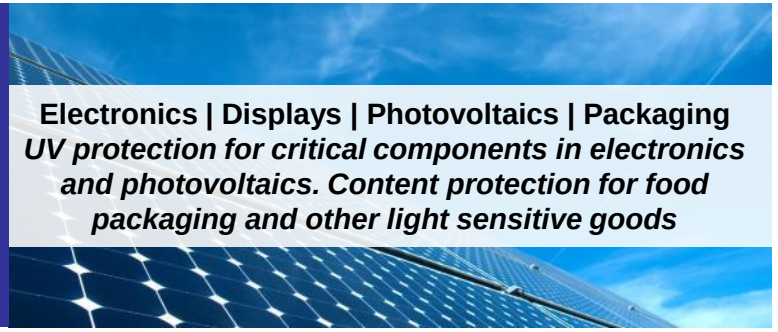
Tanks | Containers | Toys | Sport Equipment
Outstanding durability for outdoor applications

BUILDING AND CONSTRUCTION



Roofing Membrane| Siding | Shutter
Superior UV and thermal stability protection of both appearance and physical properties

SPECIALTY FILMS



Electronics | Displays | Photovoltaics | Packaging
UV protection for critical components in electronics and photovoltaics. Content protection for food packaging and other light sensitive goods

Emerging Needs for Resin Producers and Masterbatchers

- Extended UV durability for natural and pigmented parts
  - Color lightfastness, gloss, and physical properties
- Easy color matching - low color contribution of additives
- Compliance with FDA and major global food contact regulations

Resin Producers - Injection Molding & Blow Molding Grades

- Polyolefins are replacing heavier materials (metal, wood, other polymers, etc.)
- Resin producers are transforming themselves into specialty resin suppliers
  - Shale gas boom leading to abundant supply of commodity resins
  - Create higher value-added products
  - Extended UV durability would open opportunities to new higher performance applications

Masterbatchers - Combi-batches and Superconcentrates

- Desire to increase formulation flexibility to produce combi-batch providing multi-function properties
  - Free up volume for a higher loading or additional functional additives
- Ability to reduce let-down percent to improve return on net assets
  - New product needed to improve operational efficiency

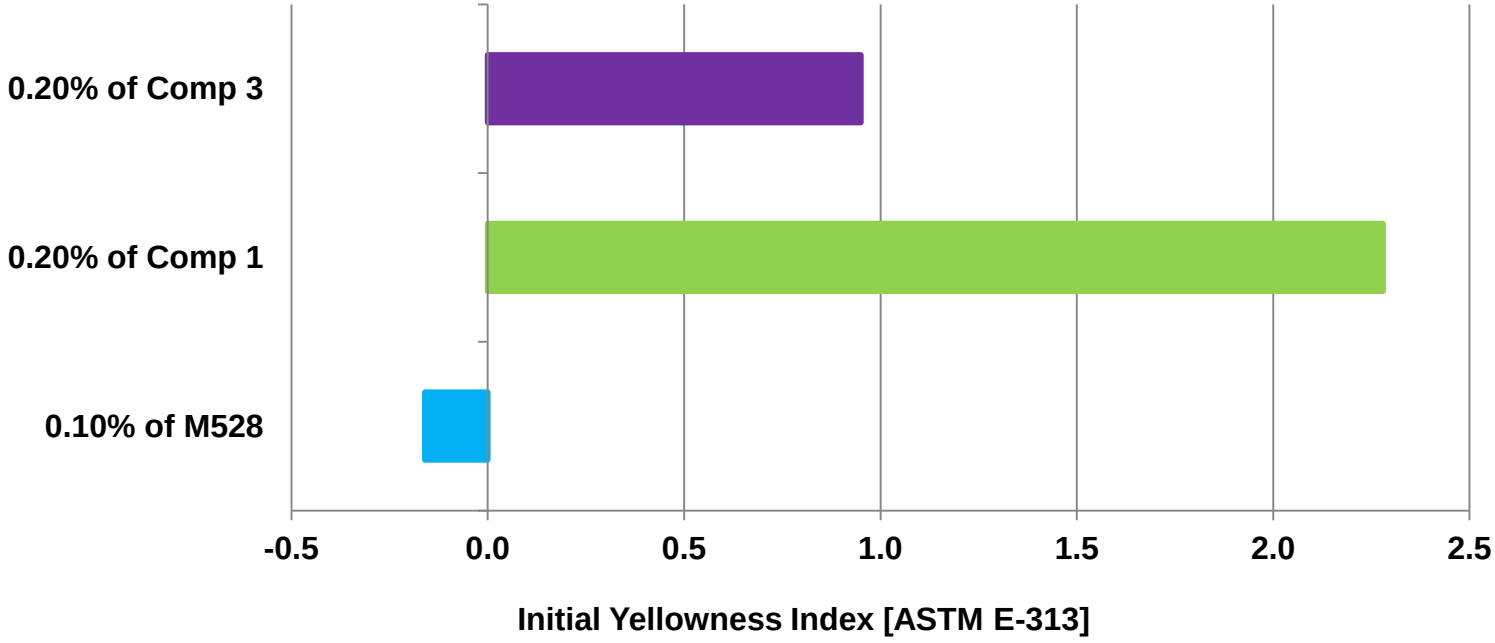
Market needs are constantly evolving and require advanced stabilization solutions

Minimal Initial Color Contribution

Product	Color Properties
M528	+++
Comp 1	+
Comp 3	++

+++ = best ++ = good + = fair/poor

Initial Color Contribution of Commercial HALS
HDPE, No Pigment
Injection Molded Plaques



M528 imparts minimal color to the polymer for easy color matching

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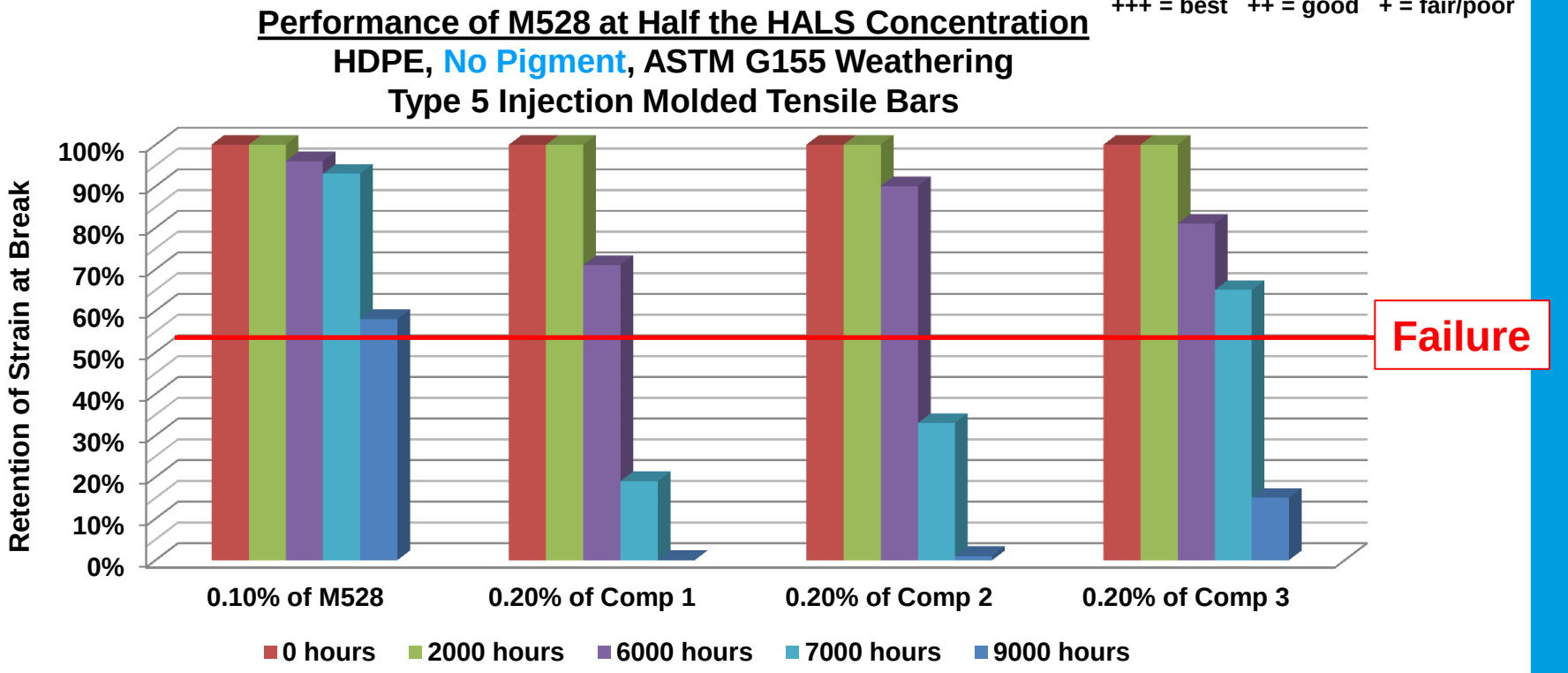
Excellent Physical Property Protection At Half the Concentration

Product	Physical Properties
M528	+++
Comp 1	+
Comp 2	+
Comp 3	++

+++ = best ++ = good + = fair/poor



M528 delivers outstanding physical properties protection compared to traditional HALS at half the concentration

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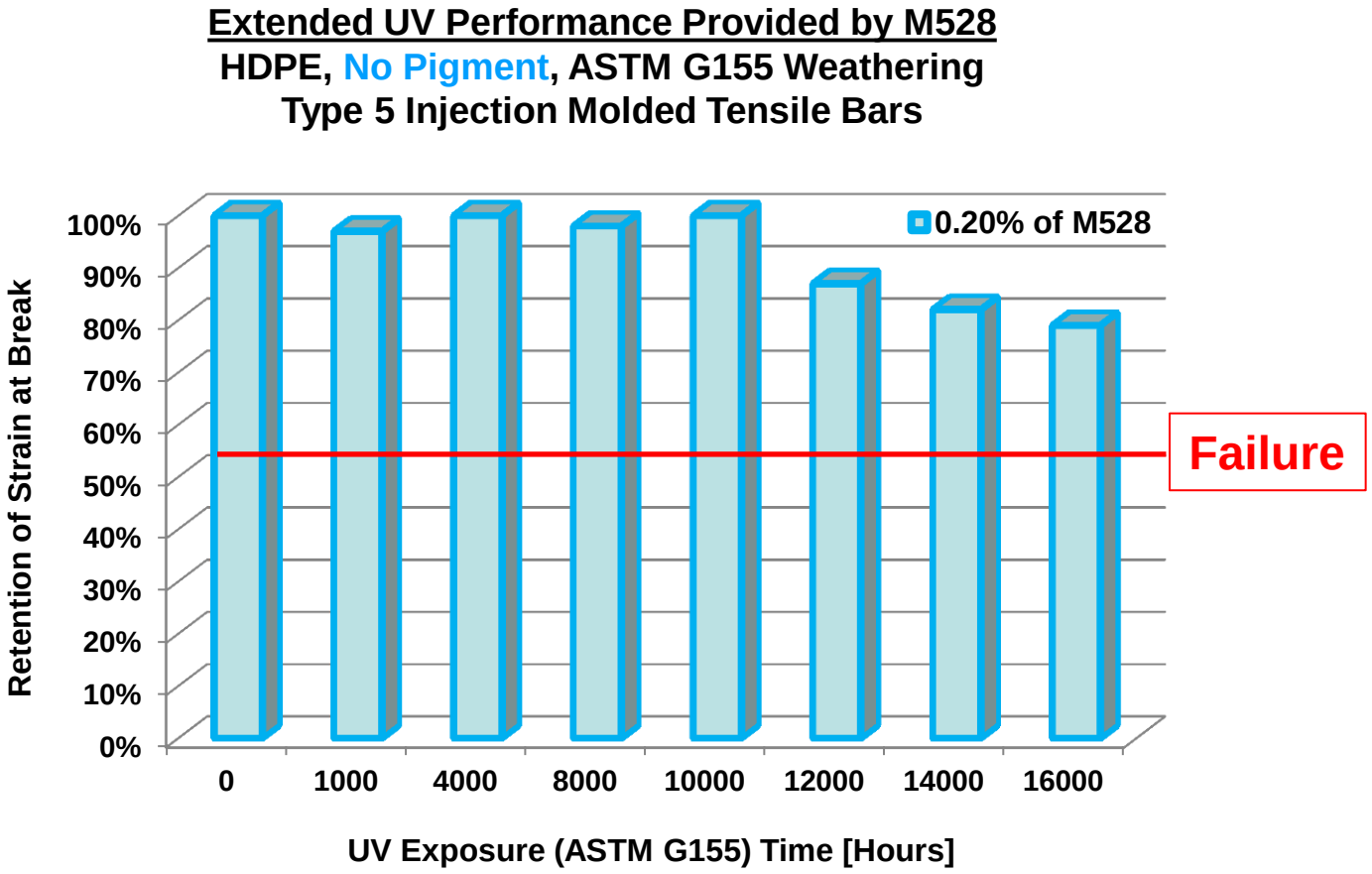
Extended UV Performance for Resin Producers



M528 delivers UV stabilization from UV-4 to UV-16 while remaining within FDA limits

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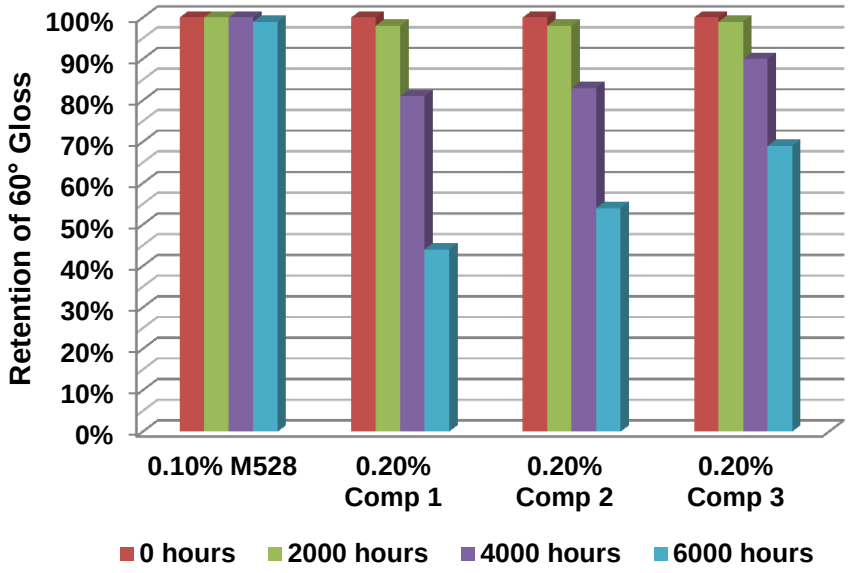
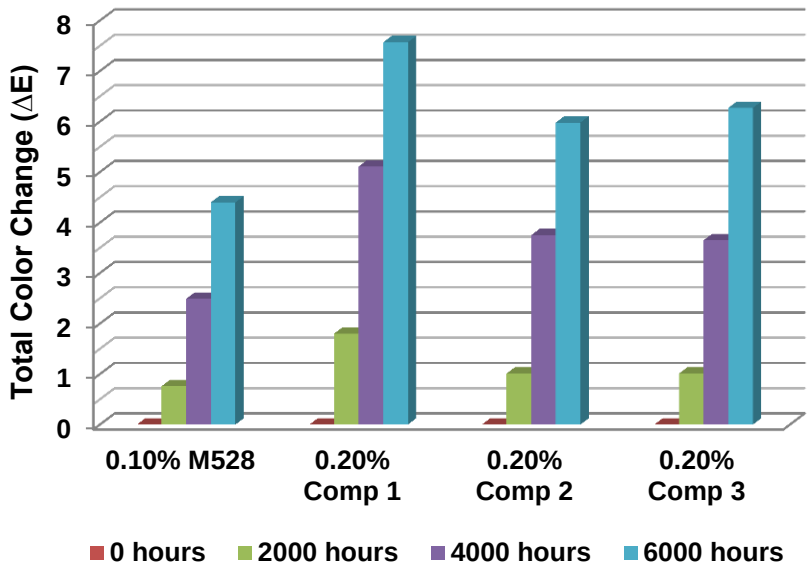
Excellent Surface Protection At Half the Concentration

Product	Surface properties
M528	+++
Comp 1	+
Comp 2	++
Comp 3	++

+++ = best ++ = good + = fair/poor

UV Performance of M528 in Pigmented Articles
HDPE, Blue Pigment, ASTM G155 Weathering
Injection Molded Plaques





M528 provides outstanding gloss retention and color stability of pigmented articles at half the concentration

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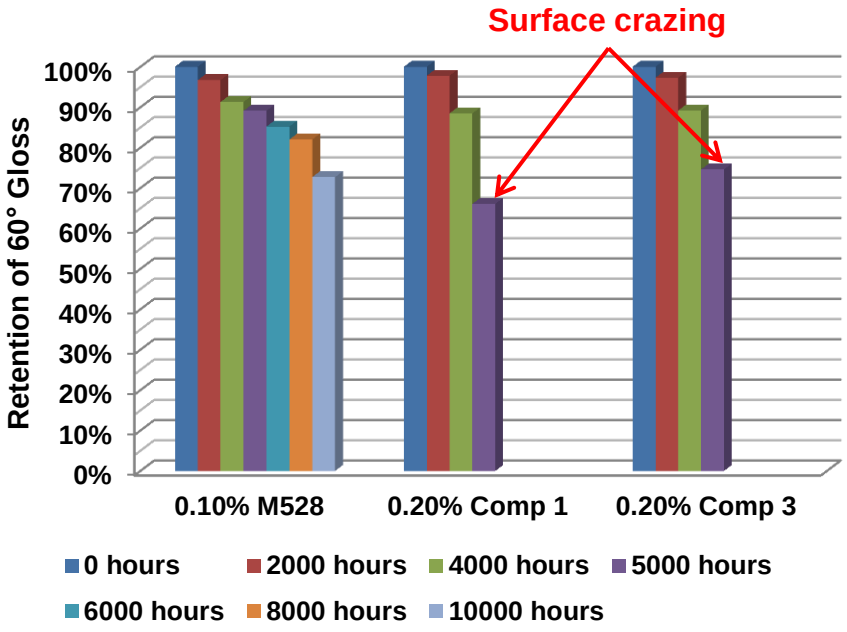
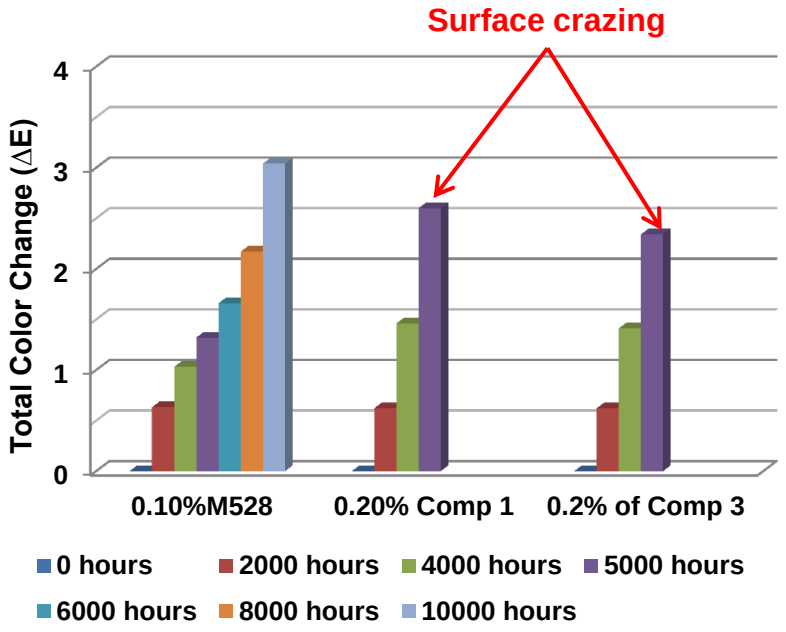
Excellent Surface Protection At Half the Concentration

Product	Surface properties
M528	+++
Comp 1	+
Comp 3	+

+++ = best ++ = good + = fair/poor

UV Performance of M528 in Pigmented Articles
HDPE, Green Pigment, ASTM G155 Weathering
Injection Molded Plaques





M528 can allow doubling the service life of pigmented article at half the concentration

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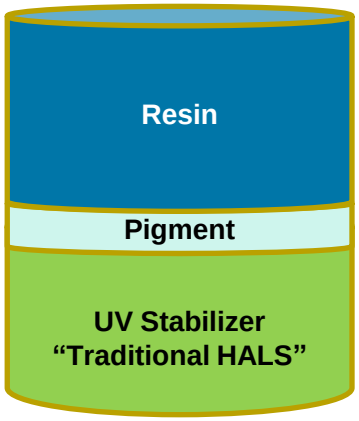
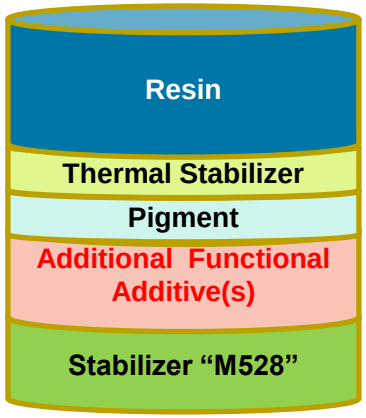
M528 Advantages in Combi-batch *vs.* Traditional HALS

Product	Formulation Flexibility
M528	+++
Trad. HALS	+

+++ = best ++ = good + = fair/poor



Traditional HALS Masterbatch



M528 Combi-Batch

UV Performance Advantage of M528

- 2x M528 *vs.* 1x traditional HALS
- Equal performance at half the concentration of traditional HALS
- Extra free volume enables the addition of other functional additives

- M528 can be used at half the concentration to provide equivalent UV stabilizing performance compared to traditional stabilizer products
- The extra free volume created by the use of M528 can be used for adding other functional additives, creating value-added multi-functional masterbatch (combi-batch)

High stabilizing efficiency of M528 allows for formulation flexibility by addition of other functional additives

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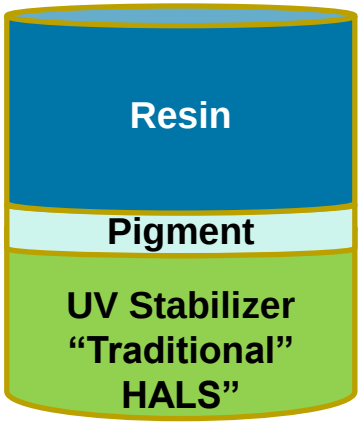
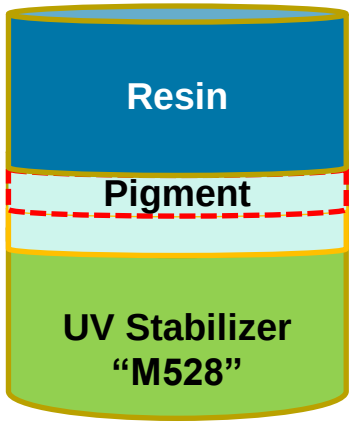
M528 Advantages in Super-concentrate *vs.* Traditional HALS

Product	Opertional Flexibility
M528	+++
Trad. HALS	+

+++ = best ++ = good + = fair/poor



Traditional HALS Masterbatch



M528 Superconcentrate

UV Performance Advantage of M528

- 2x M528 *vs*. 1x traditional HALS
- Super concentrated additives allows for lower let-down percent
- Leading to significant financial gains in manufacturing efficiencies

Role of M528 In Masterbatches

- Masterbatcher can fill an order using only 5 mt of M528 containing superconcentrate *vs.* 10 mt of product with traditional HALS

Benefits of M528 In Masterbatches

- Frees up production time to fill additional orders
- Increases operational efficiency
- Optimizes return on net assets

M528 allows to increase operational efficiency and improve return on net assets

CYASORB CYNERGY SOLUTIONS® M528 Stabilizer

Key Features & Benefits

- Provides Excellent UV Stabilization to PE Molded Durable Applications
  - Broad and extended UV performance, e.g. UV-4 to UV-16
  - Outstanding physical property retention
  - Excellent surface protection of pigmented parts
- High stabilization efficiency - equivalent or better performance to traditional HALS at half the concentration
- Low initial color contribution for easy color matching
- Improves formulation flexibility and profitability of masterbatchers
  - Advantageous in combi-batch and superconcentrate manufacturing
  - Significant improvement in production efficiency, leading to cost savings or higher profits
- Broad food contact approvals, e.g. FDA sanction
- Easy-to-disperse granules

M528 allows YOU to achieve MORE with LESS!

Conclusions

- Polyolefins are the **polymer of choice** for materials replacement in durable applications due to their versatility and ability to acquire new properties through formulation
- **Sustainable product development** is necessary to accelerate growth
- Leveraging its experience in polyolefin stabilization, **Solvay** is helping companies throughout **the plastics value chain** deliver exceptional performance and improve operational efficiencies
  - **CYASORB CYNERGY SOLUTIONS® B878T Stabilizer** has shown unmatched performance in stabilizing building & construction materials under extreme UV and thermal performance requirements
  - **CYASORB CYNERGY SOLUTIONS® M528 Stabilizer** has been demonstrated to deliver equal performance at reduced concentrations over competitive stabilizers in PE molded durable applications
- Solvay continues to lead technology innovation to **extend the performance** of plastics and open additional **high-value opportunities** for polyolefins

more future

Thank you.

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