GARAMITE®

MIXED MINERAL THIXOTROPES

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ROCKWOOD ADDITIVES

SOUTHERN CLAY PRODUCTS, INC. | A ROCKWOOD SPECIALTIES, INC. COMPANY

SOUTHERN CLAY PRODUCTS, INC.

Garamite® Additives - High Performance with Low Viscosity

CONTENTS

Southern Clay Products, Inc: An Introduction 2

Garamite® Additives – Product Description 3

The Advantages of Garamite® Additives 4

Garamite® Additives in Unsaturated Polyester Resins (UPR) 6

Incorporation of Garamite® Additives into UPR Systems 10

Garamite® Additives in Epoxy Resin Formulations 12

Garamite® Additives for High Solids Epoxy Formulations 14

Garamite® Additives for Epoxy Coating Formulations 15

Garamite® 1958 in a High Gloss Epoxy Topcoat 15

Garamite® 1958 in a High Build Epoxy Finish 16

Garamite® 1958 in Filled Epoxy Resin Systems 17

Garamite® 1958 in Vinyl Ester Resin Systems 18

At Southern Clay Products, Inc., our goal is to deliver solutions to our customers... "we create and deliver solutions."

In the late 1940's, Southern Clay Products was created with a vision – innovate and expand. We began in Gonzales, Texas as miners and suppliers of unprocessed ore and simple milled products from local reserves. We have since steadily expanded our scope, acquiring and processing minerals from a wide range of global sites – from Texas to China to Spain to Morocco to Turkey.

In 2000, Southern Clay Products became part of Rockwood Specialties, Inc. Headquartered in Princeton, New Jersey, Rockwood Specialties is a leading manufacturer of specialty chemicals and minerals throughout the world. Rockwood Specialties substantial commercial and financial support will allow Southern Clay Products to strengthen our position as an international leader in our fields.

As 2005 drew to a close, Southern Clay Products completed the acquisition of the rheological additives business of Sud Chemie, including operating sites and laboratories in Louisville, Kentucky and Moosburg, Germany. These locations joined previously existing sites in Gonzales, Texas and Widnes, England to form a global physical presence for Southern Clay Products.

Through technical and commercial partnerships, joint ventures, and acquisitions, Southern Clay Products has grown into a world leader in specialty additives. Specialty additives manufactured by Southern Clay Products are used by customers to formulate unique products in an extensive number of markets.

Today, scientists from many disciplines and diverse backgrounds work in our modern, well-equipped laboratories to develop more advanced products and technologies based on a variety of chemistries. Our scientists work with world leaders in universities and industry, including our suppliers and customer partners, to ensure that Southern Clay Products continues to be the preferred supplier of high value, multi-functional additives.

From computer modeling of ore deposits and complex chemical reactions to sophisticated rheological characterizations or additive enhanced formulations, Southern Clay Products differentiates itself through state-of-the-art technology. We are committed to meeting the needs of our customers both now and in the future through world class commercial development, product design, manufacturing, technical selling, and customer partnerships.

Garamite® additives are the culmination of a concerted development effort by Southern Clay Products, Inc. to design a product that would answer the rheological needs of a number of industries that have used fumed silica as their primary thixotrope. The result of this development effort was the creation of Mixed Mineral Thixotrope (MMT) technology for which a patent has been issued to Southern Clay Products.

MTT technology involves the blending of acicular and platey minerals that are then surface modified for resin compatibility. The combination of different mineral morphologies promotes particle spacing creating a product that disperses very easily. The commercialization of the MMT technology spawned the Garamite® brand of additives. Garamite® additives differ from other organically modified mineral thixotropes by exhibiting unparalleled ease of dispersion, ease of use, high efficiency, and high performance without unwanted viscosity.

Garamite® additives have several distinct and quantifiable advantages compared to fumed silica additives:

- Higher bulk density
  - Less dust during handling
  - Less storage space required
  - Reduced order frequency
- Easier incorporation into resin or solvent
- Higher efficiency in use (typically 30-40% more efficient)
- Higher sag and slump resistance
- Easier application of products due to an improved performance/viscosity ratio

The volume of 10 grams each of fumed silica and Garamite® 1958. Due to its higher bulk density, Garamite® 1958 reduces dust, reduces storage space required, and reduces order frequency versus fumed silica additives.

Garamite® additives are unique in their ability to provide high performance in composite and coating systems without creating large unwanted and unnecessary increases in viscosity as is common with other rheology control additives. It is also possible to use Garamite® additives to create high solids and 100% solids environmentally compliant formulations because of their ability to develop performance prior to the onset of any significant increase in viscosity. Garamite® additives are the first additives available to formulators of composites and coatings that allow for improvements in sag resistance, anti-settling, syneresis, orientation of metallic particles, and spray atomization while having a minimal impact on viscosity.

Garamite® additives will improve the economics, manufacturing, storage and application of most formulated products:

Economics

Because Garamite® additives are typically 30-40% more efficient than other common thixotropes, overall formulation cost can typically be lowered by choosing to use a Garamite® additive.

Manufacturing

Garamite® additives incorporate much more readily and quickly than other thixotropes. Garamite® additives also do not require high shear mixing or chemical or heat activation. Garamite® additives require less storage space than bulky additives such as fumed silica.

Stability

Garamite® additives control settling/floating of particles and lightweight materials and prevent phase separation and/or syneresis in formulated products.

Application

Formulated products containing Garamite® additives thin quite rapidly when shear is applied for better application properties.

Post Application

The fast recovery of viscosity for formulated products containing Garamite® additives enables coatings to be applied to vertical or inclined surfaces without running or dripping. Heavy coating weights can also be applied to molds or surfaces without fear of slump or sag.

Garamite® additives are characterized by high efficiency and ease of incorporation. Furthermore, Garamite® additives develop desired performance properties without contributing an appreciable increase in viscosity to the formulation. Garamite® additives employ the concept of focused performance to deliver desired performance with fewer unwanted negative side effects.


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GARAMITE® ADDITIVES IN UNSATURATED POLYESTER RESINS (UPR)

Garamite® additives are very effective rheology modifiers in UPR systems versus competitive chemistries. Garamite® additives offer the following benefits over other commonly used rheology control additives:

- Application performance without high viscosity
  - Lower viscosity allows formulation solids to increase, thus reducing VOC emissions
  - Increased sag resistance versus other rheology control additives
  - Ease of processing, pumping, and application
- Higher bulk density and easier handling than fumed silica
  - Less dusting
  - Less storage space required
  - Less order frequency
- Incorporation without high shear, heat, or polar activation
  - No special equipment needed
  - Less energy required per batch
  - Reduced number of processing steps versus some rheology control additives
- Typically 30-50% more efficient per unit weight than other rheology control additives
  - Possible reduction in formulation cost
- Synergy with common rheology enhancers such as BYK® R-605
  - Will allow for even higher efficiency per unit weight versus other rheology control additives further reducing formulation cost

Mixed Mineral Thixotrope technology effectively uncouples viscosity and performance. In the case of Garamite® additives, viscosity is not a good indicator of application performance. Specifications for formulations containing Garamite® additives should be set around actual performance parameters such as sag resistance and not based on older fumed silica rheology profiles.

Typically in UPR formulations when Garamite® additives are compared to fumed silica additives at equal loading levels, the formulations containing Garamite® additives exhibit a higher low shear viscosity and a lower high shear viscosity as seen in FIGURE 1. This type of rheology profile has two advantages. The first is that it allows the creation of formulations that exhibit higher sag and better suspension properties due to the higher yield value of the formulation. FIGURE 2 and FIGURE 3 provide visual confirmation of these benefits. The second advantage is that formulations containing Garamite® additives have a lower application viscosity (high shear viscosity) making the products easier to handle and apply.

TABLE 2 shows that as formulation solids are raised the increase in viscosity for the hydrophilic fumed silica formulations is very pronounced when compared to the values in TABLE 1. The formulation containing Garamite® 1958 maintains a significantly lower viscosity and shows much less increase in viscosity as formulations solids are increased. Performance without excess viscosity is one of the key benefits of Garamite® additives and allows for the formulation of higher solid and lower VOC products.

FIGURE 1 - A comparison of the hysteresis flow curves of Garamite® 1210 and fumed silica.

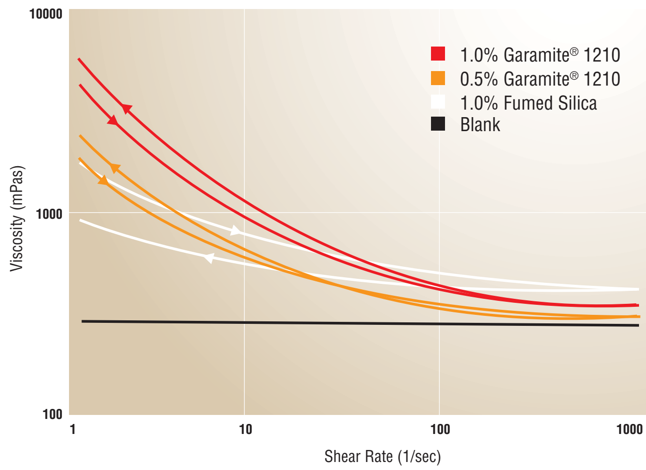


TABLE 1

65% Solids Ortho Resin	Loading	Sag in mils(microns)	Brookfield LVT in cps		Thix Index
			6 rpm	60 rpm	
Garamite® 1958	0.50	6 (152)	2500	600	4.17
Hydrophilic Fumed Silica	1.00	6 (152)	2700	800	3.38

TABLE 2

69% Solids Ortho Resin	Loading	Sag in mils(microns)	Brookfield LVT in cps		Thix Index
			6 rpm	60 rpm	
Garamite® 1958	0.54	8 (203)	2800	900	3.11
Hydrophilic Fumed Silica	1.00	8 (203)	3900	1100	3.54

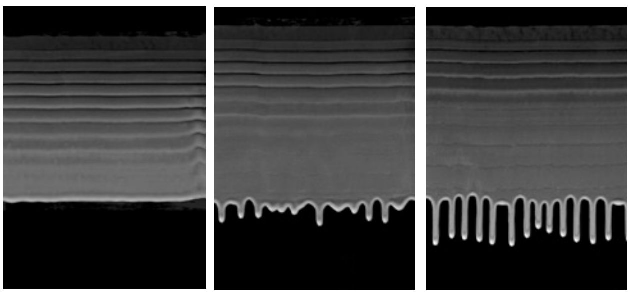
The efficiency of Garamite® additives can be further improved by using them in combination with a rheology enhancer such as BYK® R-605. Adding as little as 10% of the weight of the Garamite® additive in the formulation will allow the formulator to reduce the level of the Garamite® additive by up to 40% thus further reducing the cost of the formulation. TABLE 3 illustrates that 0.6% Garamite® 1958 used with BYK® R-605 can approximate the performance of 1.0% Garamite® 1958 alone.

TABLE 3

DCPD Resin	Brookfield LVT in cps			Thix Index (1/10)	Thix Index (10/100)	Sag in mils (microns)
	1 rpm	10 rpm	100 rpm			
1.0% Garamite® 1958	6000	1450	515	4.14	2.82	8(203)
0.6% Garamite® 1958 + 10%* BYK® R-605	5000	1250	470	4.00	2.66	6(152)

* Based on the weight of the Garamite® 1958

FIGURE 2 - Lenata Sag Comparison



0.3% Garamite® 1958 0.5% Fumed Silica 0.5% Organoclay

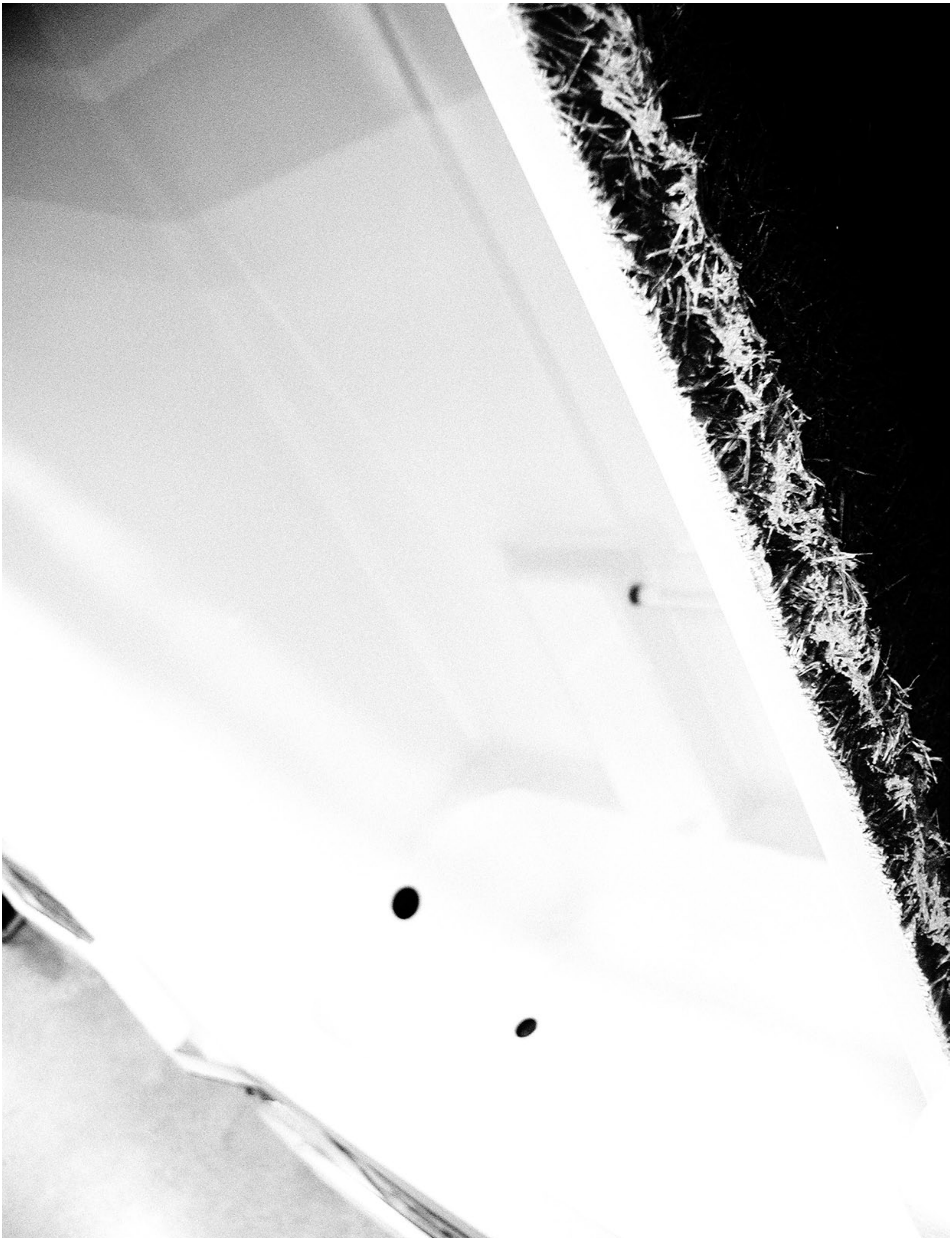
FIGURE 3 - Suspension Comparison

INCORPORATION OF GARAMITE® ADDITIVES INTO UPR SYSTEMS

For maximum performance in UPR systems, Garamite® additives should first be predispersed in monomer or solvent. The following process is highly recommended to ensure maximum performance of Garamite® additives in all UPR systems:

- **DO** add Garamite® additives to the solvent or monomer phase of your product. Do **NOT** add dispersant, wetting agent, surfactant, defoamer, or rheology enhancer to the solvent **PRIOR** to the addition and mixing of Garamite® additives into the monomer or solvent.
- In situations where no solvent is present, utilize any diluents that are available to disperse Garamite® additives. If diluents are not available, then disperse in the lowest viscosity component of the formula. **ONLY** minimal shear is necessary to incorporate Garamite® additives in the predispersion phase.
    - Typically, a high speed mixer, such as a MorehouseCowles or Hockmeyer, is more than adequate for mixing Garamite® additives. In many cases, Garamite® additives can be incorporated into a solvent, monomer or low molecular weight resin using a positive displacement or Moyno® type pump.
    - The mixer speed should be sufficient to generate and maintain a visually apparent vortex for 5 to 10 minutes. Additional shear may entrain air into your predispersion.
    - If air entrapment problems are encountered, using minimal mixing shear can sometimes alleviate those problems. The use of air release agents tailored to the individual system may also be beneficial.
- For maximum efficiency, the concentration of Garamite® additive in the predispersion should be above 8% and not exceed 15%. At these concentrations, the Garamite® additive predispersion will remain pumpable and pourable.
- The Garamite® additive predispersion may be added to your formula at any point in your manufacturing process. In some instances (most notably unsaturated polyester resins) it is preferable to drop the resin into the Garamite® additive predispersion.

Typically you will find that Garamite® additives incorporate much more readily than conventional thixotropes. They do not require high shear, heat activation, or polar activation. Reductions in processing time of 50% or more are common. We recommend that laboratory evaluations confirm the most efficient method of dispersion and order of addition for your specific applications.



GARAMITE® ADDITIVES IN EPOXY RESIN FORMULATIONS

Garamite® additives are used in a wide range of epoxy formulations. In epoxy formulations, Garamite® additives are characterized by high efficiency, ease of incorporation, excellent stability, and superior performance at low viscosity. Typical epoxy systems containing Garamite® additives will employ 25 to 50% less thixotrope while maintaining or improving sag resistance versus thixotropes such as fumed silica, hydrogenated castors, polyamides, and organoclays. When using Garamite® additives in epoxies, solids increases of 4 percentage points or more are possible while sacrificing no performance or application properties. The following pages detail a number of evaluations that were conducted to characterize the performance of Garamite® 1958 in various epoxy formulations. Garamite® additive benefits in epoxy resin systems include:

- ► Application performance without high viscosity
  - Lower viscosity allows formulation solids to increase reducing VOC emissions
  - Increased sag resistance versus other rheology control additives
  - Ease of processing, pumping, and application
- ► Higher bulk density and easier handling than fumed silica
  - Less dusting
  - Less storage space required
  - Less order frequency
- ► Incorporation without high shear, heat, or polar activation
  - No special equipment needed
  - Less energy required per batch
  - Reduced number of processing steps versus some rheology control additives
- ► Typically 25-50% more efficient per unit weight than other rheology control additives
  - Possible reduction in formulation cost

GARAMITE® ADDITIVES FOR HIGH SOLIDS EPOXY FORMULATIONS

Garamite® additives can be used in place of or to replace fumed silica and other rheology additives allowing for an increase in formulations solids and a corresponding reduction in VOC emissions. Due to the fact that Garamite® additives develop high performance without a significant viscosity contribution, formulation solids can be increased while remaining in a target viscosity range.

To illustrate this property of Garamite® additives, a study was conducted to match the performance of a fumed silica containing formulation with a Garamite® additive containing formulation, but at a higher solids level (Table 4).

A glance at TABLE 4 below quickly reveals one of the main benefits of formulating with Garamite® additives. Formulations can be created that perform similar to the control, but at a higher solids level which reduces VOC emissions. This is particularly important in regions where VOC emissions must be reduced significantly.

It must be noted that the performance of an epoxy formulation containing a Garamite® additive can vary depending on the chemistry of the hardener that is used. TABLE 5 exhibits the results of the same experiments run in TABLE 4 except that a different hardener chemistry was used.

TABLE 4 - Solids optimization study with Ancamine® 2280[1]

	Control	Check at equal loading	Reduce solvent level	Reduce Garamite® additive level	Reduce Garamite® additive level and solvent level	Compare to fumed silica at same values
	Hydrophobic Fumed Silica	**Garamite® 1958**	**Garamite® 1958**	**Garamite® 1958**	**Garamite® 1958**	**Hydrophobic Fumed Silica**
Parts thix/100 parts resin	2	2	2	1.5	0.75	0.75
Parts solvent	18	18	10	10	6	6
% Solids	90	90	94	94	96	96
A Side Viscosity @ 5 rpm	14,240	7,280	22,280	11,600	16,080	25,280
A + B Sag Resistance*	20 (508)	25 (634)	30 (761)	20 (508)	20 (508)	12 (305)
	Goal is to match the sag of the control	Too much sag	Too much sag	Equal sag and higher solids	Equal sag and much higher solids	High viscosity and low sag

[1] Air Products
*mils (microns)

TABLE 5 - Solids optimization study with Epi-Cure® 3140[1]

	Control	Check at equal loading	Reduce solvent level	Reduce Garamite® additive level	Reduce Garamite® additive level and solvent level	Compare to fumed silica at same values
	Hydrophobic Fumed Silica	**Garamite® 1958**	**Garamite® 1958**	**Garamite® 1958**	**Garamite® 1958**	**Hydrophobic Fumed Silica**
Parts thix/100 parts resin	2	2	2	1.5	0.75	0.75
Parts solvent	18	18	10	10	6	6
% Solids	90	90	94	94	96	96
A Side Viscosity @ 5 rpm	14,240	7,280	22,280	11,600	16,080	25,280
A + B Sag Resistance*	20 (508)	27 (685)	27 (685)	20 (508)	20 (508)	18 (457)
	Goal is to match the sag of the control	Too much sag	Too much sag	Equal sag and higher solids	Equal sag and much higher solids	High viscosity and lower sag

[1] Hexion
*mils (microns)

Garamite® additives can be used to create a wide range of epoxy coating formulations. The properties that Garamite® additives provide to epoxy coating formulations lend themselves to high build formulations or formulations that require a certain amount of resistance to sag. Performance comparisons of Garamite® additives versus fumed silica and other commonly used rheology modifier chemistries are discussed below.

Garamite® 1958 in a High Gloss Epoxy Topcoat

In a high gloss epoxy topcoat, Garamite® additives provide low "A" side viscosity with high sag resistance in the final product. The formula in TABLE 6 shows a typical high gloss epoxy topcoat. In this evaluation, Garamite® 1958 was incorporated in the "A" side, although the formulator may optionally incorporate Garamite® 1958 in the "B" side. Advantages to the formulator in this system include high sag resistance at low viscosity as well as faster and easier incorporation. Details of the performance of Garamite® 1958 in this type of system are shown in FIGURE 5 below.

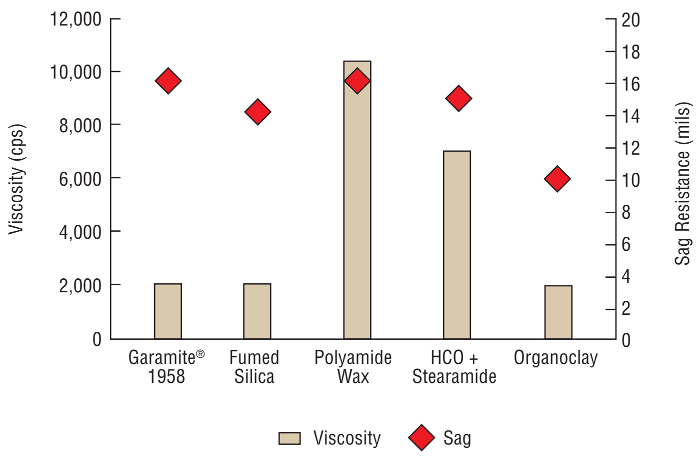
TABLE 6

A Side (parts by weight)	
DER® 671-X-75 [1]	100
n-butanol	10
xylene	6.4
Tronox® CR-800 [2]	54.8
Talcron MP 12-50 [3]	26.6
Thixotrope*	1.3
Propylene Carbonate**	0.6
n-butanol	12.6
xylene	32.7
B Side (parts by weight)	
Ancamine® 2280 [4]	58

[1] Dow Chemical, EBW 425-500; 75% solids; Visc @ 25 C = 6,500 - 12,000 cps.
[2] Tronox, titanium dioxide
[3] Barretts Minerals, talc
[4] Air Products, HEW 110; Visc @ 25 C = 4500 cps
* Formulator may choose to try to use thixotrope on B Side
** Polar activator used where applicable

FIGURE 5

Garamite® 1958 in a High Gloss Epoxy Topcoat



Thixotropes added to resin/solvents

Garamite® 1958 in a High Build Epoxy Finish

In high build epoxies, Garamite® additives can offer up to double the sag resistance of fumed silica at lower viscosity. This unique combination of high sag resistance at relatively low viscosity offers the highest sag to viscosity ratio of any thixotrope on the market today. Coupled with the advantage of being the most easily incorporated thixotrope for epoxies, Garamite® additives are the obvious choice for manufacturers of high build epoxies.

For this evaluation, the formula used is found in TABLE 7. The results are found in TABLE 8 below. The last column in TABLE 8 again demonstrates the potential for Garamite® additives to generate performance properties far in excess of what one would expect from the measured viscosity. Note the rating of 6.25 for hydrophobically modified fumed silica versus the measurements of between 24 and 28 for Garamite® 1958. Garamite® 1958 delivers performance that is 300% more focused upon the properties that matter - and it does so with a product that is less expensive and much easier to incorporate.

TABLE 7

A Side (parts by weight)	
Epon® 828[1]	100
Tronox® CR-800[2]	54.8
Sparmite[3]	26.6
Thixotrope*	1.3
n-butanol	12.6
xylene	32.7
Propylene Carbonate**	0.6
B Side (parts by weight)	
Ancamine® 2280 [4]	58

[1] Hexion, EBW 188
[2] Tronox, titanium dioxide
[3] Elementis, barium sulfate
[4] Air Products, HEW 110; Visc @ 25 C = 4500 cps
* Formulator may choose to try to use thixotrope on B Side
** Polar activator used where applicable

TABLE 8 - High Build Epoxy Results

Thixotrope	Method of Addition	50 rpm	Sag Viscosity mils (microns)	1000 X Sag Resistance / 50 rpm
Garamite® 1958	Predispersed in solvent	1,040	25 (634)	24.04
Garamite® 1958	Dispersed in resin/solvent	670	18 (457)	26.87
Garamite® 1958	Direct add to resin	560	16 (406)	28.57
Fumed Silica				
Hydrophilic	Predispersed in resin/solvent	750	12 (305)	16.00
Hydrophobic	Predispersed in resin/solvent	1,920	12 (305)	6.25
Organoclay				
Conventional	Predispersed in solvent + P.A.[1]	610	10 (254)	16.39
Activator Free	Predispersed in solvent	880	12 (305)	13.63
Polyamide Wax	Predispersed in solvent	950	8 (203)	8.42
HCO + Stearamide	Predispersed in solvent	660	12 (305)	18.18

[1] P.A. = Polar Activator

GARAMITE® 1958 IN FILLED EPOXY RESIN SYSTEMS

In filled epoxy systems, Garamite® additives exhibit very high flexibility in their ability to function efficiently with a variety of different fillers. Garamite® additives suspend a wide variety of materials while providing superior sag resistance to the coatings formulator.

Using the simple formula in TABLE 9, three fillers were evaluated: TiO_2, $CaCO_3$, and silica flour. All three were evaluated using Garamite® 1958, hydrophobically modified fumed silica (FS - hydrophobic), and a hydrophilic fumed silica (FS - hydrophilic). Results are shown in TABLE 10. Again Garamite® additives generate sag resistance at less or equal viscosity with lower dosing of the additive.

The ease of incorporation and handling coupled with the substantial reduction in the level of additive employed in the formulation makes Garamite® 1958 the thixotrope of choice for filled epoxy systems.

TABLE 9

A Side (parts by weight)	
Epon® 828 [1]	100
Thixotrope*	1 - 3
Filler	25 - 50
B Side (parts by weight)	
Ancamine® 2280 [2]	58

[1] Hexion, EBW 188
[2] Air Products, HEW 110; Visc @ 25 C = 4500 cps
* Formulator may choose to try thixotrope on B Side
** Polar activator used where applicable

TABLE 10 - Evaluation of fillers with Garamite® 1958

Extender	Thixotrope	Loading	10 rpm Viscosity	Sag Resistance mils (microns)
TiO_2	**Garamite® 1958**	1.5%	100,000	20 (508)
TiO_2	FS - Hydrophobic	2.0%	135,000	20 (508)
TiO_2	FS - Hydrophilic	2.5%	140,000	20 (508)
$CaCO_3$	**Garamite® 1958**	1.3%	60,000	10 (254)
$CaCO_3$	FS - Hydrophobic	1.6%	80,000	10 (254)
$CaCO_3$	FS - Hydrophilic	2.4%	100,000	10 (254)
Silica Flour	**Garamite® 1958**	1.0%	80,000	10 (254)
Silica Flour	FS - Hydrophobic	1.4%	70,000	10 (254)
Silica Flour	FS - Hydrophilic	2.4%	90,000	10 (254)

GARAMITE® 1958 IN VINYL ESTER RESIN SYSTEMS

Garamite® 1958 offers substantial performance and cost savings advantages to manufacturers of vinyl ester resin systems. Using the formulation in TABLE 11, both hydrophobically modified fumed silica and hydrophilic fumed silica were evaluated versus Garamite® 1958. All three products were evaluated for efficiency as well as response to BYK® R-605, a commonly used rheology enhancer.

In this evaluation, all three thixotropes that were tested were first added to Derakane® 411-350 while being mixed on a high speed mixer.

Garamite® 1958 has the lowest viscosity of all three thixotropes tested at the 30 mil sag rating.

A multiple cost savings is provided by using less Garamite® 1958 versus fumed silica and by reducing the amount of rheology enhancer. The results indicate that in addition to using less Garamite® 1958, the manufacturer can also use less BYK® R-605.

Garamite® additives are the obvious choice of thixotrope for formulators of high performance vinyl esters who want thixotropic properties with a minimum level of additive.

TABLE 11

Derakane® 411-350 [1]	100
Titanium Dioxide [2]	2
Thixotrope*	1 - 3
BYK® A - 555 [3]	0.5
BYK® R - 605 [3]	*
Cobalt Naphthenate 6% [4]	0.3
DMAA [5]	0.15
CHP - 5 peroxide [6]	1.5

[1] Ashland, 350 Visc - 45% solids
[2] Tronox CR - 800; Tronox
[3] BYK-Chemie
[4] Promoter; OMG
[5] Accelerator; Aldrich
[6] Catalyst; Wilco Chemical
* as noted in Table 12

TABLE 12 - Evaluation of Garamite® 1958 when using a commonly used rheology enhancer

Thixotrope	Level	BYK® R - 605 Level [1]	10 rpm Viscosity[2]	Sag Resistance mils (microns)
Garamite® 1958	2.0%	3%	8,600	14 (356)
Garamite® 1958	2.0%	17%	8,600	30 (762)
Garamite® 1958	2.0%	31%	8,600	30 (762)
FS - Hydrophilic	2.0%	3%	12,000	4 (102)
FS - Hydrophilic	2.0%	17%	12,000	16 (406)
FS - Hydrophilic	2.0%	31%	12,000	30 (762)
FS - Hydrophobic	1.3%[3]	0% [3]	10,000	10 (254)
FS - Hydrophobic	2.0%	0%	10,000	20 (508)
FS - Hydrophobic	2.7%	0%	10,000	30 (762)

[1] As a percentage of the thixotrope level
[2] Viscosity did not change when rheology enhancer level was varied
[3] Experimental design showed that thixotrope and rheology enhancer levels did not affect viscosity

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