Improving the Performance and Application of HIGH SOLIDS PROTECTIVE COATINGS

Environmental regulations continue to drive the development of coating technologies with low volatile organic compound (VOC) content. For many applications, the focus has been on waterborne alternatives, with coating systems available today that equal or outperform their older, solvent-based counterparts. Where protective coatings are required, however, waterborne formulations do not yet provide the level of performance needed, both in terms of application behavior and applied film properties. Instead, high solids systems have been the preferred method for meeting the regulatory requirements for lower VOCs. Even this approach presents challenges, though. Several developments in resin and additive technologies are, however, enabling the formulation of high solids protective coatings that have application and performance properties similar to conventional high VOC systems.

WHY NOT WATERBORNE?

Although most paint and coating manufacturers and resin and additive producers are working to identify solutions for the formulation of waterborne high performance protective coatings, limitations of the technology remain that have not yet been overcome. "With the very high performance requirements needed for corrosion resistance, durability, chemical resistance, and dry time under widely varying global exterior application conditions, the use of waterborne coatings is still very limited in the protective coating and marine segment," says Jeffrey Arndt, a technical account coordinator with Arkema. Generally, notes Kinan Baikernik, a senior R&D manager for Dow Coating Materials, high solids systems are preferred over alternative low-VOC technologies for applications requiring heavy duty performance (e.g., C4–C5 corrosion resistance or very high resistance to chemical immersion) or for applications in adverse environmental conditions (e.g., low temperature or high humidity). Specific examples for epoxy coatings include applications in marine coatings and tank linings for chemical and potable water tanks, while polyurethane is used for heavy equipment and military applications.

High solids coatings are more tolerant of poor surface preparation and are used in original equipment manufacturing (OEM) and maintenance applications where this issue is a concern, according to Jeff Danneman, an advanced research associate with Reichhold. Ramesh Subramaniam, R&D director for Nuplex Resins, adds that the ability to achieve thicker film builds is another advantage of high solids coatings over waterborne formulations. In addition, in the case of in situ field applications, high solids protective coatings are more tolerant of variable weather conditions, particularly with temperature and humidity, and from an applicator point of view, the transition from solventborne to high solids coatings is much smaller than from solvent-based to waterborne, notes Kees Van Der Kolk, global technology director for PPG Protective and Marine Coatings. "Also with respect to application, higher solids coatings enable fewer coats to reach the desired film build, thus facilitating increased productivity, efficiency, and labor savings," says Baikernik. Furthermore, older paint application systems that are not constructed of stainless steel and do not have adequate temperature and humidity controls are also generally not suited for waterborne systems, but will accommodate high solids coatings, adds Michael Vocelko, North American OEM technology director with Axalta Coating Systems.

CHALLENGES WITH HIGH SOLIDS

Even though high solids formulations are preferred for many protective applications, the development of effective high performance systems does present numerous challenges to both raw material suppliers and coating manufacturers. "The main issues for high solids protective coatings are related to applying thicker films without sag, the humidity dependence of some high solids chemistries during both manufacturing and application, maintaining a simple component ratio for these typically two-component systems, and managing the rheology of lower molecular weight resins," observes Subramaniam. Many of these issues are related, and as a result, achieving low-VOC content through a high solids approach creates challenges in terms of viscosity and film build control, with the former affecting sag and the latter determining the curing properties, according to Danneman.

The main difference in high solids versus traditional solvent-based coatings is the use of lower molecular weight resins in order to achieve a sprayable viscosity. "Systems based on less viscous resins lack the intrinsic rheology of conventional formulations, and thus have little viscosity build following solvent evaporation, and resin crosslinking requires more time to build sufficient molecular weight to contribute to the rheology," Aedid explains. In addition, denser and heavier high solids coatings are more likely to suffer from sagging, running, and slumping, which is even more of an issue when applicators look to use fewer, higher build coats to achieve target specifications, he adds. Furthermore, high solids systems require the use of complex spray equipment due to the higher formulation viscosity, which presents challenges in sprayability, pumping, and handling of the formulation, particularly in colder environments, Baikernik notes.

Formulators of two-pack reactive high solids coatings must also be aware of the issues raised by using higher reactive resin concentrations, according to Van Der Kolk. "A careful balance is required to maintain coating reactivity versus acceptable pot life, particularly for products that are meant to be used under tropical or low-temperature conditions," he notes. Van Der Kolk adds that a higher resin concentration also leads to denser crosslinked networks that may result in less flexibility and stress buildup when cured, which in turn may increase the susceptibility to micro-crack formation during the lifespan of the system, particularly in areas with high thicknesses and at weld seams.

Incorporation of pigments into high solids formulations is yet another challenge. "It can be difficult to combine high volume solids with high pigment volume concentration (PVC) and still achieve easy spray application and high performance," comments Baikernik. In addition, metallic flake control to achieve the same final color position in high solids formulations as that observed for conventional solventborne systems requires significant expertise, according to Vocelko. He adds that high solids metallic coatings are also more susceptible to circulation degradation and can require special flakes to maintain color control.

There are also production challenges when manufacturing high solids coatings. "The removal of solvent and the need for higher levels of certain rheological additives can cause incorporation, gloss loss, and rheology modifier activation issues," he states. For example, the higher levels of fumed silica and organoclay often required can affect the gloss and increase the spray viscosity.
Environmental regulations continue to drive the development of coating technologies with low volatile organic compound (VOC) content. For many applications, the focus has been on waterborne alternatives, with coating systems available today that equal or outperform their older, solvent-based counterparts. Where protective coatings are required, however, waterborne formulations do not yet provide the level of performance needed, both in terms of application behavior and applied film properties. Instead, high-solids systems have been the preferred method for meeting the regulatory requirements for lower VOCs. Even this approach presents challenges, though. Several developments in resin and additive technologies are, however, enabling the formulation of high-solids protective coatings that have application and performance properties similar to conventional high-VOC systems.

WHY NOT WATERBORNE?

Although most paint and coating manufacturers and resin and additive producers are working to identify solutions for the formulation of waterborne, high-performance protective coatings, limitations of the technology remain that have not yet been overcome. “With the very high performance requirements needed for corrosion resistance, durability, chemical resistance, and dry time under widely varying external application conditions, the use of waterborne coatings is still very limited in the protective coating and marine segment,” says Jeffrey Arend, a technical account coordinator with Arkema. Generally, notes Kinrin Baikerikar, a senior R&D manager for Dow Coating Materials, high-solids systems are preferred over alternative low-VOC technologies for applications requiring heavy duty performance (e.g., C4–C5 corrosion resistance or very high resistance to chemical immersion) or for applications in adverse environmental conditions (e.g., low temperature or high humidity). Specific examples for epoxy coatings include applications in marine coatings and tank linings for chemical and potable water tanks, while polyurethanes are used for heavy equipment and military applications.

High-solids coatings are more tolerant of poor surface preparation and are used in original equipment manufacturing (OEM) and maintenance applications where this issue is a concern, according to Jeff Danneman, an advanced research associate with Reichhold. Ramesh Subramanian, R&D director for Nuplex Resins, adds that the ability to achieve thicker film builds is another advantage of high-solids coatings over waterborne formulations. In addition, in the case of in situ field applications, high-solids protective coatings are more tolerant of variable weather conditions, particularly with temperature and humidity, and from an applicator point of view, the transition from solventborne to high-solids coatings is much smaller than from solvent-based to waterborne, notes Kees Van Der Kolk, global technology director for PPG Protective and Marine Coatings. “Also with respect to application, higher solids coatings enable fewer coats to reach the desired film build, thus facilitating increased productivity, efficiency, and labor savings,” says Baikerikar. Furthermore, older paint application systems that are not constructed of stainless steel and do not have adequate temperature and humidity controls are also generally not suited for waterborne systems, but will accommodate high-solids coatings, adds Michael Vecellio, North American OEM technology director with Axalta Coating Systems.

CHALLENGES WITH HIGH SOLIDS

Even though high-solids formulations are preferred for many protective applications, the development of effective high performance systems does present numerous challenges to both raw material suppliers and coating manufacturers. “The main issues for high-solids protective coatings are related to applying thicker films without sag, the humidity dependence of some high solids chemistry during both manufacturing and application, maintaining a simple component ratio for these typically two-component systems, and managing the rheology of lower molecular weight resins,” observes Subramanian. Many of these issues are related, and as a result, achieving low-VOC content through a high-solids approach creates challenges in terms of viscosity and film build control, with the former affecting sag and the latter determining the curing properties, according to Danneman.

The main difference in high solids versus traditional solvent-based coatings is the use of lower molecular weight resins in order to achieve a sprayable viscosity. “Systems based on less viscous resins lack the intrinsic rheology of conventional formulations, and thus there is little viscosity build following solvent evaporation, and resin crosslinking requires more time to build sufficient molecular weight to contribute to the rheology,” Arend explains. In addition, denser and heavier high-solids coatings are more likely to suffer from sagging, running, and slumping, which is even more of an issue when applicators look to use fewer, higher build coats to achieve target specifications, he adds. Furthermore, high-solids systems require the use of complex spray equipment due to the higher formulation viscosity, which presents challenges in sprayability, pumping, and handling of the formulation, particularly in colder environments, Baikerikar notes.

Formulators of two-pack reactive high solids coatings must also be aware of the issues raised by using higher reactive resin concentrations, according to Van Der Kolk. “A careful balance is required to maintain coating effectiveness versus acceptable pot life, particularly for products that are meant to be used under tropical or low-temperature conditions,” he notes. Van Der Kolk adds that a higher resin concentration also leads to denser crosslinked networks that may result in less flexibility and stress buildup when cured, which in turn may increase the susceptibility to microcrack formation during the lifespan of the coating, typically in areas with high thicknesses and at weld seams.

Incorporation of pigments into high solids formulations is yet another challenge. “It can be difficult to combine high volume solids with high pigment volume concentration (PVC) and still achieve easy spray application and high performance,” comments Baikerikar. In addition, metallic flake control to achieve the same final color position in high solids formulations as that observed for conventional solventborne systems requires significant expertise, according to Vecellio. He adds that high solids metallic coatings are also more susceptible to circulation degradation and can require special flakes to maintain color control.

There are also production challenges when manufacturing high solids coatings. “The removal of solvent and the need for higher levels of certain rheological additives can cause incorporation, gloss loss, and rheology modifier activation issues,” he states. For example, the higher levels of fumed silica and organoacyl often required can affect the gloss and increase the spray viscosity.

Improving the Performance and Application of HIGH SOLIDS PROTECTIVE COATINGS

by Cynthia Challenger, Contributing Writer

August 2014 COATINGS TECH
Also, organoclay activation requires polar activa-
tor solvents, which are limited in very high solids
systems. Traditional polyamide rheology modifiers,
meanwhile, require higher temperatures to activate
in very high solids, low-solvent formulations and
can require extra time to cool before packaging.

Simultaneously meeting varying VOC level
requirements and the wide variety of expected
performance levels around the world is another
significant challenge when formulating high solids
protective coatings, according to Beth Ann Pearson,
global products manager for Metal & Plastics with
Sherwin-Williams Product Finishes. “In addition,
global coatings manufacturers must ensure com-
patibility with changing standards and regulations
different approaches to formulation and appli-
cations,” she says. For example, she adds, North
America relies heavily on the use of exempt solvents
that have been classified as having no effect on
the environment or VOC calculations when added
to meet stringent VOC levels without sacrificing ap-
plication quality or overall performance, as well as
the use of differing applications methods, includ-
ing air-assisted airless spray, bell, electrostatic, and
disk. “Adding to this complexity,” she continues, “is
the need for coating manufacturers to keep costs
in check, particularly given that the use of exempt
solvents often leads to cost increases.”

RESIN AND ADDITIVE APPROACHES

Given that the use of low molecular weight res-
ins and the consequent viscosity is a critical issue
for high solids protective coatings, it is no surprise
that significant effort has been invested in improv-
ing both resin and rheology control technologies.
Curing agents (drier systems) and flexibilizers have
also received attention, considering the problems
that can arise with curing of thicker film builds.

Because the resins used in high solids coatings contribute less to the final application rheology
profile, additives must now exhibit greater control
and do so with minimal undesirable side effects,
according to Arendt. Rheology modifiers for these
systems must offer high efficiency and incorporate
with greater ease,” he notes. Research also con-
tinues in the area of reactive diluents to develop
resins at lower viscosity levels, which could result
in the advancement of solvent-based systems
with lower VOCs and a lower demand for exempt
solvents, thus improving efficiency, reducing cost,
and advancing environmental attributes, according
to Pearson. Van Der Koek adds that stress buildup
must be minimized by compatible resin flexibilizers
and engineered curing agents, and for two-pack
high solids epoxies, low-viscosity polyamine and
polyamide curing agents can result in greater sus-
cceptibility of coatings to so-called surface amine
blushing (reaction with CO₂ and H₂O). “To address
this issue, chemical modification is required in or-
der to prevent intercoat adhesion problems when
multiple coats are to be applied,” he says.

RECENT SOLUTIONS

With respect to additives, several rheology
modification technologies have been developed
to improve the performance of high solids protec-
tive coatings. Nuplex Resins, for example, has
introduced dispersed urea crystals and surface-
modified resin particles as new rheology modifiers
for this application. AkzoNobel, meanwhile, has
developed organovox polyamide rheology modifiers
that can activate in very high solids and solvent-free
systems at easily achievable production tempera-
tures. “Because it is not necessary to push these
milks to unusually high temperature temperatures,
to achieve processing time is not needed for heat
atmosphere and post-production cooling, unlike
conventional polyamide products,” notes Arendt.
He adds that each of the products—one for high
solids and the other for 100% solids coatings—also

offer sag performance robustness over a wider
processing temperature window than previously
possible. AkzoNobel also offers pre-activated pastes
that simplify the processing needed to incorporate
polyamide powder rheology additives, as well as
liquid additives for addition to high solids formula-
tions with different polarities. Pearson also points
to improved thixotropes that provide both improved
rheology and coating stability.

Van Der Koek also associates the wider avail-
able of reactive diluents and resin flexibilizers,
which is enabling more paint engineering flexibility
and providing new opportunities to drive solid con-
tent to higher levels with even better long term pro-
tective performance. Advanced nanotechnologies
and the development polymers derived from renew-
able resources are also providing unique solutions
to coatings development, according to Viscopell. “In
addition, dual functional polymers and oligomer
technologies have been under development and
are beginning to make it into the market place that
are enabling higher solids coatings that maintain
desired film properties,” Viscopell says. Nuplex,
for example, offers castor-oil based resins and is
extending acrylic polyol technology—originally de-
veloped for the vehicle finish market for protective
coating applications—that provides fast cure with a
balanced pot life, according to Subraniann.

Dow has applied throughout technology to
significantly accelerate the synthesis, formulation,
and application testing of high solids systems.
As a result, the company has developed novel resin
technologies that offer benefits in ease of applica-
tion, lower VOC, and higher performance, accord-
ing to Baikerikar. “In particular, our new develop-
ments in epoxy technologies have enabled high
solids, high PVC coatings that can be applied with
conventional spray equipment and demonstrate
equivalent performance compared to traditional
epoxy systems.”

Advancements in anticorrosive pigment tech-
tology are also important for Sherwin-Williams.
“Coating protection is no longer solely dependant
on the resin system; anticorrosive pigments can

increase the lifetime of a coating system, translating
to cost savings for the end user,” Pearson asserts.
A focus on the implementation of compact process
technology is also a valued tool to end users to coat ef-
f ectively and quickly by making the coating process
leaner in some way, such as through a faster cure
time or the elimination of a coating layer, according
to Pearson. She points to a new MIL-PRF-22750G
Type III high solids epoxy recently introduced by
Sherwin-Williams that can be applied directly-to-
metal (DTM) as a single-coat application over zinc
phosphate steel or treated aluminum.

“...denser and heavier high solids coatings are more
likely to suffer from sagging, running, and slumping, which
is even more of an issue when applicators look to use
fewer, higher build coats to achieve target specifications.”

“...it can be difficult to combine high volume solids with
high pigment volume concentration (PVC) and still achieve
easy-spray application and high performance.”

“...it is important to keep in mind that, as with any
type of coating, careful selection of the polymer,
pigment, and additives is required to ensure that
a high solids protective coating formulation meets the
regulatory, performance, and applications require-
ments.” Dannemann states. Developing new, innova-
tive protective coatings with higher solids content
also requires more than paint engineering work,
according to Vos Der Koek. “PPG invests in research
that provides a better fundamental understanding
of crosslinking, substrate adhesion, and failure
mechanisms. With a greater understanding of the
chemical and physical interactions of the various
high solids materials and their substrate adhesion
performance, more direction and guidance can be
provided to determine further innovation routes for
resins, resin flexibilizers, and curing agent technol-
yogy, which in turn drives future-higher solids tech-
nology,” he explains. The overall result, according
to Van Der Koek, is an improved ability to reduce VOC
emissions while realizing equal or better perfor-
mance from heavy-duty coating systems.

“The industry is making real progress in devel-
oping new technologies to address performance
requirements for demanding, high solids, industrial
coating applications,” agrees Baikerikar. “At Dow,
for example,” he continues, “we are developing
approaches to further reduce VOCs and push the
performance limits for durability, low tempera-
ture cure, and corrosion, thermal, and chemical
resistance.” Pearson also stresses that while
waterborne may be the up-and-coming technology,
manufacturers such as Sherwin-Williams are not
abandoning current users of solvent-based high
solids coatings who rely on suppliers for technol-
ogical advancements. “End users who work with a
manufacturer that is a leader in both waterborne
and solvent-based technologies receive the most
benefit,” she concludes.
Also, organoclay activation requires polar activa-
tor solvents, which are limited in very high solids
systems. Traditional polyamide rheology modifiers,
meanwhile, require higher temperatures to activate
in very high solids, low-solvent formulations and
can require extra time to cool before packaging.
Simultaneously meeting varying VOC level
requirements and the wide variety of expected
performance levels around the world is another
significant challenge, according to John Ackerman,
organoclay and organofunctional resin expert.

Because the resins used in high solids coatings
contribute less to the final application rheology
profile, additives must now exhibit greater control
and do so with minimal undesirable side effects,
according to Arendt. Rheology modifiers for these
systems must offer high efficiency and incorporate
with greater ease," he notes. Research also con-
tinues in the area of reactive diluents to develop
resins at lower viscosity levels, which could result
in the advancement of solvent-based systems
with lower VOCs and a lower demand for exempt
solvents, thus improving efficiency, reducing cost,
and advancing environmental attributes, according
to Ackerman. Van Der Kolk adds that stress buildup
must be minimized by compatible resin flexibilizers
and engineered curing agents, and for two-pack
high solids epoxies, low-viscosity polyamine and
polyamide curing agents can result in greater sus-
ceptibility of coatings to so-called surface amine
blushing (reaction with CO₂ and H₂O).
To address this issue, chemical modification is required in or-
der to prevent intercoat adhesion problems when
multiple coats are to be applied," he says.

NEW RESIN SOLUTIONS

With respect to additives, several rheology
modification technologies have been developed
to improve the performance of high solids protec-
tive coatings. Nuplex Resins, for example, has
introduced dispersed urea crystals and surface-
modified resin particles as new rheology modifiers
for this application. AkzoNobel, meanwhile, has
developed organowax polyamide rheology modifiers
that can activate in very high solids and solvent-free
systems at easily achievable production tempera-
tures. "Because it is not necessary to push these
materials to unusually high temperature tempera-
tures, extra processing time is not needed for heat
generation and post-production cooling, unlike
conventional polyamide products," notes Arendt.
He adds that each of the products—none for high
solids and the other for 100% solids coatings—also

... denser and heavier high solids coatings are more
likely to suffer from sagging, running, and slumping, which
is even more of an issue when applicators look to use
fewer, higher build coats to achieve target specifications."

offer sag performance robustness over a wider
processing temperature window than previously
possible. AkzoNobel also offers pre-activated pastes
that simplify the processing needed to incorporate
polyamide powder rheology additives, as well as
liquid additives for addition to high solids formula-
tions with different polarities. Pearson also points
to improved thixotropes that provide both improved
mechanical and coating stability.

Van Der Kolk also emphasizes the widely avail-
able reaction diluents and resin flexibilizers,
which is enabling more paint engineering flexibility
and providing new opportunities to drive solid con-
ten to higher levels with even better long-term pro-
tective performance. Advanced nanotechnologies
and the development polymers derived from renew-
able resources are also providing unique solutions
to coatings development, according to Voss, why: "In
addition, dual functional polymers and oligomer
technologies have been under development and
are beginning to make it into the market place
that are enabling higher solids coatings that maintain
desired film properties," Vossel says. Nuplex, for
example, offers castor-oil-based resins and is
extending acrylic polyester technology—originally
developed for the vehicle finish market for protective
coating applications—that provides fast cure with a
balanced pig, according to Subramanian.

Dow has applied high throughput technology to
significantly accelerate the synthesis, formulation,
and application testing of high solids systems. As
a result, the company has developed novel resin
technologies that offer benefits in ease of applica-
tion, lower VOC, and higher performance, accord-
ing to Baikerikar. "In particular, our new develop-
ments in epoxy technologies have enabled high
solids, high VOC coatings that can be applied with
conventional spray equipment and demonstrate
equivalent performance compared to traditional
epoxy systems."

Advancements in anticorrosive pigment tech-
tnology are also important for Sherwin-Williams.
"COrrosion protection is no longer solely dependant
on the resin system; anticorrosive pigments can
cleanse the lifetime of a coating system, translating
to cost savings for the end user," Pearson asserts.
A focus on the implementation of compact process
technology has also allowed end users to cost ef-
tectively and quickly by making the coating process
leaner in some way, such as through a faster cure
time or the elimination of a coating layer, according
to Pearson. She points to now MIL-PRF-22759G
Type III high solids epoxy recently introduced by
Sherwin-Williams that can be applied direct-to-
metal (DTM) as a single-coat application over zinc
phosphate steel or treated aluminum.

“It can be difficult to combine high volume solids with
high pigment volume concentration (PVC) and still achieve
easy-spray application and high performance.”

“It is important to keep in mind that, as with any
type of coating, careful selection of the polymer,
pigment, and additives is required to ensure that
a high solids protective coating formulation meets the
regulatory, performance, and applications require-
ments,” Danneman states. Developing new, innova-
tive protective coatings with higher solids content
also requires more than paint engineering work,
according to Vos Der Kolk. “PPG invests in research
that provides a better fundamental understanding
of crosslinking, substrate adhesion, and failure
mechanisms. With a greater understanding of the
color and physical interactions of the various high
solids materials and their substrate adhesion
performance, more direction and guidance can be
provided to determine further innovation routes for
resins, resin flexibilizers, and curing agent technol-
ogy, which in turn drives higher solids tech-
nologies,” he explains. The overall result, according
to Vos Der Kolk, is an improved ability to reduce VOC
emissions while realizing equal or better perfor-
mance from heavy-duty coating systems.

The industry is making real progress in devel-
oping new technologies to address performance
requirements for demanding, high solids, industrial
coating applications,” agrees Baikerikar. “At Dow,
for example,” he continues, “we are developing
approaches to further reduce VOCs and push the
performance limits for durability, low tempera-
ture cure, and corrosion, thermal, and chemical
resistance.” Pearson also stresses that, while
waterborne may be the up-and-coming technology,
makers such as Sherwin-Williams are not
abandoning current users of solvent-based high
solids coatings who rely on suppliers for technol-
ogical advancements. “End users who work with a
manufacturer that is a leader in both waterborne
and solvent-based technologies receive the most
benefit,” she concludes.