Improvements in Productivity and Efficiency of Modern Solventless Adhesives

Larry Jopko – TS&D
The Dow Chemical Company

Solventless application machinery technology has improved and continues to do so, resulting in higher line speeds and increased productivity potential. While solventless adhesive which has been used since the 1980's has also evolved, there is still significant room for improvement in the chemistry and properties of solventless adhesives to take advantage of the higher machine line speeds. These improvements include (i) acceptable appearance of the laminated structure at high machine line speed, (ii) faster cure for shorter work-in-process time and yet with a long mixed pot life with ease of clean up, and (iii) broad performance utility across many diverse substrates. Added to these potential improvements, are requirements for higher food law acceptance in the ever changing global food law landscape. The latest high efficiency solventless adhesive system will be discussed that addresses all of these improvements and requirements.

What is the issue?

Current solventless machines can run much faster than ever before. While many adhesives can also be applied at these high line speeds, there are limitations in the adhesive application and appearance in the lamination. These limitations limit the effective line speed of the laminator. This has resulted in the requirement for solventless adhesives that can be applied at higher line speeds while maintaining current performance and food law compliance and improving appearance.

Beginnings of solventless adhesives

The beginning of modern solventless adhesives used in flexible packaging had a major driving force caused by the oil embargo of the 1980's. With energy and petroleum based raw materials becoming in short supply and at higher cost, there was an impetus to reduce both the energy requirement to apply the adhesive as well as use less materials in the make-up of the adhesive. One approach was to use no energy in drying volatiles form the adhesive and apply the adhesive as 100 % solids materials (so-called solventless adhesive). The machine manufacturers responded by making the first solventless application and lamination lines for food packaging. Back then, the adhesives were difficult to apply, of high viscosity requiring heating to 70 – 90 C and took up to 2 weeks to fully cure. Line speeds were slow and cleanup a chore because of the higher heated systems. Soon, two part systems were developed with lower viscosity, reduced heating times, faster cure of 7 to 14 days and better bonding to diverse substrates.

Current and new products

Fast forward to today. Machines can now mechanically reach over 600 meters per minute (MPM) in line speed. The commercial solventless adhesives can be applied with good bonding performance, heat and chemical resistance to most commonly used substrates of food packaging, but seldom at these high speeds. Because they are lower in viscosity than earlier versions, they are mostly lower temperature applied, making handling and pumping easier. Compliance to various food laws has increased. The chemistry of the adhesive and related properties now permits application at almost room temperature or slightly heated, with shorter cure times. At lower applied speeds, the appearance quality is very good, the bonding performance is good for the intended package use and the cure time is reduced to 2 to 7 days (depending of type of adhesive, laminated structure of the package and that the various food law requirements are met).

At higher line speeds, though, there are issues of maintaining good appearance, especially on reverse white print laminated to metallized film or aluminum foil. A phenomenon of misting can occur, which is of safety concern.

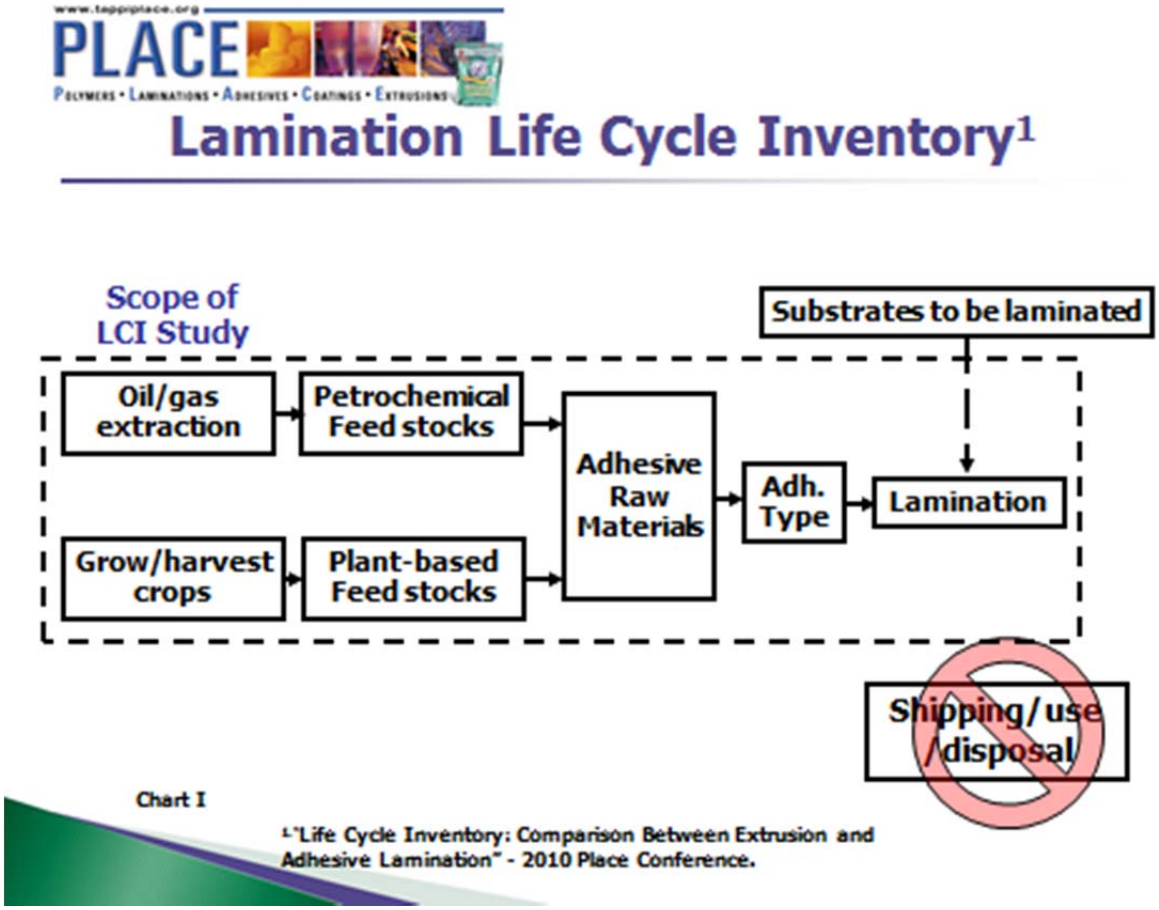
There are also issues of good wetting at high application line speeds which can result in a textured adhesive appearance, sometimes called orange peel.

Further improvements in the chemistry and physical properties of the solventless adhesive are continuing. Today, the presentation will explore an improved solventless adhesive that tackles the issues of high speed misting and superior appearance on metallized laminations, while still maintaining fast cure, ease of clean up and the necessary food laws for a broad range of food packages.

Economics of Adhesives

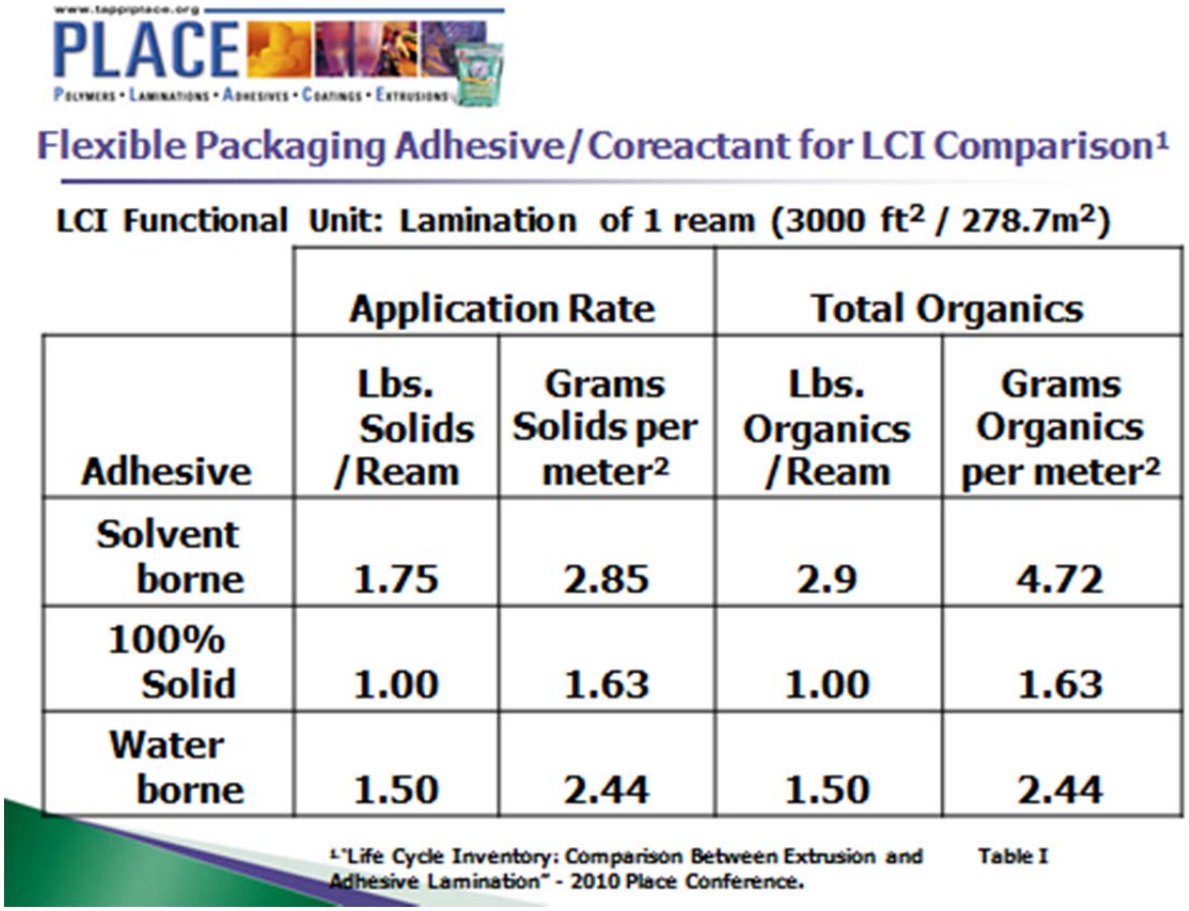
Solventless adhesives are the lowest cost per unit adhesive weight applied. A study was presented at the 2010 TAPPI PLACE Conference on the Life Cycle Inventory comparing the cost, organic material usage and energy usage of packaging adhesives and extrusion coating/lamination. This explored the inherent cost of raw materials of adhesives up to the moment of lamination. The cost of substrates and subsequent production and shipping cost were not included.

Chart I



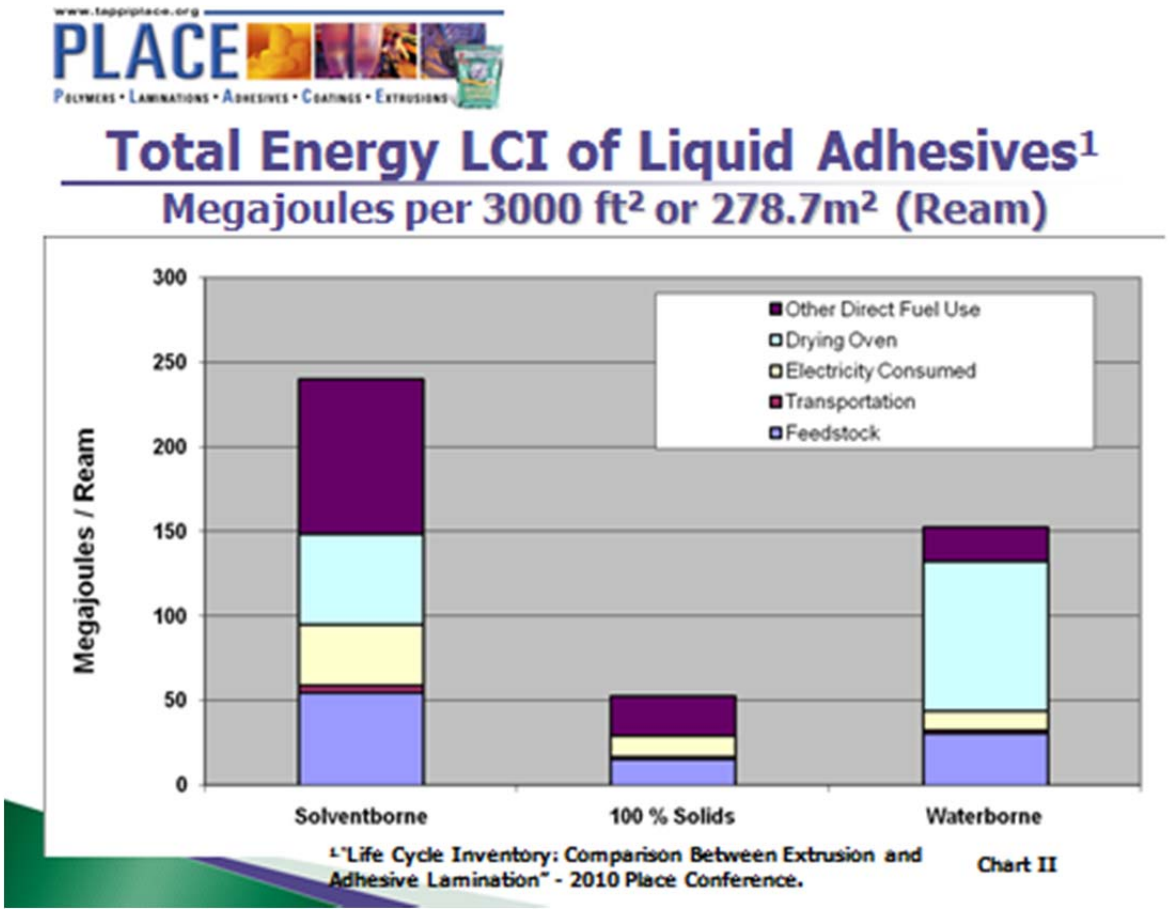
It is common for the solventless adhesive to be applied at a lower weight per unit area, compared to water borne or solvent borne adhesives. This also means that the solventless adhesive use less organic material in the final lamination as well. Solvent borne adhesive apply much more organic material due to the use of solvents. Please note that this calculation for solvent borne adhesive is done before any additional solvents are added for press side solids reduction or viscosity reduction – the organic consumption is higher in practice.

Table I



On the energy consumption side, it is clear that solventless adhesives require much less per unit area of lamination, encompassing the energy to make the raw materials, transportation, electricity, drying energy and other direct fuel costs.

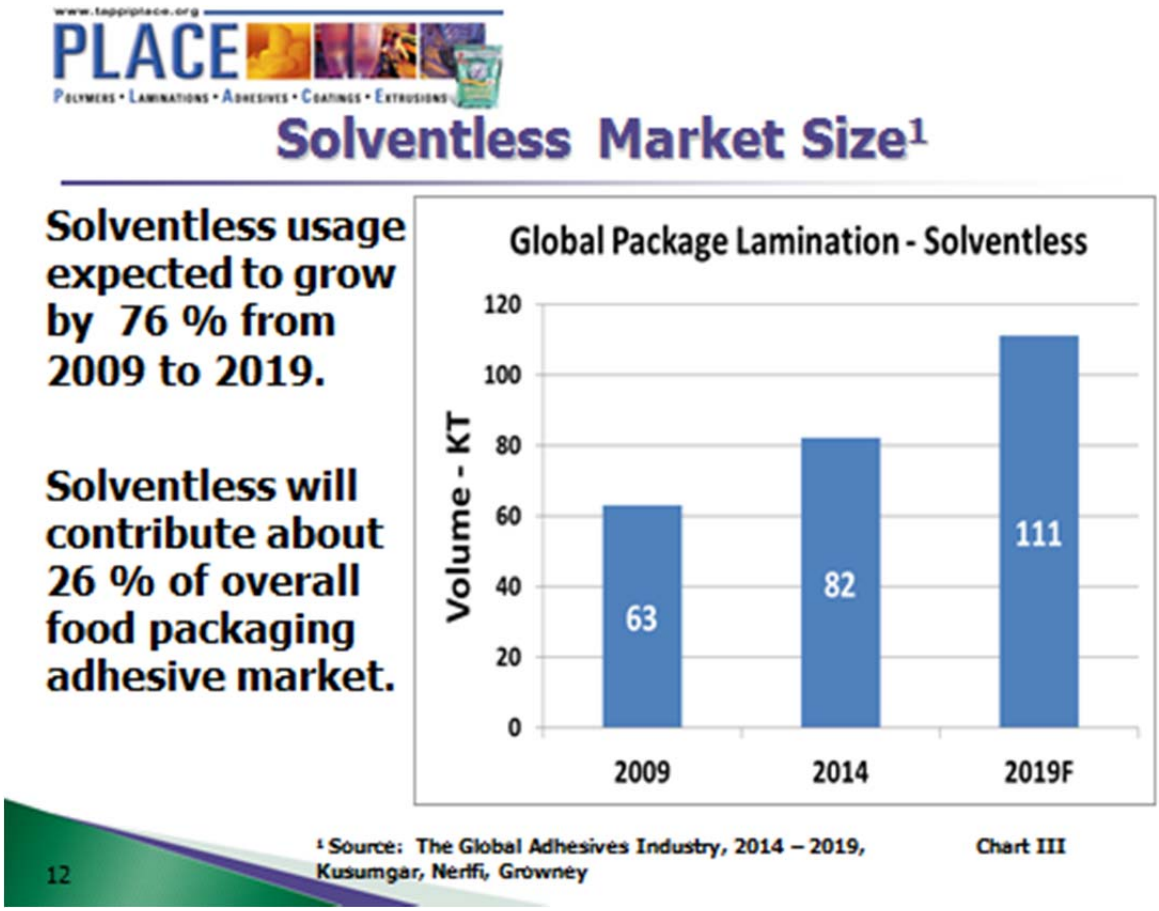
Chart II



Global Growth of Solventless Adhesives

The growth in solventless adhesives is projected to reach 26 % of the food flexible packaging adhesives market globally by 2019. There is good reason for the growth due better efficiencies and lower cost compared to other adhesive systems. Because of various advantages in applied costs, waste reduction and increased line speed, there is good incentive to increase the usage of solventless adhesives – if certain limitations can be overcome.

Chart III



Road to Improved Economy

The goal is to maintain or improve several key characteristics of today's commercial solventless adhesives. These requirements include:

- Increase line speed with no misting.
- Improve appearance on metallized film structures.
- Maintain bonding to diverse substrates.
- Maintain or improve rate of cure.
- Maintain or improve heat and chemical resistance.
- Meet all food law requirements for the intended package use.
- Maintain or improve incompatibility to common lamination grade inks.
- Maintain or improve clean up characteristics.

The improved high efficiency solventless adhesive presented addresses these requirements and meet or exceed all the targets.

What impact will this have on production? When the production line speed can be increased and still maintain the desired appearance of the lamination and performance, there are savings for the converter. By increasing the speed with acceptable appearance from 210 to 300 MPM or even to 425 MPM, productivity increases, and lamination output can double. As an example of economy, if the machine rate used for bidding quotations is USD 500 per hour, then up to two times the lamination can be made, effectively reducing the machine time cost in half.

With the high efficiency solventless adhesive presented here, the design targets are met:

High Running Speeds:

- 400 + MPM, without misting: increased productivity.
- Excellent appearance in white / metalized film lamination.
- Easy cleaning, less machine down-time, more production time.

High Performance:

- Good adhesion & chemical resistance on a range of structures including foil.
- "All-in-one" usage (GP to HP, except retort).
- Reduced operator error (no switching adhesives).
- Fast curing: slit in 3-4 hrs.
- Pouch next day, food contact in 2 days.
- COF neutral.
- Reduced antiseal potential.

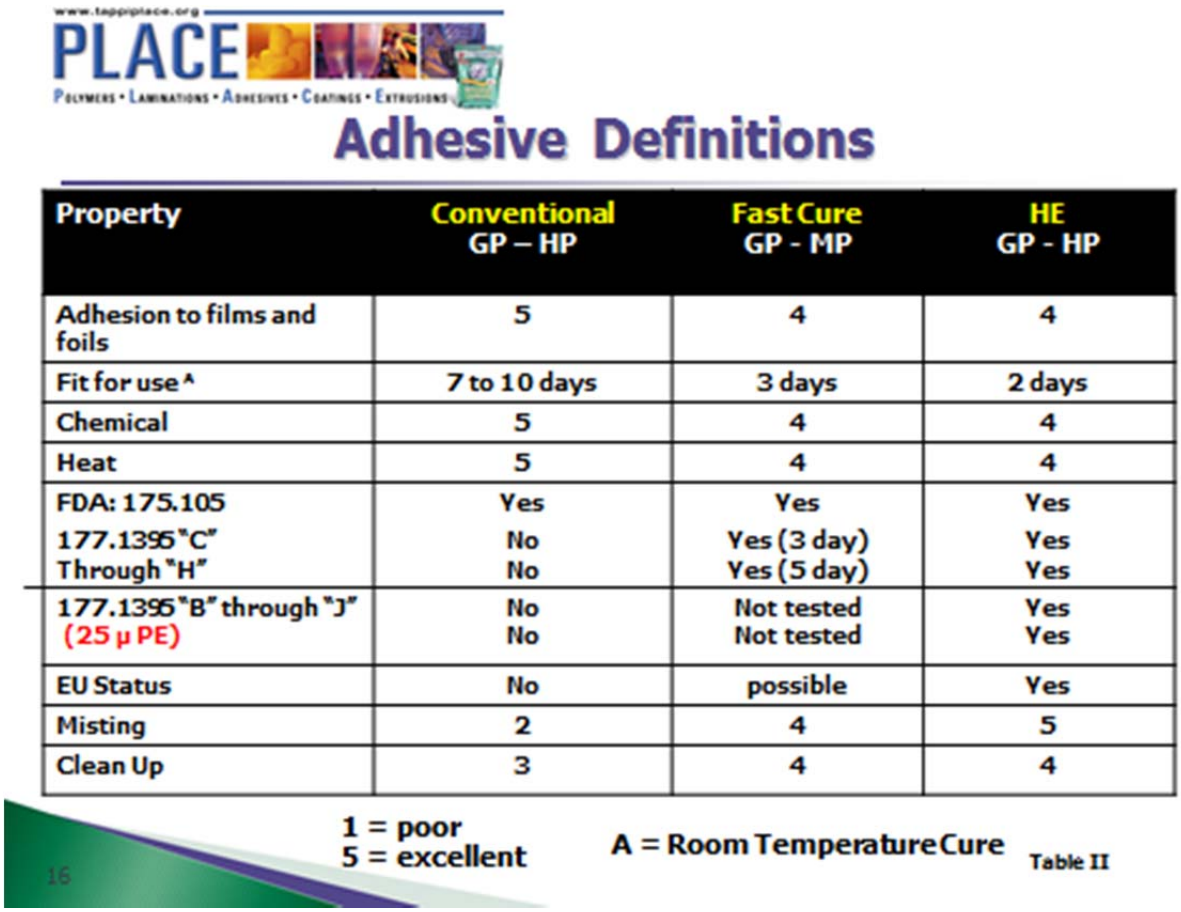
High Food Safety compliance:

- Two day cure on 25 micron (1mil) PE sealant layer, FDA 177.1395 C thru J.
- No need to switch adhesive to meet FDA.
- EU 10/2011 compliance.
- Fast PAA decay in 2 days.

Adhesive Definitions in Data

For the sake of comparison, a conventional and a fast cure solventless adhesive were compared to the new high efficiency solventless adhesive. The characteristics are presented here. It is notable that the conventional cure adhesive took much longer to cure at 7 to 10 days, and the fast cure was 3 days, while the new high efficiency adhesive was only 2 days to reach full food safety cure. And this was using 25 micron (1 mil) sealant polyethylene, not coextruded or enhanced barrier, or higher thickness food contact layer films. The new adhesive also had higher FDA status in less cure time, as well as EU food law compliance. This was determined by migration and polyaromatic amine (PAA) testing. Ease of clean-up was maintained. From a productivity point of view, the high efficiency adhesive had a much higher line speed misting threshold, while maintaining excellent appearance.

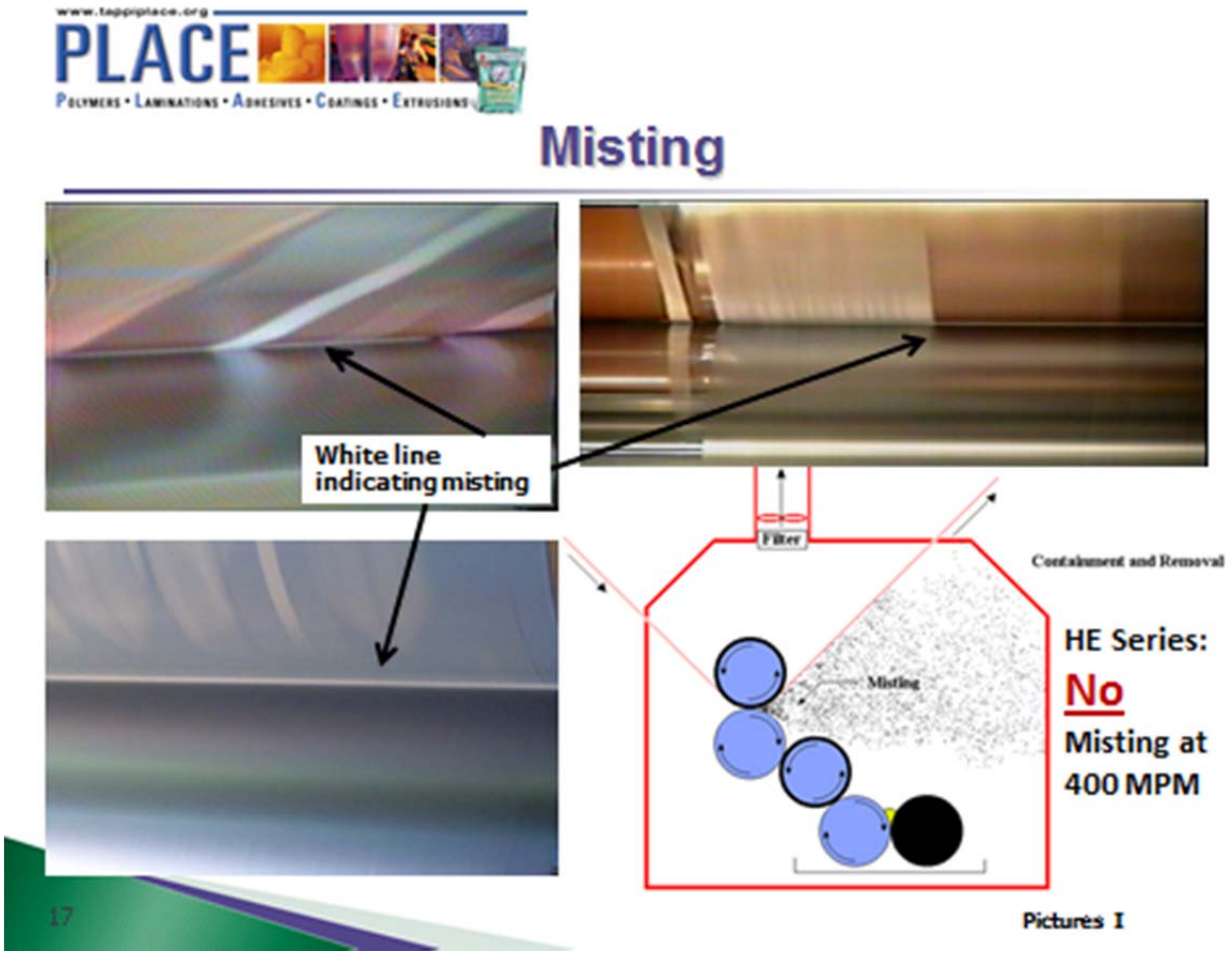
Table II



Misting

There can be a phenomenon produced in high speed running of solventless adhesives called misting. The is where an aerosol of droplets of adhesive are produced during the transfer of adhesive on the application rollers and is usually most pronounced between the last application roller and the substrate. While this can be contained by engineering controls – an enclosure of the coating head with exhaust – it is best to avoid misting in the first place. In the enclosure, there are filters that can become plugged with the aerosol adhesive - remember it will cure – and decreases the exhaust flow. This can produce a safety concern for the operational personnel. While there is some machine settings that help to reduce the amount of misting, the real solution is through the characteristics of the adhesive. The new solventless adhesive can run in excess of 400 MPM with no sign of misting.

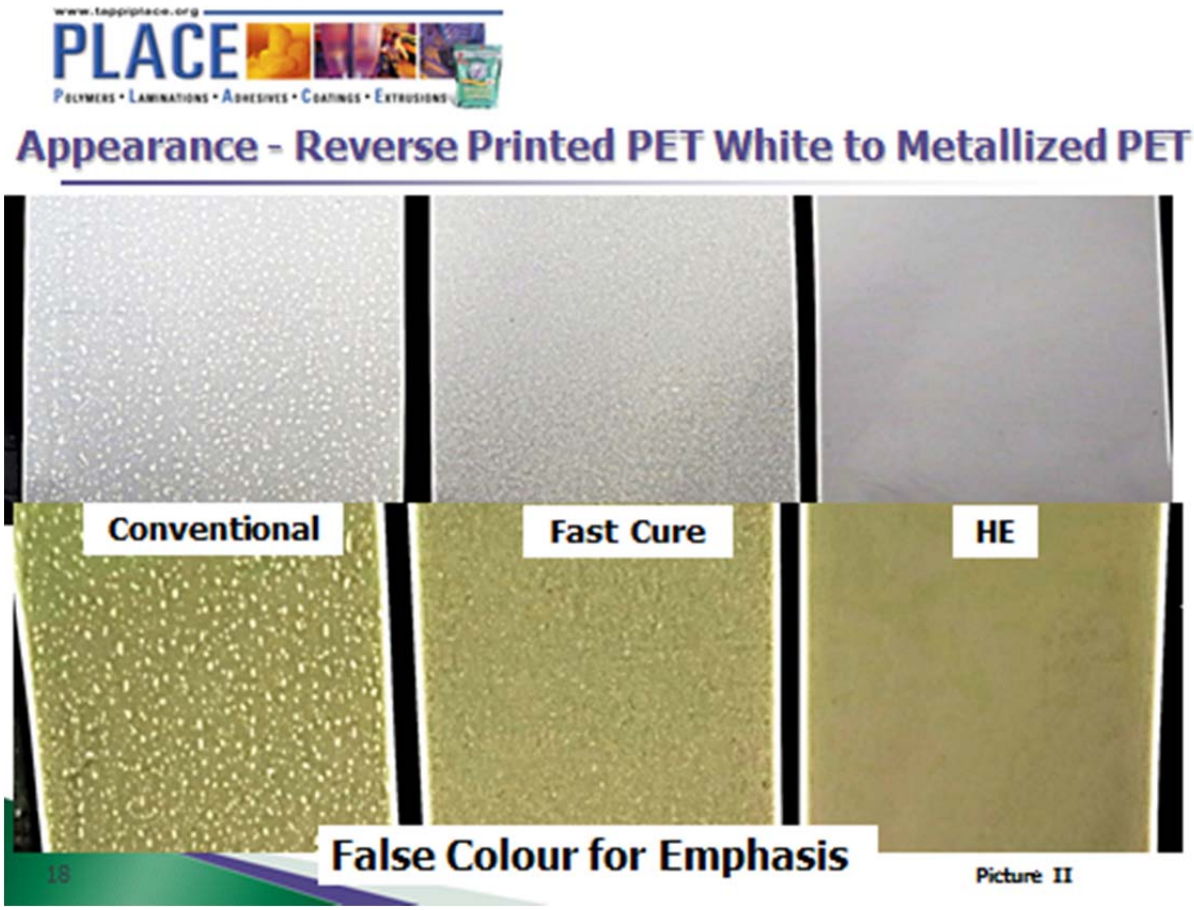
Picture I



Laminated Appearance

One of the prime challenges for high speed lamination is to have a uniform appearance on reverse printed white ink laminated to metallized film. Shown here are examples of conventional, fast cure and the high efficiency solventless adhesive, laminated at 400 MPM. The colour has been distorted to enhance the defects in appearance. All samples were made using the same machine, the same application conditions, the same films – nothing was changed between each run except the adhesive.

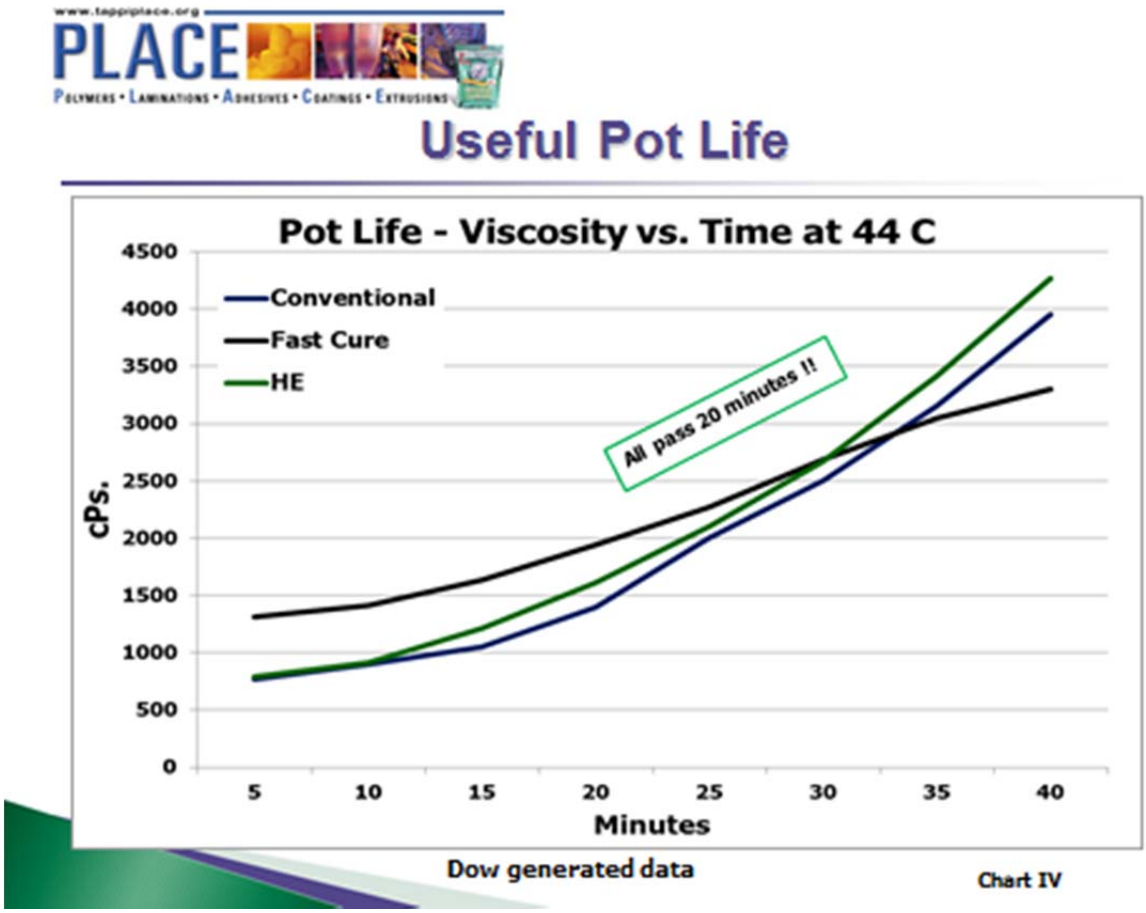
Picture II



Useful Pot Life and Clean-up

Another important requirement for the adhesive is to have a suitable mixed pot life. It is accepted that solventless adhesives cure more quickly that other conventional adhesives, but there still needs to be a good working time for the adhesive. Generally, if the adhesive can be applied beyond 20 minutes after mixing, then the mixed pot life goal is met. The viscosity over time data at 44 C for the new solventless adhesive verifies a useful application time exceeding 20 minutes, minimizing wastage and need for frequent cleaning.

Chart IV

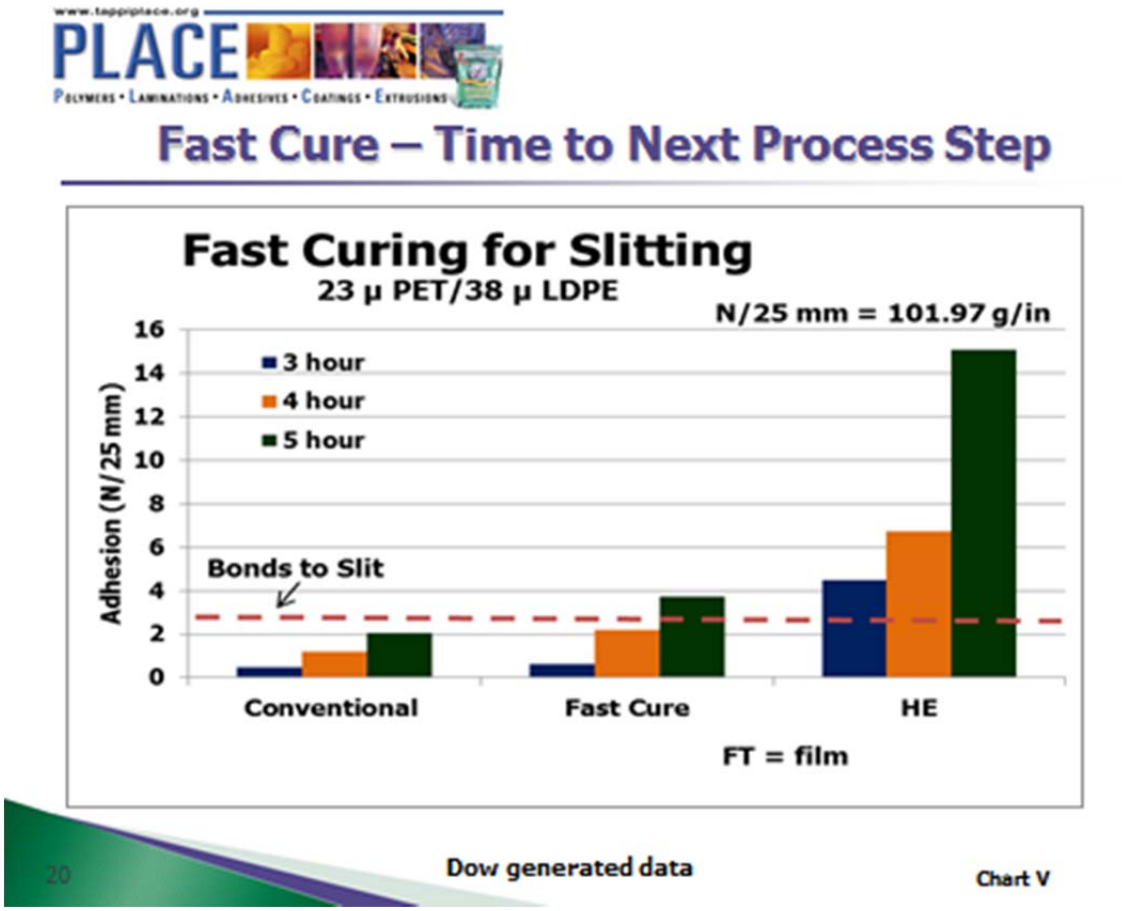


Another important aspect of solventless adhesives is to be operator friendly. Usually this means to avoid having to pre-heat the adhesive before pumping and mixing, and apply at a lower temperature. Additionally, the adhesive must be easy to clean-up once beyond the useful mixed pot-life. This avoids long down times to clean the application rolls between production runs or shut downs, and avoid operator frustrations. The high efficiency solventless adhesive is low temperature applied at 40 – 45 C and is just as easy to clean as the current line of solventless adhesives provided by Dow Chemical.

Fast Cure and Substrate Diversity

There is a need for reduction of work-in-process lamination, awaiting cure and bond development before proceeding to the next process. This may be another lamination pass or slitting. If one assumes a minimum bond of 3 N/25 mm (305 grams/inch) target, then the high efficiency solventless adhesive has exceeded the target bond in three hours. This is advantageous over conventional and even fast cure systems. Less waiting time improves the efficiency and work flow in the converting operation.

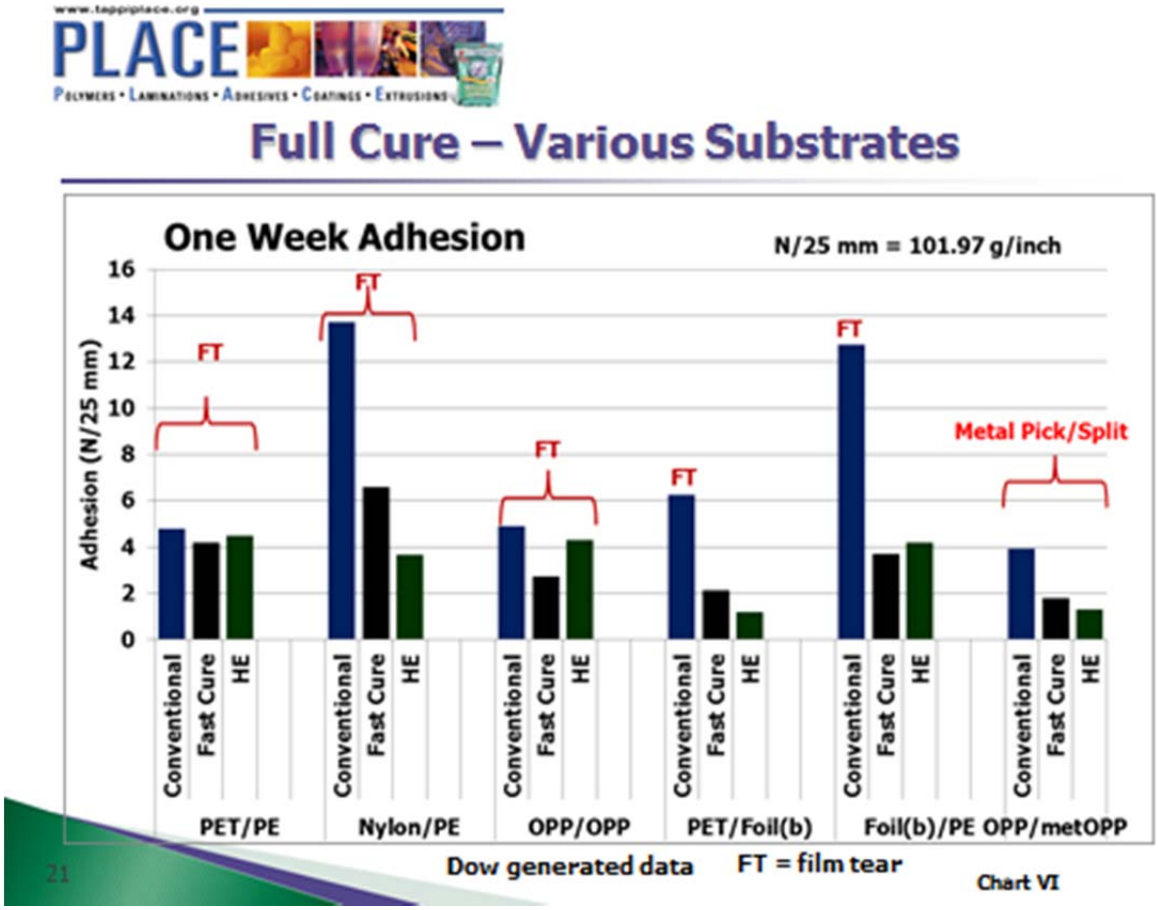
Chart V



In modern food packaging, there is a wide range of substrates used. It is highly desirable to use one adhesive on most, if not all of the common substrates to avoid stoppage and adhesive changes when changing substrate combinations. Many current adhesive systems are able to do this. The new high efficiency solventless adhesive also performs well across many substrate combinations. The conventional cure solventless adhesive is still well suited for metallized films or foils. The new high efficiency solventless adhesive compares very favourably with the current fast cure adhesive. All three types are good on all-plastic laminations. No need to change adhesives with substrate changes. (The PET/Foil(b) means that the foil side of a PET – Foil lamination was used in test lamination to PET film. The Foil(b) means that the foil side of a PET-foil lamination was used to laminated to PE film.)

Nonetheless, individual substrates need to be tested and confirmed that the bond and other performance characteristics are suitable.

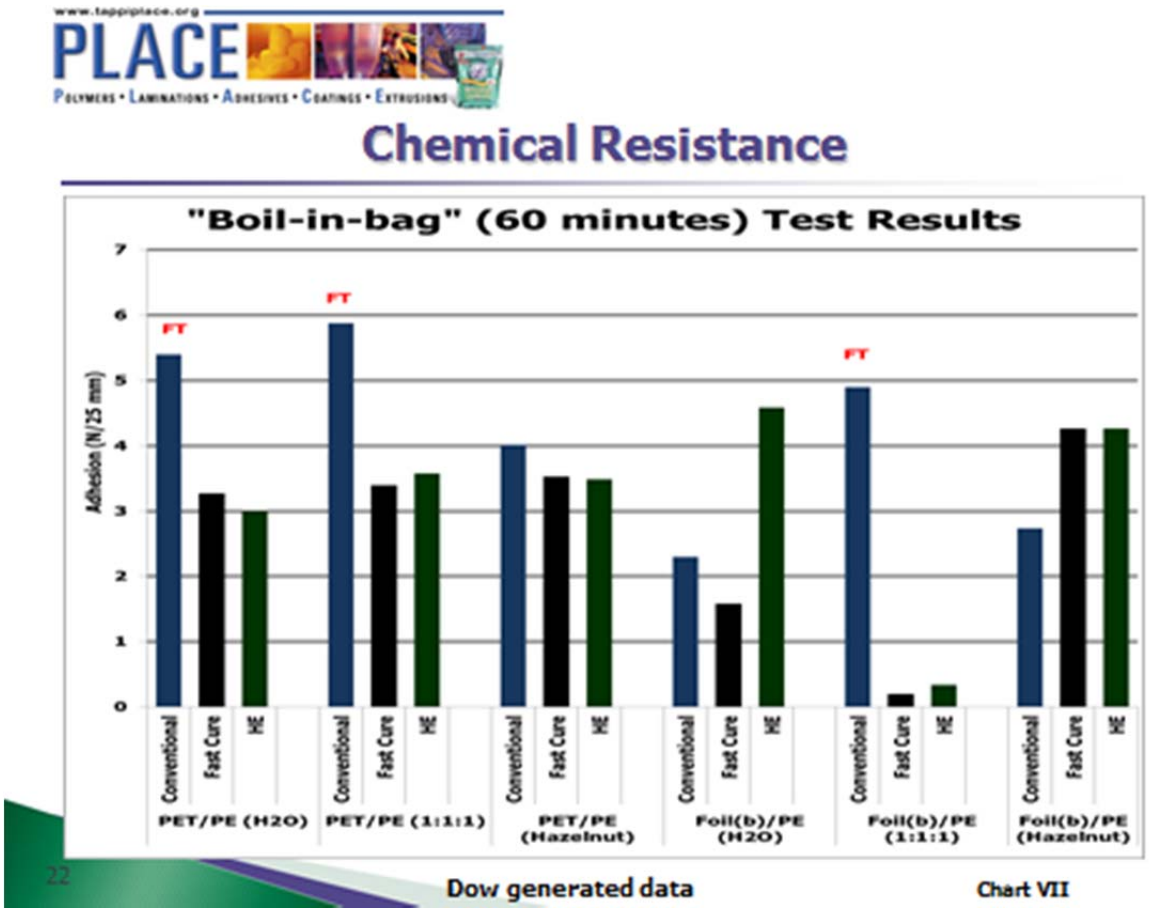
Chart VI



Chemical Resistance

One of the challenge tests for chemical resistance of the adhesive was to make a lamination of various substrate combinations. These laminations were made into pouches, filled with challenge foods or simulants, sealed and put in boiling water for up to 60 minutes. The Conventional adhesive provided good chemical resistance as expected, since this was developed for higher chemical resistance, but it did not have extended food law compliance. The new solventless adhesive HE C compared very favourably with the Fast Cure adhesive.

Chart VII



Outcomes

In summary, a set of goals and targets were set for improving the efficiency of a new adhesive system. All the goals were met or exceeded:

- Fast line speed with excellent appearance.
- Faster cure for reduced wait time.
- Fit-for-use in 2 day at RT on 25µ PE.
- Compliant with FDA and EU food laws including elevated temperature use.
- Maintain acceptable performance on various substrates.
- Maintains same pot life and ease to clean-up.

In addition, there is a path to improve both the efficiency and the economics of the converting process. Therefore the goals for the new MOR-FREE™ Solventless Adhesive line have been met.

™ Trademark of The Dow Chemical Company ("Dow") or an affiliated company of Dow.

Acknowledgment

The author would like to thank The Dow Chemical Company for providing the many Chemists for creating the chemistry and doing the research to develop these products, as well as the many Technicians that ran the internal and customer trials for testing of the high efficiency MOR-FREE™ Solventless Adhesive.

References

1. Jopko, L., “Life Cycle Inventory: Comparison Between Extrusion and Adhesive Lamination” - 2010 Place Conference.
2. Kusumgar, Nerlfi, Growney, “The Global Adhesives Industry, 2014 – 2019”.
3. The Dow Chemical Company – internal and customer generated data.