

HIGH PERFORMANCE HOT MELT ADHESIVES FOR POLYETHYLENE COATINGS IN PIPELINE CORROSION PROTECTION

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Introduction

Over the past 50 years, pressure sensitive tapes have been used to coat water, oil and gas pipelines around the world. These coatings are expected to protect the pipeline from corrosion for 30+ years. In order to achieve a permanent bond between the tape and the steel pipe surface, a liquid adhesive is used to prime the surface of the pipe. These liquid adhesives have been historically made using a blend of solvents, butyl rubber and hydrocarbon resins. Due to VOC concerns with these adhesives, some locations require the liquid adhesive to be made using low VOC solvents which can add cost and slow down the production rate due to the required drying time. In addition to health and safety concerns, solvent based adhesives have inherent problems associated with transportation costs, limited green strength, evaporation under the tape coating causing “blisters” if not properly dried and disposal of contaminated containers. To eliminate all of these concerns and weaknesses, a new hot melt adhesive was developed specifically for pipeline coatings. This adhesive is still based on butyl rubber and hydrocarbon resins to assure that the hot melt provides a permanent bond between the tape and the pipe surface.

Coatings for Corrosion Protection: Opportunities and Background

Worldwide Coating Opportunities

Oil, gas and water transmission and distribution pipelines are considered an essential part of infrastructures worldwide. Despite the global economic downturn, 120,000 miles of new crude oil and natural gas pipelines are being built, planned or studied globally, see Figure 1. (1) This total does not include new water distribution pipelines or the rehabilitation of existing oil, gas and water pipelines, so the total opportunity is likely approaching 200,000 miles of pipeline worldwide. Nearly all of these pipelines utilize a coating or lining to protect the steel from corrosion. As the world’s population continues to grow, the demand for potable water, natural gas and oil will continue to grow for the foreseeable future.



Figure 1. New Crude Oil and Natural Gas Pipelines Worldwide (1)

Cold Applied Tape Coating System Components and Functions

The coating system is comprised of a liquid adhesive (primer), a corrosion prevention layer of tape (inner layer) and a mechanical layer of tape (outer layer), see Figure 2. The primer is applied directly to the pipe surface to assure that the inner layer of tape is permanently and strongly bonded to the pipe. The inner and outer layers of tape have polyethylene (PE) backings with butyl rubber based adhesives. The PE backing is formulated differently for the inner layer and outer layer due to the different properties that are desired. The inner layer mostly consists of low density PE which allows it to be conformable to the pipe surface. The outer layer has more high density PE to allow the tape to be conformable, but also provide protection to the inner layer from damage during storage, transportation, installation and throughout the lifetime of the pipeline. The adhesive in both tape layers are composed of butyl rubber, hydrocarbon resin, filler, oil and antioxidant. Butyl rubber is used due to its molecular structure of low unsaturation levels, which yield unique characteristics. These characteristics include: chemical and moisture resistance, thermal stability, weathering and gas permeability; all essential properties required for long term in-ground performance. The adhesive of the inner layer is formulated to work in conjunction with the primer to form a strong bond to the steel substrate. This bond provides the corrosion protection and long term performance that the pipe requires. Additionally this bond is critical to preventing cathodic disbondment and increasing the shear adhesion of the inner layer to the pipe to reduce the effect of the stress imparted by the soil.

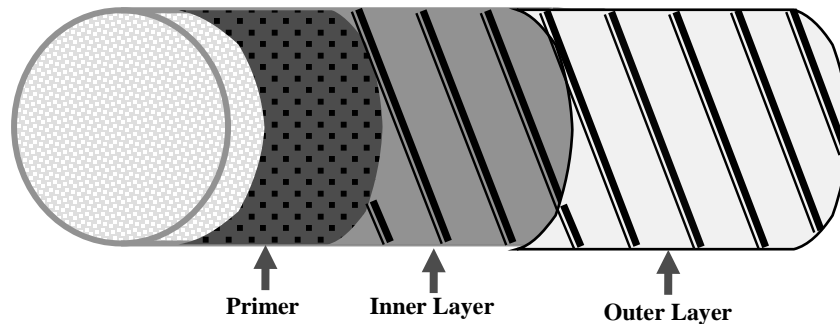


Figure 2. Cold Applied Tape Coating System

Pipeline Coating Process

New mainline pipelines are usually coated in 20 or 40' sections in facilities designed to move pipe around using conveyor systems, referred to as the plant coating process. These steel pipes can range in diameter from 2" to 144" and sometimes can be even larger. The following is a summary of the steps during the coating process, also see Figure 3.

1. Pipe is cleaned of any mill grease or lacquer using solvents
2. Pipe is grit blasted to create a 1-3 mil profile on the pipe
3. Pipe is coated with liquid adhesive primer, 3-4 mil wet film thickness
4. Pipe is coated with a corrosion protection layer of pressure sensitive tape
5. Pipe is coated with 1 or 2 layers of mechanical protection. These layers can either be pressure sensitive tapes or a polyolefin that is fused to the inner layer.

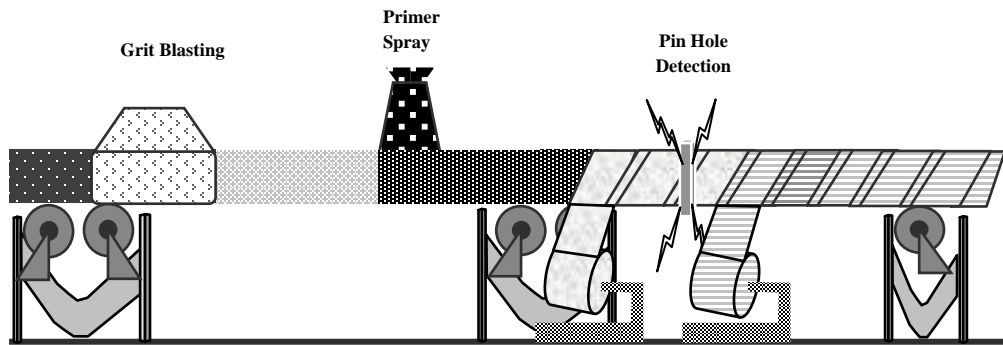


Figure 3. Schematic of plant coating process

In addition to the plant coating process, pipelines can also be coated in the field or “in situ”. This type of application can be done on both new pipelines and pipelines that are in service. Depending on the size of the job these applications are often completed with the assistance of hand or machine powered wrapping machines. For the purposes of this paper, the use of hot melts adhesives will focus on the plant coating process.

Challenges with Solvent-based Liquid Adhesive Primers

While solvent based primers have been used for over 50 years, there are several disadvantages related to their use during the coating process. Often the line speed of the coating process is dependent on the solvents used in the liquid adhesive. If the tape layers are applied prior to complete solvent evaporation, blistering can occur under the coating. These areas of unbounded coating not only look bad, but can lead to premature corrosion of the pipe. Pipes showing evidence of blistering need to be stripped and recoated which can add significant cost to the project. In addition to the different solvents used, there can also be complications caused by the coating process due to slow solvent evaporation during the cold, winter months. The combination of a slow evaporating primer with a cold climate can lead to slow coating speeds, which reduces throughput and increase the cost of coating the pipe.

Another disadvantage with solvent based liquid adhesives is that the coating system cannot be tested for peel adhesion to the pipe for 24 hours. This dwell is needed in order to allow the adhesion of the inner layer tape to the primer to increase to a level where it reaches the minimum requirements of the appropriate standards. During the 24 hour period a plant can coat a significant amount of pipe without knowing for sure that the peel adhesion will meet the required specification. If a pipe is found to fail the adhesion test, the cost of recoating a day’s worth of pipe can be very expensive for the coating plant and the manufacturer of the primer and tape.

A growing problem with solvent based primers is the restriction on volatile organic compounds (VOCs) that are becoming more prevalent at local, state and national levels. Often the primer that is used for a particular project is chosen specifically to adhere to the VOC regulations at the location of the coating plant. There are also significant costs added to the coating system due to the cost of shipping and disposing of these hazardous materials. Moving to solvent based primers with lower or zero VOCs can add significant cost to the coating system. Further complications are found in how VOCs are defined throughout the world; for example a zero VOC primer in the US cannot always be described as such in Europe.

Developing a Butyl Rubber Hot Melt Adhesive Coating System

Initial Project Constraints

The biggest hurdle for making a change to a coating system that has over 40 years of track record is to confirm that the change will in no way effect the long performance of the coating system. Developing a hot melt adhesive with butyl rubber was the key to making this possible. Butyl rubber has been chosen for formulations throughout the pipeline coating and other industries primarily due to its inert behavior that allows adhesives and sealants to stay flexible over a long period of time for the reasons described above. By staying with this chemistry the long term performance of the coating system could be assured. Another initial constraint in developing a hot melt adhesive was to find a method of application making sure the above coating process did not need to be altered drastically. The coating lines that use the hot melt primers would still be used for other coatings as well, so the overall process could not be significantly changed. Coating pipes of various diameters that are traveling down a coating line and spinning at various speeds was a challenge that took numerous prototypes and several years to solve. To solve this problem a spray head was developed in order to apply a randomized pattern of adhesive on the pipe at a uniform thickness.

Development of Spray Equipment

Unlike most hot melt applications, pipeline coatings require complete coverage of a large rotating substrate. In order to meet the technical requirements expected of pipeline coatings, complete coverage of the steel substrate is absolutely required. Any potential voids in the coating could become a weak spot in the coating allowing the corrosion process to begin. The corrosion cycle will not start in the absence of air and water, so having a fully bonded inner layer of tape is the most critical step in the coating process. The pipe preparation and use of a primer is critical to assure the permanent bond of the inner layer of tape.

In order to achieve the desired coating a spray head was designed to coat the pipe surface. Through numerous trials, multiple combinations of the orifice size and number of orifices per inch were used before the complete coverage of the substrate could be achieved. The injection of hot air into the hot melt nozzles also played a key role in fiberizing the hot melt allowing for complete coverage on the steel substrate. The hot melt viscosity, melt temperature, air temperature and air pressure also all play an important role in creating a uniform, void free coating. Finally the distance between the spray head and the substrate also affected the hot melt coating. Finding a combination of all of these factors and creating a process window large enough to be used at multiple locations and different coating line designs proved to be the biggest challenge in this application. Figures 4 and 5 show the hot melt being sprayed and the resulting coating on the pipe surface.



Figure 4. View of the hot melt being sprayed from a 12” wide spray head

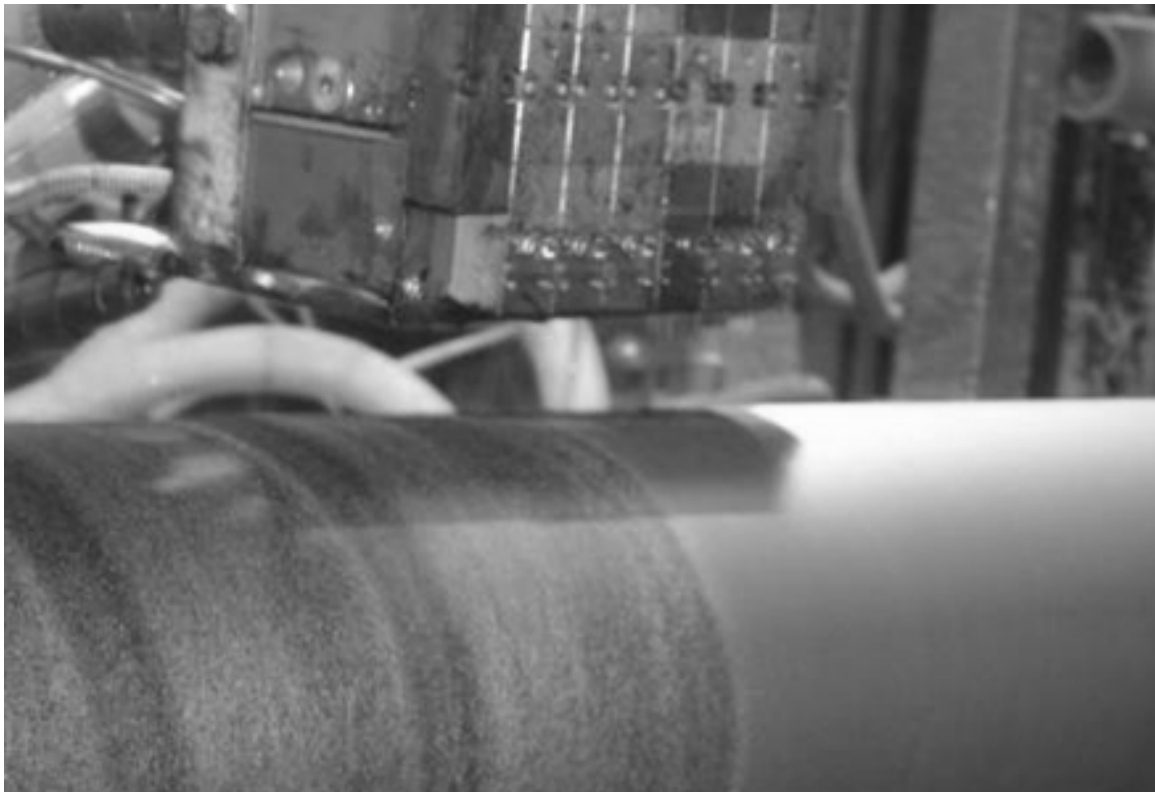


Figure 5. Hot melt being applied to an 8” OD pipe

Butyl Rubber Hot Melt Adhesive

Several hot melt adhesive formulations were used during the early development of the spray equipment. In fact, most of the trials that were run utilized a different hot melt adhesive than what is used commercially now. While the initial hot melt adhesive formulations were all butyl rubber based; various viscosities, rubber/resin ratios and glass transition points all have a significant impact on the application of the hot melt and the performance of the coating system. To make a hot melt that is butyl rubber based, liquid butyl rubber was used. Liquid butyl rubber has the same properties of butyl rubber that make a great choice for pipeline application. Utilizing a liquid butyl rubber is vital to creating a 100% solid, hot melt adhesive that can be sprayed and used with pipeline coatings without losing the track record gained in last 50 years of in-ground service. Throughout numerous trials the proper hot melt viscosity was identified to work in conjunction with the spray equipment. The rubber/resin ratio and glass transition proved to be very important in achieving the required peel adhesion and peel mode between the inner layer of tape and the hot melt. These properties also allowed for the peel testing to be done at the temperature that is commonly used in the field, 50-90°F. While the test standards state that the peel testing must be done from 68-78°F, it became apparent during large scale trials that coating facilities expected the hot melt to give the required peel adhesion at ambient temperatures. These facilities are located at various climates and are typically in large, unconditioned areas where it is not always realistic to keep an entire 40' pipe at 68-78°F.

Product and Process Validation and Approval Process

Product Material Requirements

Due to the expected lifetime of pipeline coatings and the critical infrastructure they protect, any changes to the coating materials needs to be fully validated. There are several test standards used globally that can help to define this validation plan. Some of these standards include ANSI/AWWA C209, C214 and C225, EN 12068 and DIN30672. The validation trials and testing for the hot melt primer have, so far, been focused on ANSI/AWWA C214 and C225. While these standards were written around the solvent based primers, the coating system properties of a system using the hot melt could be compared to the requirements within these standards. For the most part the C214 and C225 requirements are focused on the performance of the tapes so additional testing was completed in order to show that the hot melt would be able to stand the test of time. Table 1 shows the requirements in C214 and C225 that would be affected by the use of the hot melt primer and the additional testing that was completed. All of this testing was completed with 2-3 mils of hot melt sprayed onto the pipe surface. While the standards don't define a minimum primer thickness, internally this range was chosen to given the needed performance while minimizing cost.

Table 1. Overview of Product Performance

Property	Test Method	Requirement	Actual Value
Adhesion of Inner Tape to Prepared Steel (C214)	ASTM D1000 (Modified per C214)	16#/inch minimum	30-50 #/inch
Adhesion of Inner Tape to Prepared Steel (C225)	ASTM D1000 (Modified per C225)	32#/inch minimum	45-60 #/inch
Cathodic Disbondment (C214)	ASTM G8	15mm radius maximum	0-5 mm radius
Adhesion of Inner Tape to Prepared Steel after 120 days oven aging at 50°C (Internal)	ASTM D1000 (Modified per C214)	< 25% reduction in value	5-10% reduction
Adhesion of Inner Tape to Prepared Steel after 120 days water immersion at 50°C (Internal)	ASTM D1000 (Modified per C214)	< 25% reduction in value	5-10% reduction

Application Validation

As mentioned previously, one coating plant is different from the next. While a hot melt was developed to meet the requirements above, the most challenging part of the validation process was to get the hot melt to spray uniformly at different coating plants and on different pipe sizes. Ultimately a hot melt was developed to that allowed for a reasonable operating window and met the requirements above. The next hurdle was to meet various customer expectations and requirements that are not part of the recognized standards. This includes minimal pre-heat temperature of the pipe to reduce energy costs, the ability to test peel adhesion at temperatures as low as 50°F, a cohesive peel mode in the inner layer tape adhesive and (of course) the desire for a black hot melt. Most of these expectations were created because the current solvent based primers have been applied and tested this way for 50 years. Through modification of the hot melt and the processing these requirements have been all met except for the color. Adding color to a hot melt for spray applications has proved to be a difficult task, so for now the hot melt will remain clear.

Product Approval

The last step in the validation is to have the hot melt primer written in to standards and engineering specifications; and to begin to create a track record. Most coating projects go through a bid process, so in order to be considered the hot melt must be approved by the end user or the engineering firm that is responsible for the project. Meeting the standards listed above is not enough, engineers want to see the product application and they want to know where else it has been used. This can be a difficult process in the beginning, but as the number of approvals and jobs grow so does the willingness of other users to approve and use the new technology.

Conclusions

Advantages with Hot Melt Primer

In addition to meeting the requirements of the coating system, the use of a hot melt primer offers several distinct advantages. The first is that the hot melt is solvent free which reduces the current expenses paid to ship, store and dispose of solvent based primers. The hot melt is also cost competitive with low or zero VOC solvent systems. Also, because the hot melt is solvent free it can be defined as zero VOC by all authorities and used worldwide without worrying about local safety regulations. Additional benefits are gained due to increased coating speeds that can be realized by the coating plants. There is no dry time or solvent evaporation associated with the hot melt, so the coating speed can be increased without

the fear of coating over wet solvent based primer. The lack of solvents also means that the coater will never need to strip a coated pipe due the blisters in the coating caused by solvent under the coating. Lastly, the time to test the coated pipe can be decreased from 24 to 2 hours allowing for faster corrections if there is an issue with the materials or coating process.

Future Opportunities

The focus so far has been on plant coatings for pipes carrying water and natural gas. These types of pipelines are typically operated at temperatures less than 50°C, with water pipelines operating at less than 30°C. There are significant opportunities for applications at 50°C and higher as described in the beginning of the paper. These opportunities will likely require hot melt adhesives with a different melt profile so that they don't soften at the pipeline operating temperature and become susceptible to soil stress. There are also significant opportunities for in situ applications. The world's pipeline infrastructure is aging and the rehabilitation of these pipelines and coatings is an ever growing area of opportunity. For this type of application the delivery system of the hot melt would need to be portable and able to be used in remote locations. The added difficulty of in situ applications would be the complications due to the wind. The wind could likely blow dirt, sand and other debris onto the hot melt before it is covered with tape, which would be perfect sites for corrosion. Certainly, the potential market for hot melts adhesives should provide an incentive to overcome the material and application related hurdles.

Citations

1. Tubb, Rita (2011), "2011 Worldwide Pipeline Construction Report," *Pipeline and Gas Journal*, January

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