Polyurethanes (PU) have been used as coating resins for well over half a century. In that time, knowledge of the roles played by the polyol and isocyanate segments and the impacts of variations in their structural and chemical properties has been greatly expanded. The development of waterborne and 100% solids polyurethane raw materials has led to their increased use in many applications. The introduction of polyaspartics is another recent advance. Continued raw material innovation and the ongoing identification of new coating applications are creating opportunities for even further growth of the polyurethane market.

Leading experts at selected polyurethane resin and coating manufacturers recently discussed the key drivers influencing PU technology development for coatings applications, new advances that have affected PU coating formulation, and technologies currently under development that may have a noticeable impact in both the near future and the longer term. Participants in the roundtable included Joanne R. Hardy, North America technical director and Marc B. Goldfinger, research manager, both with Axalta Coating Systems; Tom Hall III, market manager for industrial coatings with BASF Corporation; Jim Charron, vice president of application development in North America for the coatings, adhesives, and specialties business unit of Bayer MaterialScience LLC; Sylvia Insogna, North America marketing manager for Dow Coating Materials; Avery Watkins, a business development manager with Dow Polyurethanes in North America; Shi Yang, urethane senior technology manager at Reichhold; and David Calabra, global market director for general finishing with The Sherwin-Williams Company.

**Yang, Reichhold:** Polyurethanes have been widely used in various types of coatings for many years due to the unique properties that these coatings offer, such as exceptional abrasion resistance and various degrees of flexibility for use over rigid or soft substrates. These coatings still play an important and active role today, but as VOC regulations continually change, the market is moving towards systems with low levels of volatile organic compounds (VOCs). As has occurred with other coating technologies, the approaches to reducing the VOC content of polyurethane coatings include developing high solids or waterborne formulations or using exempt solvents.

**Hall, BASF:** We also see the need to reduce VOCs in PU systems as the single most important driver of technology development. The challenge is to achieve lower VOC levels while maintaining or improving coating performance. Doing so is difficult because the reduction of VOC limits the ability to use traditional high glass transition temperature (Tg) polyols and solvent combinations that formulators have used for many years and are known to deliver excellent hardness development, appearance, exterior durability, and chemical resistance.

**Goldfinger, Axalta:** The key driver for PU coatings is to develop systems that meet customer requirements while remaining competitive from a cost perspective. Key
performance criteria include application robustness, superior appearance, and rapid cure, all while meeting environmental regulations.

**Insogna, Dow Coating Materials:** Today, many coating applicators have expressed a need for faster drying and hardness development than can be achieved with current isocyanate chemistry, which is limited in part by a need to balance cure time with acceptable pot life.

**Calabra, Sherwin-Williams:** Polyurethane-based coatings can save finishers money in several ways while delivering similar color, durability, and chemical resistance traits as traditional coatings, across many substrates. With respect to energy and equipment savings, because polyurethane finishes can air-dry or be forced-dried at lower temperatures than typical baking enamels, ovens may not be needed at all or energy use may be reduced. Even with energy costs dropping over the past several months, the energy savings add up over time, and by eliminating ovens or reducing their use, maintenance costs will likely decrease as well.

Polyurethane coatings also allow a finisher to use one coating to coat many substrates, including plastic, wood, composite, and metal. Using one product line for multiple substrates reduces the carrying costs of keeping several coatings in inventory. Additionally, the improved adhesion characteristics of polyurethane coatings have reduced the need for primers, which not only lowers inventory costs, but also the process time needed for coating.

Finally, the trend for multiple colors or custom colors is still growing, and the ability to provide new colors, metallics, and micas in polyurethane chemistries with short lead times is critical.

**Charron, Bayer MaterialScience:** Changing substrates, improvements in application processes, and the faster or low temperature curing of coatings in both factory and field applications are three important drivers of polyurethane technology development. For automotive coatings, the need to reduce fuel consumption and CO₂ emissions is spurring the development of lightweight motor vehicles made from a mix of different materials. New coatings technologies are needed to adapt to these new substrates. The cost and energy efficiency of the coating process also plays a crucial role, as does the appearance of a coating—from the purchase of a car to its resale.

New direct-to-metal (DTM) technologies for industrial factory-applied coatings that reduce the number of coats and energy costs in the heavy equipment and general industrial markets are the next frontier for polyurethanes and polyaspartic technologies. Lower temperature and ambient-cure, DTM technologies provide the opportunity to reduce oven temperatures or eliminate ovens altogether in industrial coating processes.

In the industrial maintenance sector, the need for speed and efficiency in corrosion-protective coating systems for infrastructure is driving changes in specifications around the world. These specifications now include high performance, two-coat polyaspartic systems that meet the performance criteria once only attainable with traditional three-coat systems.

“Lower temperature and ambient-cure, DTM technologies provide the opportunity to reduce oven temperatures or eliminate ovens altogether in industrial coating processes.”

**Watkins, Dow Polyurethanes NA:** We see the growth of the oil and gas industry as a key driver fueling the development of polyurethane coating technology. Polyurethane coatings are gaining momentum in both primary and secondary containment applications due to their unique properties and easy, fast return-to-service compared to other technologies. In addition, polyurethanes offer damage tolerance and flexibility across a broad temperature range and can withstand the rigorous conditions commonly seen in oilfields. Furthermore, when polyurethanes are properly designed and formulated, they can also provide good resistance to a variety of chemicals that may be employed in these containment applications. This combination of mechanical performance and long-term stability, along with the very fast cure and return-to-service times, is unique to polyurethane and polyurea materials.

**CT:** Will these trends continue for some time, or do you see new issues arising down the road that will also have an impact on polyurethane technology for coatings applications?

**Hardy, Axalta:** Productivity, appearance, and cost-competitiveness have continued to be the trends that drive the development of new PU coatings. Advances may be achieved by employing leading-edge polymer science and formulation technology. Regulations challenge the materials used to achieve these trends. Any regulations concerning isocyanates will have an impact on polyurethane coatings.

**Hall, BASF:** The VOC component in coatings is the most compelling challenge for the coatings industry. Therefore, raw material suppliers will expend significant research and development dollars to develop newer technologies to address the “zero-VOC” target. An additional issue faced by formulators of polyurethane coatings is the continued evaluation of their impact on health and the environment. An example is the move in the European Union to eliminate tin as a catalyst for polyurethane coatings.

**Yang, Reichhold:** In polyurethane coatings, the amount of solvent greatly affects performance and application properties, particularly in solventborne systems. However, VOC limits continue to decrease. For wood coatings, the current SCAQMD VOC regulation is 275 g/L and the OTC limit is 350 g/L, although the latter will be going to 275 g/L soon. With regulations continually driving VOC reduction, high solids polyurethanes may not be the ultimate direction of future development due to performance shortcomings resulting from the low molecular weight of these systems. Furthermore, there is a poten-
tial for compatibility issues and cost limitations surrounding the use of exempt solvents. For these reasons, Reichhold’s developmental efforts are focused more on waterborne approaches to enable the continued use of polyurethanes down the road.

**Charron, Bayer MaterialScience:** We think that fuel economy standards in cars and the expectations for efficiency in factory-applied and field-applied coatings will drive these trends for the next decade and beyond.

**Watkins, Dow Polyurethanes NA:** As oil and gas development continues and pushes to increasingly harsh environments, we expect the interest in polyurethanes to continue to grow, because corrosion risk is a consistent issue. The new performance standards set by polyurethane and polyurea coatings are just the beginning. At Dow, we see a large untapped potential for polyurethane innovation and are investing in fundamental science and new materials where we can provide growth for our customers and meet unmet application needs, starting at the molecular level.

**Calabra, Sherwin-Williams:** The use of polyurethanes should continue to grow as manufacturers turn to new substrates and the reduction of energy costs remains a concern. In many cases, manufacturers are expanding their use of substrates; in addition to steel and aluminum, entry doors are now made from fiberglass or composites, PVC is used for windows, and fiberglass for light poles. While energy costs remain a wild card, the ability to utilize a coating that can air-dry and eliminate or reduce the need for energy in the process is an attractive one.

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**CT: What have been specific noteworthy advances in recent years? Why have they been important? What impact have they had?**

**Goldfinger, Axalta:** For two-component polyurethanes, the most significant advances have been the development of VOC-compliant, productive products. New clearcoats introduced by Axalta help our customers achieve reduced cycle times.

With respect to one-component systems, the mechanical properties and hydrolytic stability of polyurethane dispersions (PUDs) have been improved through the use of different building blocks. Today, waterborne coatings with properties similar to those of comparable solventborne systems are available. The PUDs allow for the use of high molecular weight polymers in the form of a dispersion, in contrast to solventborne systems, wherein high molecular weight polymers lead to unacceptable high solution viscosities.

**Calabra, Sherwin-Williams:** New resin developments have yielded polyurethane coatings with lower levels of VOCs and reduced hazardous air pollutants (HAPs), which is key to the growth of polyurethane technology as finishers work to meet environmental standards. Flow, appearance, and cure rates for the coatings with lower VOCs have been a challenge; the market is moving toward products that offer a lower isocyanate ratio for a better value proposition, plus an improved cure response and an improved pot life.

**Hall, BASF:** Improvement in the performance of polyurethane dispersions has contributed to the utilization of water-based coatings for many market applications. In particular, the continued effort to improve water-based isocyanates and OH-functional dispersions has also led to greater acceptance of water-based systems.

**Yang, Reichhold:** Although waterborne technology allows for polyurethane coatings with high molecular weights and low VOCs, the polymers are essentially linear with lower solids compared to solvent-based systems. In most cases, they also require a co-solvent in the manufacturing process and for coating film formation. To overcome these drawbacks, new chemistries and processes are being explored for polyurethane systems. In particular, self-crosslinking, UV curing, and the development of highly nonvolatile, low co-solvent, and even co-solvent-free systems.

**Watkins, Dow Polyurethanes NA:** Dow has concentrated its efforts on enhancing flexibility and chemical resistance properties to provide customers with the corrosion resistance of polyurethane coatings for use in the tough environments experienced in the oil and gas industry. We recently introduced a spray elastomer system that helps protect steel and concrete in harsh environments, extending the life of steel tanks, pipelines, and chemical holding tanks and enabling a lower total cost of ownership. The polyurethane spray elastomer system for coating applications was designed specifically for the surface protection of porous concrete containment structures and steel exposed to advanced chemical attack. The system is a high performance, two-component polyurea hybrid coating material, and its low viscosity facilitates processing and allows applicators to achieve a smooth, high gloss finish and fast return-to-service.

**Charron, Bayer MaterialScience:** To address changing substrate needs and the desire for low temperature cure in the automotive industry, Bayer MaterialScience has developed an innovative and sustainable technology for coating plastic add-on parts at low temperature. The product is a thermolatent hardener, and coatings formulated with it initially flow unimpeded over the surface of the plastic, forming a uniform film. The hardener is activated once the film is heated.
to 90°C, at which temperature the coating is rapidly cured. Importantly, no significant changes to existing coating formulations are needed.

The topcoats cure up to 30% faster than conventional two-component polyurethane coatings without compromising the outstanding appearance. In the medium term, the coating system will most likely be suitable for the mixed coating of plastic, composite, and metal substrates. The low temperature also makes it possible to fire the oven with alternative energy sources, such as district heat. As a result, automakers can achieve time and cost savings while simultaneously realizing a substantial ecological savings potential. A study conducted by Bayer found that this technology can reduce energy consumption by 15% and CO₂ emissions by 10% compared with the best current process.

Polyaspartic technology is suitable for the very cost-effective application of coatings to a range of different substrates. In contrast to conventional systems, this technology often requires fewer coating layers and curing takes place quickly. For example, polyaspartic coatings have proven their usefulness in protecting wind turbines, bridges, industrial plants, and agricultural and construction machinery against corrosion. Polyaspartic floor coatings also provide fast return-to-service due to the rapid curing process; several layers of such polyaspartic coatings can be applied in a single day using standard equipment. The coatings are applied at room temperature and can be walked on after just a few hours, minimizing downtime and saving money on construction sites.

**CT: What challenges remain with respect to PU coatings that might be addressed with further advances in resin, additive, or general formulation technology?**

**Hall, BASF: The film properties of polyurethane coatings, specifically the exterior durability of acrylic polyls and aliphatic isocyanates, are desired for many industrial applications. Therefore, formulators and suppliers will try to push the chemistry into different coating systems. A good example is the drive in the industrial market for faster turnaround times by reducing the number of coating layers needed to protect the substrate, which is leading to the demand for direct-to-metal or single-coat polyurethane coatings. Another challenge is improvement of the ease of application and performance of water-based polyurethane coatings used in field applications so they match those of solvent-based systems. These technical hurdles are daunting for the coatings formulator. BASF has a team of formulators in our Formulation Service Institute that analyzes the interaction of all of the components in a polyurethane coating system in order to identify opportunities for the development of new resins, additives, and even pigment technologies to address market performance demands.**

**Watkins, Dow Polyurethanes NA: Two key challenges, although not specific to polyurethanes, continue to be chemical and temperature resistance. The combination of chemical exposure at elevated temperatures can push coatings to their limits of performance, and further innovation will be needed as new applications in harsher environments are explored. Polyurethane coatings will also be developed to meet the specific needs of an application and customer, and there are opportunities to leverage these systems across geographies and into other regions.**

**Calabra, Sherwin-Williams: It’s really all about working to reduce VOCs and HAPs while continuing to provide the best appearance, performance, and process cost. Overall product improvements, such as improving the pot life, are under study, but equipment manufacturers have developed new spray equipment that mixes two-part coatings at the point-of-use, so that’s an improvement that makes polyurethanes easier to use without changing the finish itself. Communicating with the finisher is the key. It’s imperative that a coatings supplier work with the finisher to understand their needs and the capabilities of their finishing lines in order to ensure quality finishes.**

**Yang, Reichhold: Waterborne polyurethanes have high molecular weight, and, generally speaking, their coating performance is not as good as that of solventborne counterparts due to the linear structure of the polymer. To address this issue, Reichhold has been focusing on oxidative self-crosslinking technology. This technology allows the polyurethane film to undergo environmentally friendly post-crosslinking to form a crosslinked film. Reichhold’s biobased series of waterborne polyurethanes are vegetable oil-modified and offer coatings with equal or better film performance than their solvent-based counterparts.**

**Insogna, Dow Coating Materials: While a number of technologies have been developed that lead to the formation of polyurethanes without the use of isocyanates, these approaches lack the ability to cure at ambient temperatures. To address this issue, Dow has developed a high performance, ambient crosslinking system for solventborne two-component (2K) urethane systems that is isocyanate-free and formaldehyde-free and cures rapidly at room temperature or can be force-cured (60°C) if appropriate. With the new technology, formulators and applicators don’t have to sacrifice cure speed to extend pot life, or vice versa, applicators have a wider working window, and there is less material waste. In addition, the fast curing capability of the new system allows for faster return-to-service.**