ANTIOXIDANTS FOR POLYURETHANE APPLICATIONS

SI Group®

The Substance Inside

MARCH 2021

Dr. Thomas Hopfmann

ANOX™
LOWILITE™
LOWINOX™
NAUGARD™
WESTON™

CONTENT

SI Group's antioxidants can play an integral role in solving your technical issues & complying with stringent standards, including:

- **Liquid or solid antioxidants for all dosing requirements**
- **Emission control** and **compliance** with VDA or Oekotex standards
- **Improved polyol stability** and **scorch protection of polyurethane applications** for greater production safety & better quality
- **UV resistance** for sensitive light colored & white PU applications

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WELCOME TO NEW SI Group

The Substance Inside

SI Group is committed to **developing innovative technologies for polyurethane applications** (i.e. furniture, clothing, & automotive applications) that enable **emission reduction** complying with the most stringent VDA automotive and OEKO-TEX standards and improved **gas fading resistance**

EXPANDED
product offerings

RELIABLE
global footprint

INNOVATIVE
solutions provider

Our Global Reach

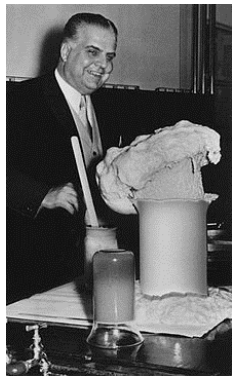
30
Manufacturing Facilities & 5 Joint Ventures

3,000
Global Workforce

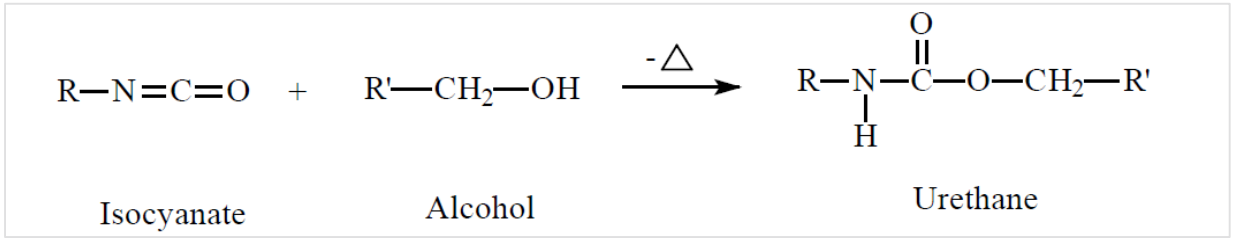
$2+
Billion in Annual Sales

POLYURETHANE

The basic principle for **polyurethane** (short: PU or PUR) chemistry was invented in 1937 in the research laboratories of **Bayer AG (now COVESTRO)** by **Dr. Otto Bayer** in Leverkusen, Germany.



Prof. Otto Bayer (1952)



Polyurethanes are formed by reacting a **polyol** (an alcohol with more than two reactive hydroxyl groups per molecule) with a **diisocyanate** or a polymeric isocyanate in the presence of suitable catalysts, surfactants and additives. **A direct route to cross linked polymers**.

Polyurethane is a polymer composed of a chain of organic units joined by urethane links. That´s the name giving moiety.

PUR APPLICATIONS & SEGMENTATION

Raw materials	Applications	Markets
Polyol	Flexible foam	Automotive
Isocyanate TDI/MDI	Rigid foam	Apparel
	Integral foam	E&E
	Spandex	Shoes
	TPU	Building & construction
	CASE	Furniture

CASE Coating/ Adhesive/ Sealant/ Elastomer

It does not matter where you look, you are likely to find polyurethanes which improve our comfort and safety or help to reduce energy costs

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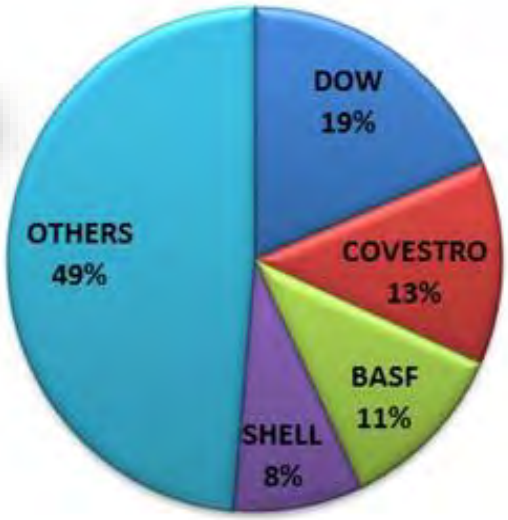
GLOBAL SLABSTOCK POLYOL PRODUCERS POLYOLS MW 3000 - 3600



Concentrated market
Top 4> 50% of market

VORANOL

ARCOL

LUPRANOL

CARADOL

ALCUPOL

CARPOL

WANOL

™/ TM Tradenames

The polyols used in PU production are predominantly polyether polyols. The slabstock polyols represent > 70% of all flexible foam applications.

PUR MARKET OVERVIEW, KEY PLAYERS & TRENDS

- **GROWTH DRIVERS (OF BETTER ANTIOXIDANTS) FOR PUR**

  - PROCESSING STABILITY, BETTER SCORCH/ / **LESS WASTE**
  - ENVIRONMENTAL, **EMISSION REDUCTION**
  - INSULATION NEEDS CHANGING, **ENERGY SAVINGS**
  - LIGHT WEIGHT CONSTRUCTION, **ENERGY SAVINGS**
  - INCREASING STANDARDS & INCREASING URBANISATION WITH LARGER MIDDLE CLASS, **COMFORT**

Sizeable AO market size (> $130M, 22 kt in 2020), growing above GDP CAGR 5.5% /y between 2012 – 2020

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CTQ MARKET DEMANDS FOR POLYOLS AND PU APPLICATIONS AND FOAMS

- Liquid and low volatility
- Good solubility and efficient dosing
- Enhanced stability over storage
  - Confers good color stability
  - Avoids hydroperoxide formation
- Effective anti-scorch package

- Reduces VOC emissions
- Reduces FOG emissions
- Improves gasfading stability
- Improves UV stability

Polyol Producer → **PUR (Foam) Producer** → **Furniture Clothing Automotive** → **End User**

Effective anti-scorch **post-treatment** additives
- Scorch protection & low emissions
- Liquid and easy to handle
- Surface protection / UV stabilisation

- Safer indoor (car) environment
- Higher quality end-products

VOICE OF CUSTOMER TO DETECT UNMET NEEDS

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VOICE OF CUSTOMER ASSESSMENT

Polymer Additives Internal Training
Internal Use Only

1. **Which types of foams/ polyols do you produce or use?**
   Please specify by grade: Slabstock; molded flexible; Rigid Foam/ or CASE polyols/ products. Polyether or Polyester polyol? More MDI or TDI formulated systems?
2. **What are the key performance criteria for your polyol or foam?**
   Is it scorch or VOC/ FOG emissions or surface foam discoloration? Do you want low or high density foam? What are the foaming agents (water, solvents?) and levels? 3 - 5 % water?
3. **Which requirement do you want to improve?** and is currently not fulfilled yet with your existing AO package ? Are there issues during production (waste, scorch problems) ? Are there issues reported at the downstream end user?
4. **What is your current stabilisation AO system?**
   Is it a plain phenolic or a combination with aminic? Do you use solid or liquid systems, can you handle both? What is the dosage level?
5. **How do you measure the effects of the antioxidant packages?**
   What are the methods and conditions used for performance evaluations, VDA or ISO or ASTM, emission test, NOx test ? (inhouse or outsourced)?
6. **What changes or trends in the market do you see and how will impact your business and who initiates this change?** Emissions, Regulatory, critical EHS parameters? Why and by when is this change needed? What is the driving force …downstream market, local or export?
7. **How can we assist & support your application efforts?**
   We have fully equipped EXPERT LAB focused on PUR applications.
8. **How is a new solution validated and adopted within your company?**
   (Stage gate, which stakeholders decide) and finally production process implementation? How do you gauge the level of priority?
9. **What is your total foam/ polyol production capacity?**
   Do you have one main grade, or special grades, Into which regions do you sell ?
10. **What is the size of opportunity and customers importance?**
    Quantify in mt/ USD etc and timelines:.. short term solution or basic research? A new development or me too with mature solutions? (Potential for jJV, ..ACFC?)

Quantifiable assessment with numbers and units that we understand the value with improved productivity, improved performance, less waste & savings at the customer in $´s. *Technical, Commercial and REGULATORY.*

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INTRODUCTION TO PUR STABILISERS

SI Group offers one of the **world's largest** stabilizer technology platforms for polyol & polyurethane applications with its comprehensive portfolio of antioxidant solutions:

Our portfolio for the polyurethane industry includes:

- Phenolic and amine-based antioxidants
- High performance ultra-low emissive solutions
- Amine-free blends for polyols for automotive, underwear, shoe soles, ….
- High anti-scorch performance blends for polyols for low-density foams
- Zero-phenol liquid phosphites
- UV stabilizers

ANOX™

LOWILITE™

LOWINOX™

NAUGARD™

WESTON™

All are BHT & PTZ free!

SI Group is committed to **developing innovative technologies for polyurethane applications** (i.e. furniture, clothing, & automotive applications) that enable **emission reduction** complying with the most stringent VDA automotive and OEKO-TEX standards.

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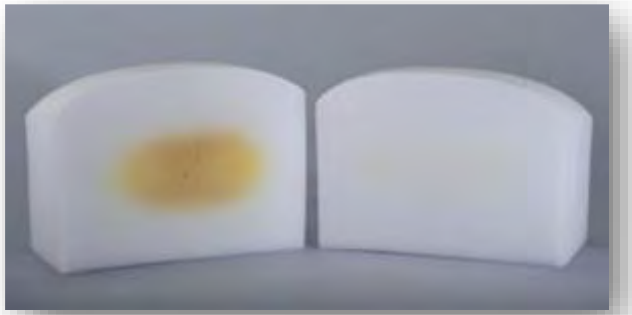
SCORCH

- **The catalytical induced polymerization reaction between polyols and isocyanates to generate the PU polymer and the foaming/ "water-blowing" reaction is accompanied by heat generation!**
- **Scorching** causes **discoloration** of the foam and can also cause **physical damage** to the foam.
  - Exothermic reactions push foam temp. up to 160°C and more.
  - It will often appear in the core of the foam, and **may, in extreme cases, lead to self-ignition of the foam**.



Foamers and Processors may still add extra ***post-treatment AO additives*** to the polyols prior to the foaming process to further reduce scorch discoloration depending on their application (low densities = higher water levels = more exotherms, flame retardants, and weather conditions (heat, moisture rate)

Scorch can be controlled by the addition of antioxidants.
Polyols are always protected with a minimum amount of antioxidants.

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POLYOLS AND STABILISATION

Polymer Additives Internal Training
Internal Use Only

Antioxidants are always added to polyether polyols and foams

- provide storage stability even at room temperature
- protect against degradation and against peroxide formation
- support scorch protection during the final foam production process.

DOSAGE RECOMMENDATIONS POLYETHER POLYOLS

- **Rigid applications** — approx. **200 to 500 pphp**
  Molding or CASE applications — approx. **500 to 1000 pphp**
- **Slabstock polyols** — need up to **2500 to 5000 pphp**

Increase of exothermic conditions

NOTE:
POLYESTER-POLYOLS do require very small loadings of AOs as they are relatively stabile against oxidation.

Antioxidants, at concentrations of 200 – 5000 pphp per hundred parts of polyols are added to the polyether polyol, whereas polyester polyols are very stable

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Effective Anti-Scorch Packages for POLYURETHANES and POLYOLS

- **NAUGARD™ PS 48** LIQUID STANDARD PHENOLIC AO **(sampling Q1, commercial quantities Q3 21)**
- **ANOX™ PP 18** and **ANOX™ 20** SOLID PHENOLIC AOs.
- **NAUGARD™ 445** solid & **NAUGARD™ PS 30** LIQUID AMINE AO SCORCH SYNERGISTS
- **NAUGARD™ PS 3015** LIQUID BLEND AS STANDARD POLYOL STABILISER
- **ULTRA LOW EMISSIVE** BEST IN CLASS **ANOX™ 1315** LIQUID PHENOLIC AO
- **HIGH PERFORMANCE** SOLID **LOWINOX™ 1790** FOR SPANDEX APPLICATIONS

NEW LIQUID BLENDS DEVELOPMENTS

- **ULTRA LOW EMISSIVE FOAMPLUS™ LE5** FOR AUTOMOTIVE SLABSTOCK POLYOLS

- ***ZERO PHENOL** phosphite **WESTON™ TDP ZP** for polyester foams
- ***ZERO PHENOL** phosphite **WESTON™ 430 ZP** for flame lamination
- **ZERO NONYLPHENOL** phosphite **WESTON™ 705 as alternative to TNPP**

(*currently not Europe, please request support by EHS for further information)

COMPETITIVE REFERENCE

	COMPETITIVE AO	Direct drop-in	BETTER SOLUTION	TOP SOLUTION	REASON
Phenolic, solid	• **AO 1076** • **AO 1076 molten** • **AO 1010**	(1) ANOX PP 18 (1) Molten ANOX PP 18 *** (1) ANOX 20	(2) ANOX 1315 (liquid)		Liquid easier handling and better dosing
Phenolic, solid	• **BHT**	-	(2) ANOX 1315 (liquid)		BHT is very emissive
Phenolic, liquid	• **AO 1135**	(1) NAUGARD PS 48 *	(2) ANOX 1315		AO 1135 is very emissve
Aminic, liquid	• **AO 5057**	(1) NAUGARD PS 30			
Aminic/ phenolic 1:2 blend	• **AO 55 = (AO 5057/ AO 1135)**	(1) NAUGARD PS 4830 **	(2) NAUGARD PS 3015	(2) FOAMPLUS LE 5	From left to right: less emissions
Phosphite	• **TDP** • **TNPP**	(1) WESTON TDP	(2) WESTON TDP ZP (2) WESTON 705		ZP Zero Phenol or nonylphenol free

* Available from Q1/ 2021. Sampling stage. Commercial quantities Q3 2021
** Available from Q2/Q3 2021
*** Available from Q1/ 2022
(1) Direct Drop-in or (2) Alternative

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PRODUCT OFFERINGS DOWNSTREAM

Solutions	AO Class	Physical Form	Polyol Storage Stability	Scorch Resistance	VOC/FOG Emissions	Minimimal Foam Surface Discoloration (NOx/UV)	Handling
ANOX® PP18	Phenolic	Solid	***	**	Low	***	**
ANOX® 1315	Phenolic	Liquid	***	**	Low	***	****
NAUGARD® PS30	Aminic	Liquid	****	***	Moderate	**	***
NAUGARD® PS 3015	Phenolic/ Aminic	Liquid	*****	****	Moderate	**	***
NAUGARD® FOAMPLUS LE 5	Phenolic/ Aminic	Liquid	*****	****	Ultra Low	**	****
LOWILITE® UV B1260	Thermal/ UV Stabilizers	Liquid	***	*	Low	**** (UV)	****

- **NEW** NAUGARD™ PS48 is a very efficient liquid phenolic antioxidant with excellent compatibility
- ANOX™ PP18 is a very efficient low VOC solid phenolic antioxidant
- ANOX™ 1315 is a very efficient low emissive liquid phenolic antioxidant (VDA 278) with excellent compatibility
- NAUGARD ™ PS 30 is a very efficient liquid aminic antioxidant used often in combination with phenolic AOs
- NAUGARD™ PS 3015 is an effective liquid anti-scorch AO blend to reduce volatile emissions of the AO package
- NAUGARD™ FOAMPLUS LE 5 is an effective liquid anti-scorch package to reduce significantly volatile emissions of the AO package , compliant to automotive standard VDA 278
- LOWILITE™ UV B1260 is a highly effective liquid blend of thermal & UV stabilizers that protects polyurethanes foams against exterior light induced weathering

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NAUGARD™ PS48

LIQUID, STANDARD PHENOLIC STABILIZATION

NAUGARD™ PS48 stabilizer is a liquid hindered phenolic for use as an antioxidant across many applications

- Offers excellent scorch protection especially for **CASE** and **rigid polyols**
- Simple and **easy drop-in** solution at typical use levels of 0,15 -0,5 php
- Especially powerful when used in **synergistic combination** with other liquid aminic stabilizers such as **NAUGARD™ PS 30** or solid **NAUGARD™ 445** to boost performance for any other polyurethane segment such as **molded or flexible foam application.**

Application

For use in polyether and polyester polyol applications at producers and polyurethane processors; excellent choice for rigid and **CASE** polyols and as basis for slabstock polyols in combination with aminic boosters

NAUGARD™ PS 48: Phenolic C7-C9 Ester: benzenepropanoic acid, 3,5-bis (1,1-dimethyl-ethyl)-4-hydroxy-C7-C9 branched alkyl esters.
CAS number: 125643-61-0

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ANOX™ 1315

LIQUID, ULTRA LOW **EMISSIVE STABILIZATION**

ANOX™ 1315 is three times less emissive than standard liquid phenolic types and superior to solid BHT

- Full compliance with automotive VDA 278 and OEKO-TEX Standard 100
- Simple and easy drop-in solution at 250-2500 ppm
- Offers excellent scorch protection especially for **CASE** and **rigid polyols**
- Especially powerful when used in synergistic combination with other liquid aminic stabilizers such as **NAUGARD™ PS 30** or solid **NAUGARD™ 445** to boost performance for any other polyurethane segment such as **molded or flexible foam application**

ANOX™ 1315: 3,5-Bis (1,1-dimethylethyl)-4-hydroxy-benzenepropanoic acid, branched C13-15 alkyl esters.
CAS number: 171090-93-0

TGA WEIGHT LOSS

N2, 10°C/min, 50°C to 400°C, 3 times

	5%	10%	15%	20%	25%	50%
BHT (solid)	120	133	141	147	151	169
ANOX™1315	256	278	289	297	304	325

Application

For use in polyether and polyester polyol applications at producers and polyurethane processors; excellent choice emission reduced rigid and **CASE** polyols and as basis for slabstock polyols in combination with aminic boosters

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NAUGARD™ PS30

LIQUID, MULTIPURPOSE **AMINIC ANTIOXIDANT**

NAUGARD™ PS30 stabilizer is a liquid amine antioxidant developed specifically for use in polyether polyols to reduce scorch associated with flexible urethane foam production.

- As a liquid, **NAUGARD™ PS30 stabilizer** can be easily blended into polyols at ambient temperatures in less time compared to conventional solid stabilization systems
- **NAUGARD™ PS30 stabilizer** is designed to be used in combination with phenolic and phosphite antioxidants to synergistically inhibit both physical and colour scorch associated with flexible urethane foam production. CAS: 68411-46-1

Appearance	Clear, reddish to brown liquid
Residual Diphenylamine (DPA)	0.05%
Viscosity, cSt @ 40 deg C	400
Gardner Color	2
Specific Gravity @ 25 deg C	0.98
Boiling Point	>200 deg C
Flash Point	180 deg C
Nitrogen Content	4.7%
Moisture	0.01%
Ash	0.01%

Application: Offers excellent scorch protection for any polyether polyol for foams for comfort, furniture, automotive and CASE applications

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NAUGARD™ 445

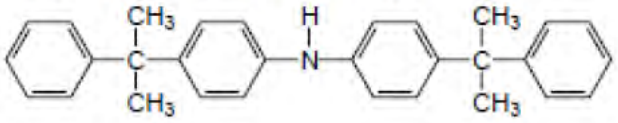
SOLID, LOW EMISSIVE AMINIC ANTIOXIDANT

Highly effective and low emissive general purpose aminic booster with full antiscorch performance which is unparalled much less emissive than a standard aminic liquid AO (equ. NAUGARD™ PS 30)

- It provides stabilization for polyol producers & polyurethane processors
- Simple and easy drop-in replacement for emissive AO 5057 at 250 – 2000 ppm requiring no capex or changes in production
- Offers excellent scorch protection in combination with ANOX™ 1315 or phosphite for flexible slabstock polyurethane foams and CASE applications
- CAS 10081-67-1

Formula

NAUGARD™ 445 stabilizer



Typical physical properties of NAUGARD™ 445 stabilizer

Appearance	White powder or granules
Molecular weight [g/mol]	406
Melting Point [°C]	98-100
Color – APHA	20
Specific Gravity at 55 °C	1.14
Flash Point [TCC/°C]	277

Application: Offers excellent scorch protection & ultra low emissions for any polyol for flexible polyurethane foams for comfort, furniture, automotive and CASE application

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NAUGARD™ PS 3015

LIQUID, FOG IMPROVED LOW EMISSIVE ANTIOXIDANT FOR SLABSTOCK COMFORT FOAMS AND MATRESSES

3 times FOG reduction in FOG compared to industry standard

- **Low emissive general purpose** stabilization **for polyol producers & polyurethane processors**
- **Compliance with OEKO-TEX Standard 100**
- Offers **excellent scorch protection** for flexible polyurethane **foams and CASE** applications
- Simple and **easy drop-in** replacement **at 3000 – 4500 ppm** requiring no capex or changes in production

Typical physical properties of NAUGARD™ PS 3015 stabilizer blend

Appearance	Yellowish liquid
Pour point [°C]	< -50
Density @ 25 °C [g/cm^3]	0,947

Thermogravimetric Analysis (10 mg @ 10 K/minute under N_2)

Weight Loss [%]	5	10	25
Temperature [°C]	219	239	272

INDUSTRY STANDARD
2:1 mix of phenolic PS 48 (CAS number: 125643-61-0) and aminic PS 30 (CAS: 68411-46-1) equivalent to NAUGARD™ PS4830 as a functional alternative to AO 55 technology.

Application: Offers excellent scorch protection in polyols for flexible polyurethane foams such as matresses, furniture and also CASE

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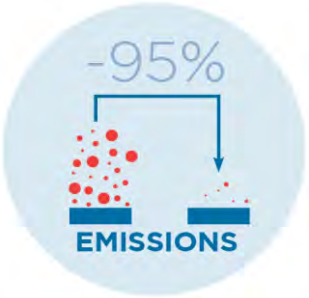
NAUGARD™ FOAMPLUS LE 5



Ultra Low Emissions

NAUGARD™ FOAMPLUS is an ultra low VOC and FOG emissive stabilization package for polyols for polyurethanes. Enabling compliance with stricter national legislations on vehicle indoor air quality (VIAQ). The new solutions are much less volatile than the industry benchmarks at the high foaming temperatures, reducing VOC & FOG emissions by more than 90%.

VDA 278 Compliance

The higher thermal stability of NAUGARD™ FOAMPLUS enables full compliance with the VOC & FOG limits of VDA 278. The VDA 278 specification is part of the delivery specs of major automobile manufacturers such as Daimler, BMW, Porsche and VW.

Excellent Scorch Protection

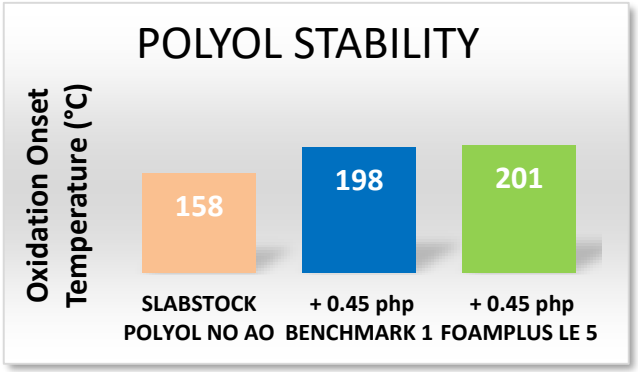
NAUGARD™ FOAMPLUS offers excellent scorch protection for flexible polyurethane foams avoiding discoloration. It offers comparable scorch performance as the existing liquid industry benchmark.

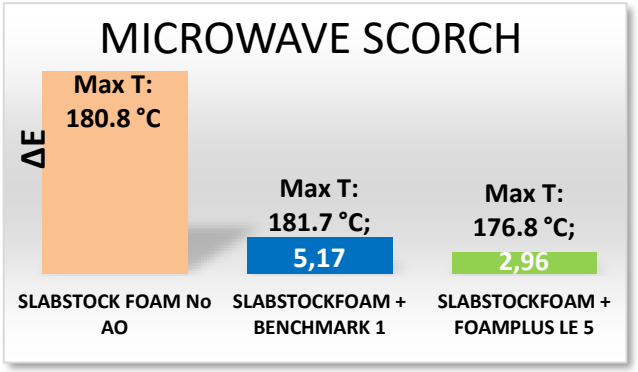
Simple Drop-in Replacement

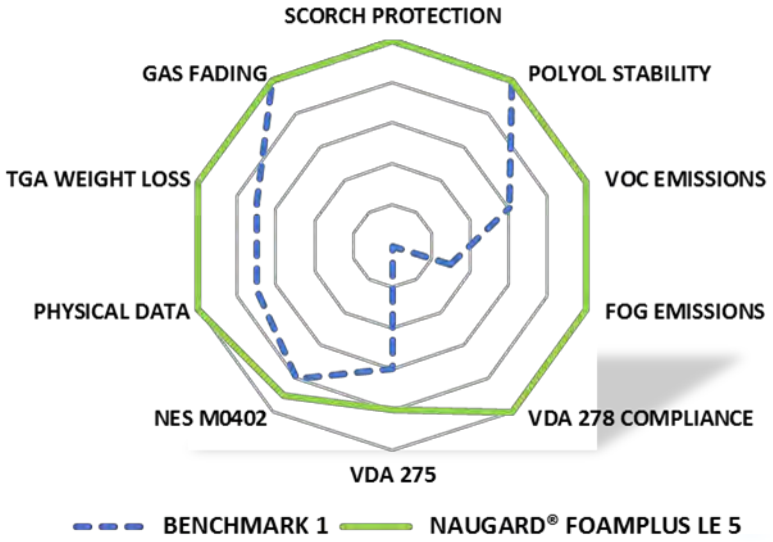
Easy drop-in replacement requiring no capex, backed by Addivant's extensive global manufacturing assets and supply chain supporting global specification standards required by the industry.

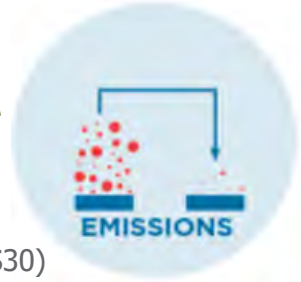
The ultra low emissive, VDA 278 compliant drop-in liquid anti scorch solution for automotive slabstock polyols with > 90 % emission reduction compared to standard 2:1 Phenolic PS 48/ aminic PS 30 system

NAUGARD™ FOAMPLUS LE 5: Technical Performance at a Glance









Tests conducted with a stabilization dosage level of 4500 ppm
Benchmark 1: NAUGARD™ PS 4830 (2:1 blend of PS48 and PS30)

NAUGARD™ FOAMPLUS LE 5 fulfils critical customer requirements

ANOX™
LOWILITE™
LOWINOX™
NAUGARD™
WESTON™

Summary

SI Group's antioxidants can play an integral role in solving your technical issues & complying with stringent standards, including:

- **Emission control** and **compliance** with VDA or Oekotex standards
- **Improved polyol stability** and **scorch protection of polyurethane applications** for greater production safety & better quality
- **UV resistance** for sensitive light colored & white PU applications

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