The effects of two key formulation variables on two-pack waterborne PU coatings based on a specific polyol dispersion were examined. Variations in the level or type of coalescing solvent had little effect on film properties. The dispersion also produced good film properties with little change in performance across a wide range of isocyanate addition levels.

2-pack wood finish offers good performance at low isocyanate levels
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The most critical component for the film formation of a waterborne one-component acrylic dispersion is the type and amount of coalescing solvent used [1]. The nature of the acrylic dispersion as well as the additives used also have significant effects. When formulating a waterborne two-component polyurethane coating, additional formulation parameters become relevant: the polyisocyanate type and amount. Of course, here too the additives and the nature of the resin used are important formulation parameters. The results discussed below relate to coatings based on one specific dispersion, referred to as polyol dispersion B. The influence of the following key formulation para meters was studied:

Coalescing solvent, type and amount: where the coatings were evaluated with constant polyisocyanate addition.
Polyisocyanate (hydrophilic) amount: where the coatings were evaluated with the coalescing solvent kept constant.
The physical characteristics of polyol dispersion B and of the polyisocyanate "Basonat LR 9056" are presented in Table 1. Polyoil dispersion B was neutralised with DMEA/water (1:1 ratio) to pH 8.3 before adding coalescing solvent and/or polyisocyanate. The types of coalescing solvents used and the abbreviations by which they are identified are presented in Table 2. In the tests with fixed amounts of coalescing solvent and variations of the hardener content, the defoamer "BYK 028" was added to minimise the levels of foam during production and application of the coating.

Test methods summarised
The MFFT (Minimum Film Formation Temperature) was measured on an MFFT bar in order to determine the minimum amount of coalescing solvent required for good film formation at 5 °C, with and without the presence of polyisocyanate. Viscosity was measured with a "Brookfield" viscometer at 60 rpm and 23 °C, at different time intervals after mixing the polyol dispersion and the polyisocyanate. The films for the acetone double rubs were prepared as follows: a 100 µm wet film was applied (using a gap blade) on glass at different time intervals after mixing the polyol dispersion and the hardener, then the films were dried at 23 °C/50 % relative humidity for seven days. 100 acetone double rubs were performed unless the film showed complete damage (removal) earlier. The foam test was performed without polyisocyanate and only with the addition of 4 % coalescing solvent (weight on dispersion as delivered). The mixtures of polyol dispersion and coalescing solvent were shaken using a Red Devil defoamer "BYK 028" was added to minimise the levels of foam during production and application of the coating. When evaluating the blocking resistance, 100 µm wet films were applied on "Leneta" gloss card (type 2A) and dried for 24 hours at 23 °C/50 % relative humidity. 240 test pieces were cut and put coating to coating. One was exposed for 1 hour at 50 °C and the other for 24 hours at 23 °C/50 % relative humidity, both with a pressure of 2 kg/cm2. After the specified time the pieces were separated and the release or possible damage was judged.

Chemical resistance and cold checking tested on wood
The chemical resistance was evaluated on primed beech veneer. A primer (formulation reference 008KW003) based on "Joncryl 8225", an RC (Rheology Controlled) acrylic emulsion from BASF, was applied by conventional spray at approximately 100 g/m2, allowed 5 minutes to flash off at room temperature and then dried for 10 minutes at 50 °C.
Before the waterborne two-component polyurethane coatings were applied the panels were sanded by hand (using P 280 sandpaper). A 100 µm wet film of the waterborne two-component polyurethane coating was applied using a gap blade and was dried at 23 °C/ 50 % relative humidity for seven days before testing the chemical resistance according to DIN 68 861 part 1B and IKEA IOS-MAT-0066 "Surface coatings and coverings general requirements".

The hot-cold checking was evaluated on beech veneer panels coated under the same application, drying and ageing conditions as for the chemical resistance tests. The test cycle comprised 1 hour at +50 °C directly followed by 1 hour at -20 °C. (No recovery time at room temperature was allowed). In total the panels were subjected to 20 cycles. Every fifth cycle the panels were inspected under a microscope for possible cracks.

Effects of coalescing solvent on MFFT summarised

A major difference was observed between the MFFT obtained in the presence of the polyisocyanate and without it. With the polyol alone, the lowest MFFT was obtained with butyl diglycol acetate or a mixture of this with butyl glycol acetate (see Figure 1).

After addition of the polyol, the effects of changes in cosolvent were much less marked. At 2 % addition, "Texanol" produced a value of about 15 °C while all the others produced values of 9-12 °C. At 4 % and 6 % additions, all cosolvents produced an MFFT below 5 °C. Therefore, to obtain good film formation at 5 °C the required amount of coalescing solvent was considered to be 4 % (calculated on binder in delivery form) for all coalescing solvents.

Coalescent strongly affects viscosity stability

To determine the visual potlife, the viscosity was measured at different time intervals after mixing the coalesced polyol dispersion B with the isocyanate. As can be seen in Figure 2, the different glycol ethers showed a higher initial viscosity and a larger reduction in viscosity.

The different acetates tested seemed to have less influence on the viscosity over time. This could be preferable when the coating is used for example, for spray applications, to avoid the need to adjust the viscosity during application.

For solvent-borne two-component polyurethane coatings, the viscosity is used to measure potlife: a doubling of the viscosity is considered to define the potlife. As can be clearly seen in Figure 2, the viscosity does not increase and so cannot be used to determine the potlife of a waterborne two-component PU coating.

The acetone double rub test was used instead to measure the functional potlife. Using this performance-related test, films applied even six hours after mixing the polylol dispersion and hardener showed excellent resistance to acetone, no damage when 4 % of coalescing solvent was used. Polylol dispersion B thus has a potlife of six hours with the hardener tested here.

Coalescents modify foaming behaviour and hardness

Both the foam development after two minutes' shaking in the Red Devil and the decreasing foam percentages over time were recorded. Polylol dispersion B develops a large amount of foam (almost 200 % initially) when it is coalesced with either "Proglyde DMM" or butyl diglycol. Any of the other cosolvents can be considered acceptable, as they produced foam levels similar to or below the levels without cosolvent and in all cases below 100 %. When hardness development was measured at different time intervals, the slow-evaporating coalescing solvent "Texanol" also showed the slowest hardness development while the fast-evaporating coalescing solvent butyl glycol gave the fastest hardness development, as shown in Figure 3.

Gloss, chemical resistance, blocking and hot-cold check
tests all produced excellent results and no differences were noted between the different coalescing solvents when the polylol dispersion was 100 % crosslinked with the test isocyanate. The results can be summarised thus:

Gloss: all values above 80 G.U. at 60 °, above 70 G.U. at 20 °;

Chemical resistance: all films showed excellent performance;

Blocking: all showed good stackability;

Hot-cold check: all passed 20 cycles.

From these tests it may be concluded that the type of coalescing agent does not significantly influence the final performance of the waterborne formulation tested here. In relation to the functional demands such as foam stabilisation, viscosity and drying some effects were observed.

As glycol ethers could theoretically influence the crosslinking density between the polylol dispersion and the polyisocyanate it was decided to continue the study with an acetate cosolvent. Because of long experience working with the combination of butyl glycol acetate and butyl diglycol acetate at a ratio of 7:3, with good results, this combination was chosen.

High tolerance for variations in isocyanate levels

The effect of varying the level of polyisocyanate (and thus the level of crosslinking) was next studied, with the chosen coalescing solvent and amount being constant. As can be seen in Figure 4, the higher NCO:OH ratios (≥ 100 %) showed a much higher initial viscosity and also a larger viscosity drop over time.

When measuring the functional potlife with 100 acetone double rubs, films applied up to six hours after mixing the polylol dispersion with different ratios of hardener practically all showed excellent resistance to acetone, with no damage. However, films with the lowest crosslinking level of 50 % showed damage after all time intervals.

These results indicate that a crosslinking level of at least 75 % between the polylol dispersion and the polyisocyanate is needed to obtain higher chemical resistance properties, while "excess" crosslinking (≥ 100 %) does not show any improvement.

The hardness development showed some trends: the lower the crosslinking the faster the initial hardness development, but the higher the crosslinking the higher the hardness after seven days (see Figure 5).

No significant differences were found in the gloss measurements, all being above 90 G.U. at 60 °. In addition, excellent stackability was obtained at all crosslinking ratios. When measuring the chemical resistance, similar trends were seen as when measuring functional potlife. A minimum of 75 % crosslinking gives higher chemical resistance properties. As can be seen in Figure 6, only the film with 50 % of crosslinking showed inadequate results with 1 hour
ammonia (10 %). Mustard is considered as one of the most
difficult household chemicals.

High performance, economy and formulating flexibility
When the formulation of waterborne one-component acrylic
coatings is compared with two-component coatings (based
on the polyl tested here) the role of the coalescing solvent
is different. In the two-component polyurethane coatings
tested here, no influence of the coalescing solvent on the
film performance was observed.
However, some influence on application and handling
performance ie, functional properties was observed. Glycol
ethers, for example, showed a higher initial viscosity and
a larger viscosity drop when the viscosity was measured
at different time intervals after mixing the coalesced polyl
dispersion B with the hardener. This effect could be
undesirable as it could make application procedures such
as spray application more complicated.
Polyol dispersion B crosslinked with the hardener tested
here could achieve its optimum performance even when
"under-crosslinked" at 75 % of the theoretical addition.
No improvement in final performance could be seen
when the coating was "over-crosslinked". This could be
attractive from an economic perspective, providing optimum
performance without any excess of hardener.
When evaluating the two key formulation parameters,
coalessing solvent and isocyanate, for a two-component
polyurethane coating based on polyl dispersion B, the
conclusion is that this product is a very robust OH-functional
dispersion, offering excellent potlife and resistance
properties combined with low solvent requirements.
It thus offers the coatings manufacturer a sustainable
highly reactive dispersion as a viable alternative to solvent-
borne systems, to meet both the ever-increasing legislative
demands for more environmentally friendly coatings, and
the ever-increasing demands from furniture manufacturers
for high quality coatings

REFERENCE
[1] Levinga D., Berkhout L., Enhancement of film properties
by the proper choice of coalescing solvents in aqueous
acrylic polymers, Advances in Coatings Technology

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evaluation.

Results at a glance
The effects of two key formulation variables on two-
pack waterborne urethane coatings based on a specific
acrylic polyl emulsion were examined. While the MFFT
of the polyl dispersion alone was considerably affected
by changes of type or amount of coalescing solvent, the
impact on a two-pack formulation was very slight. Cosolvent
addition also had little effect on most physical properties.
However, viscosity stability over time was much greater with
acetate cosolvents than with glycol ethers. With a constant
cosolvent addition, variations in the level of isocyanate
addition between 75 % and 150 % of the theoretical value
also produced remarkably little variation in final properties.
The polyl dispersion studied therefore appears to be
extremely robust in tolerating formulation variables, and

cost reductions may be achieved by using relatively low
isocyanate addition levels.

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Table 1: Physical characteristics of polyol dispersion and polyisocyanate tested

<table>
<thead>
<tr>
<th></th>
<th>Polyol B</th>
<th>Basonat LR 9056</th>
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<tbody>
<tr>
<td>Solids content</td>
<td>45 %</td>
<td>100 %</td>
</tr>
<tr>
<td>OH value</td>
<td>100 mg KOH/g</td>
<td>--</td>
</tr>
<tr>
<td>NCO content</td>
<td>--</td>
<td>18 %</td>
</tr>
<tr>
<td>pH</td>
<td>2.7</td>
<td>--</td>
</tr>
<tr>
<td>MFFT</td>
<td>~ 48 °C</td>
<td>--</td>
</tr>
<tr>
<td>Viscosity at 23 °C</td>
<td>360 mPa.s</td>
<td>1500-3000 mPa.s</td>
</tr>
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Bild zu Cutting the crosslinker
Table 2: Identification of coalescing solvents tested

<table>
<thead>
<tr>
<th>Common name</th>
<th>Abbreviation used</th>
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<tbody>
<tr>
<td>Butyl glycol acetate</td>
<td>BGA</td>
</tr>
<tr>
<td>Butyl diglycol acetate</td>
<td>BdGA</td>
</tr>
<tr>
<td>Butyl glycol acetate/Butyl diglycol acetate (7:3)</td>
<td>BGA/BdGA (7:3)</td>
</tr>
<tr>
<td>Propylene glycol diacetate</td>
<td>PGDA</td>
</tr>
<tr>
<td>Propylene carbonate</td>
<td>PC</td>
</tr>
<tr>
<td>“Proglyde DMM”</td>
<td>DMM</td>
</tr>
<tr>
<td>Butyl glycol</td>
<td>BG</td>
</tr>
<tr>
<td>Butyl diglycol</td>
<td>BdG</td>
</tr>
<tr>
<td>“Solvenon PnB”</td>
<td>PnB</td>
</tr>
<tr>
<td>“Solvenon DpnB”</td>
<td>DpnB</td>
</tr>
<tr>
<td>“Texanol”</td>
<td>Tex</td>
</tr>
</tbody>
</table>

Bild zu Cutting the crosslinker
Figure 1: MFFT of polyol dispersion B with various coalescing solvents (without isocyanate addition)
Figure 2: Brookfield viscosity changes over time with 4 % of different coalescents and hardener at OH:NCO ratio of 1:1
Figure 3: Pendulum hardness development with 4 % addition of different coalescents and OH:NCO ratio of 1:1
Figure 4: Brookfield viscosity changes over time with different OH:NCO ratios using "Basonat LR 9056" polyisocyanate
Figure 5: Hardness development at different OH:NCO ratios using "Basonat LR 9056" polyisocyanate
Figure 6: Chemical resistance evaluation with different OH:NCO ratios using "Basonat LR 9056"