

# **SOLVENTS**

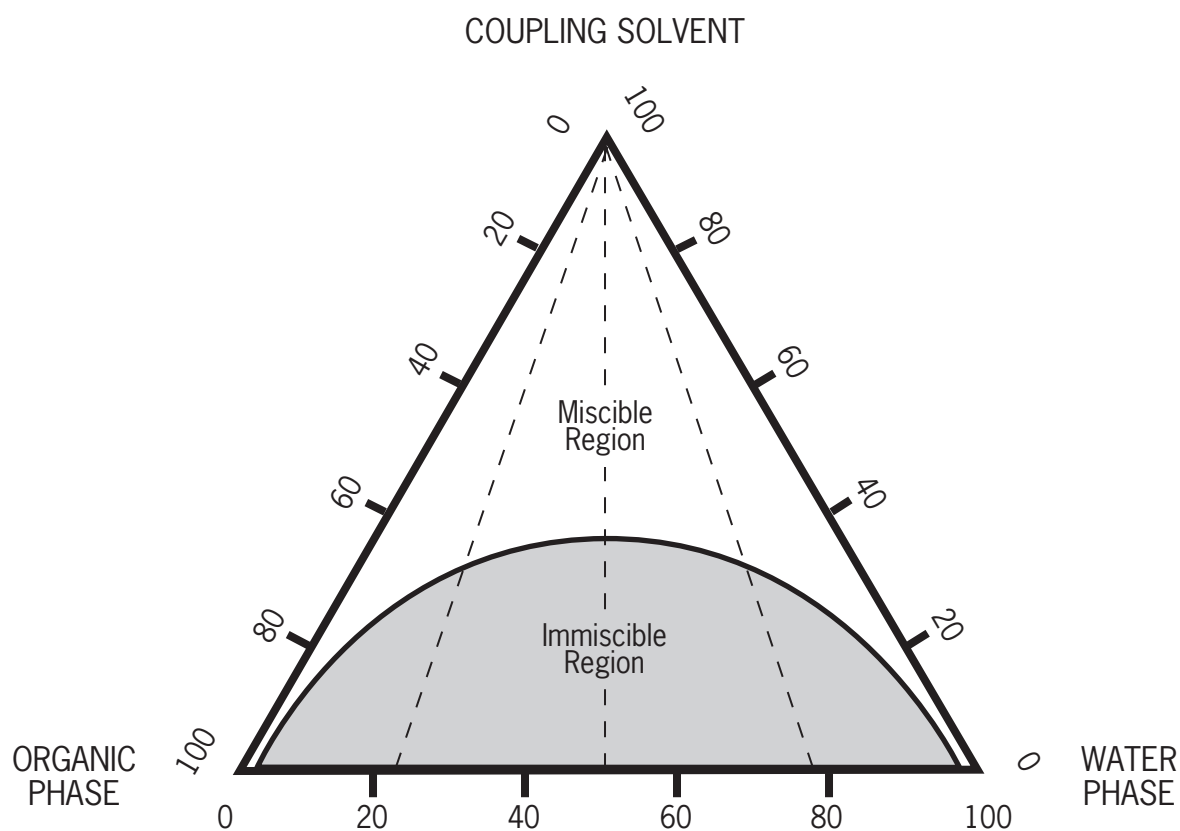
## Selecting Coupling Agents for Multiphase Models

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The principles considered in the selection of a coupling agent must be balanced against other performance factors and economics.

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# Glycol Ether/Glycol Ether Ester Nomenclature

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Ethylene Glycol Monomethyl Ether	EGME Solvent
Ethylene Glycol Monoethyl Ether	EGEE Solvent
Ethylene Glycol Monopropyl Ether	<i>Eastman</i> EP Solvent
Ethylene Glycol Monobutyl Ether	<i>Eastman</i> EB Solvent
Ethylene Glycol Monoethyl Ether Acetate	EGEEA
Diethylene Glycol Monomethyl Ether	<i>Eastman</i> DM Solvent
Diethylene Glycol Monoethyl Ether	<i>Eastman</i> DE Solvent
Diethylene Glycol Monoethyl Ether Acetate	<i>Eastman</i> DE Acetate
Diethylene Glycol Monopropyl Ether	<i>Eastman</i> DP Solvent
Diethylene Glycol Monobutyl Ether	<i>Eastman</i> DB Solvent
Propylene Glycol Monomethyl Ether	<i>Eastman</i> PM Solvent
Propylene Glycol Monopropyl Ether	PnP Solvent
Propylene Glycol Monobutyl Ether	PnB Solvent
Dipropylene Glycol Monomethyl Ether	DPM Solvent
Ethylene Glycol Monohexyl Ether	EH Solvent <sup>1</sup>
Diethylene Glycol Monohexyl Ether	DH Solvent <sup>2</sup>

<sup>1</sup>Hexyl Cellosolve Solvent—Dow Chemical Company

<sup>2</sup>Hexyl Carbitol Solvent—Dow Chemical Company

Coupling may be defined as a method of combining components of a multiphase system that results in an increase in the degree of homogeneity of the system. For a given multiphase system, more than one coupling agent may be appropriate. Combinations of coupling agents may achieve levels of activity superior to those of any single agent; thus, there may be some degree of synergism evident in a composite of coupling agents.

Without the existence of multiphase, heterogeneous systems [1], there would be little need for the concept and function of a coupling agent. In defining such systems, temperature is an important consideration. Figure 1 illustrates three multiphase systems in which a coupling agent may be required within a certain temperature range and yet be unnecessary in other thermal regions.

Other known multiphase systems are mixtures of some glycol ethers and aliphatic hydrocarbons that separate when placed in reduced-temperature environments and some organic amine neutralizing agents that have very limited solubility in aliphatic hydrocarbons (for example, VM&P naphtha or mineral spirits). At elevated temperatures [50°C (122°F)], compositions of EB solvent and water convert from homogeneous to heterogeneous character [2]. Surfactant molecules have considerable variation in aqueous or organic miscibility relative to their structure and molecular weight. Thus, organic/organic and organic/aqueous

systems [3] can exist in multiphase states in certain conditions.

In solution-type waterborne or solventborne coatings, a blend of organic solvents is frequently used. The composition of this blend will vary with the individual formulation. Solvents of the alcohol or glycol ether type are often incorporated into waterborne coating systems because many of these have an appreciable degree of water miscibility over a rather wide temperature range. Organic solvents have several functions in aqueous coating systems, one of which is to serve as coupling agents for the water-insoluble organic phases. Performance of the cosolvent composition by way of the foregoing function of coupling can provide a number of desirable properties when the solvent system is properly balanced.

## Functions of Organic Solvents in Waterborne Coatings

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- Solubilize the resin
- Improve flow properties
- Maintain homogeneity through coupling
- Control evaporation characteristics
- Keep the film open
- Control solution viscosity
- Provide desirable rheology

## Experimental

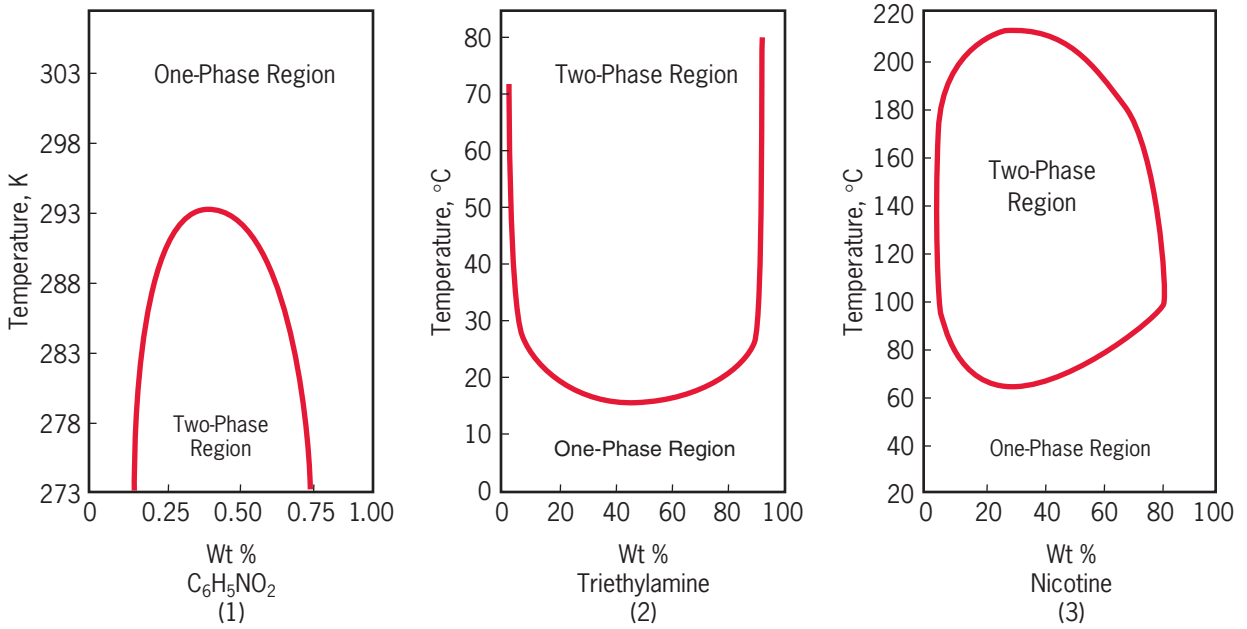
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The multiphase models chosen for this study consisted primarily of organic solvent/aqueous mixtures. Each organic phase exhibited a low degree of aqueous miscibility, thus resulting in a two-phase, layered state when combined with water. The goal of the experiment was to convert a multiphase system to a homogeneous, clear mixture with minimal use of a coupling agent. This minimal use is generally stressed from an economic vantage point, although there may be other reasons for restricting the level of coupling agent (for example, control of evaporation of the volatile components).

The coupling agents evaluated were members of the alkyl alcohol and glycol monoether class of organic solvents. The term *cosolvent* in this publication refers to the coupling agent under evaluation. *Organic phase* is used in describing the phase having a limited degree of aqueous miscibility. Particular cosolvents have inherently limited miscibility with aqueous components under elevated, or perhaps reduced, temperatures (Figure 2). In such cases, the cosolvent may assume the role of the organic phase, and in fact, another water-soluble cosolvent may need to be added to promote coupling at elevated temperatures (Figure 3).

Figure 1

**Three Multiphase Systems That May Require a Coupling Agent at Some Temperatures and Not at Others**



Multiphase Systems: (1) n-hexane + nitrobenzene, (2) triethylamine + water, (3) nicotine + water

Figure 2

**Limiting Effect of Temperature on Miscibility**

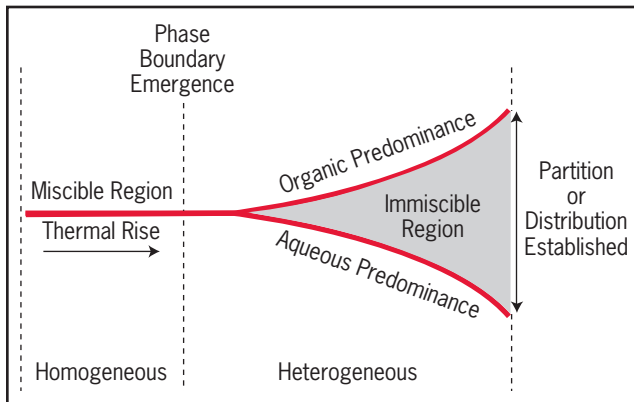
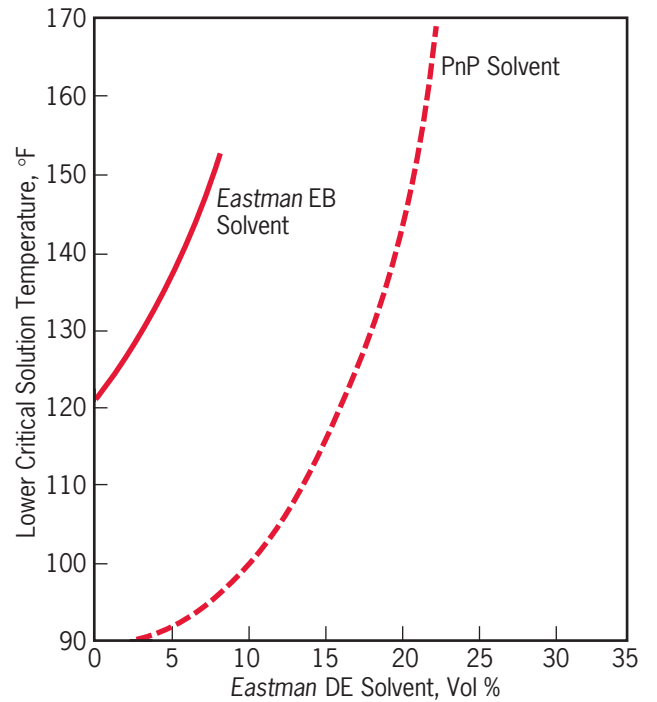


Figure 3

**Effect of Second Water-Soluble Cosolvent on Coupling**



After the multiphase model and coupling agent candidates were selected, the (1) experimental apparatus, (2) temperature range, (3) concentration level of organic phase to water, and (4) method of calculation suitable for comparing the coupling agents were chosen.

Erlenmeyer flasks, 50-milliliter burettes, magnetic stirrers, and pipettes were among the experimental apparatus. The components of the multiphase model were volumetrically pipetted into the Erlenmeyer flask. The coupling agent was placed in the 50-milliliter burette and slowly added to the multiphase model under moderate agitation until a single clear, homogeneous composition formed. A bright light viewed through the solution being titrated sometimes aided in the detection of the end point. Absence of haze was generally preferred. The total volume of coupling agent added to achieve this visual end point was tabulated to be used in future relative efficiency calculations.

For obtaining coupling data under elevated temperatures, a suitable apparatus must be available for performing titrations at higher-than-ambient temperatures. Titrations at reduced temperatures must likewise be adapted. Adequate time should be allowed for the temperatures of the coupling agent and the multiphase system to be brought into equilibrium. Heats of solution, whether endothermic or exothermic, must be dissipated. The predominant number of measurements were made at ambient temperature, with mild agitation being present throughout the

titration process. Evaporation losses during titration were minimized. In some cases, solutions were stored overnight before a decision was made as to the validity of the end point.

Concentration ranges of organic phase to aqueous phase were prepared in volume percent ratios, as noted in respective examples of the systems evaluated and discussed in this publication. In many instances, the concentration range of organic-to-aqueous component was shifted from 100/0 to 0/100 in 10 vol % increments. When comparison of coupling-agent behavior for a variety of organic phases was the purpose of the experiment, a single ratio of 50/50 (organic to aqueous) concentration level was used.

The method of calculation for comparing the behavior of the coupling agent was defined in the following manner:

$$\Delta = \left[ \frac{V_x}{V_{mp} + V_x} \right] 100 \quad \text{or} \quad \Delta = \left[ \frac{V_x}{V_{P1} + V_{P2} + V_x} \right] 100$$

where:  $\Delta$  = coupling number of the respective coupling agent for a given set of experimental conditions

$V_x$  = mL of coupling agent added to obtain the end point

$V_{mp}$  = mL of the multiphase model at initiation of the titration procedure

$V_{P1}$  = mL of phase 1 of the multiphase model

$V_{P2}$  = mL of phase 2 of the multiphase model

# Structural Characteristics

In evaluating relative coupling efficiency of a series of coupling agents, the effect of the characteristics of the organic phase was determined. A selected list of aqueous insoluble organic phases was compiled (Table 1). Each organic phase was combined with distilled water at a fixed volume ratio of 50/50, resulting in the two-phase composition. The polar and nonpolar characters of the organic phases differed among the samples. The more nonpolar phases (mineral spirits and *Aroplaz* 1351 resin)

were most efficiently coupled using EB solvent. Ketone solvents and aromatic hydrocarbons, likewise, were among the classes of organic phase models incorporated. EP and EGEE solvents were better coupling agents for the more polar phases, as evidenced by the reduced value of the calculated  $\Delta$  value. Organic phases having an inherent degree of aqueous solubility required the least amount of respective coupling agent to achieve a single phase system.

Table 1

**Coupling Efficiency of Glycol Ether Solvents for Immiscible Organic/Aqueous (50/50) Phases**

Organic Phase	Vol % Giving Miscibility					
	Ethylene Glycol Monoethers					Propylene Glycol Monoether
	Methyl (EGME)	Ethyl (EGEE)	Propyl (EP)	Butyl (EB)	Hexyl (EH)	Propyl (PnP)
Toluene	—	54.5	52.4	63.6	—	73.3
Isobutyl Isobutyrate	64.5	55.6	50.0	61.6	77.8	70.0
2-Ethylhexyl Acetate	—	55.6	45.9	58.3	—	70.6
Mineral Spirits	>83.0	80.0	70.5	57.5	77.0	71.0
Methyl n-Amyl Ketone	—	41.2	41.2	55.6	—	66.7
Ethylene Glycol Diacetate	24.5	23.1	16.7	21.6	70.0	31.0
<i>Texanol</i> Solvent	51.8	45.0	45.1	58.1	75.8	—
<i>Aroplaz</i> 1351 Resin <sup>a</sup>	—	>83.0	74.0	57.0	—	62.3

<sup>a</sup>Reichhold

For the more polar phases, EP solvent was a more efficient coupling solvent than PnP solvent. The degree of solubility of the coupling agent in the organic phase and the aqueous phase was thus an important consideration [4]. The coupling ability of a given cosolvent is related to the manner in which the cosolvent partitions among the multiphase components.

Solvent models with a polar or an aromatic character preferred EGEE or EP solvents.

The  $\Delta$  values could thus in a realistic sense attain the range of  $0 < \Delta < 100$ . Coupling agents were found most frequently to have  $\Delta$  values between 25 and 75. Although coupling numbers were “unitless” values, their magnitude reflected the efficiency of the coupling agents. The reflection was inverse. High  $\Delta$  values signified a cosolvent that was classified as a relatively “poor” coupling agent for the particular temperature and multiphase model under scrutiny. Conversely, a substantially reduced  $\Delta$  value translated to an “excellent” coupling agent.

# Water Miscibility

The water miscibility of certain glycol monoether coupling agents has been shown to be a function of (1) temperature, (2) concentration, and (3) molecular structure of the cosolvent [5]. When coupling activity is measured under ambient conditions, most couplers evaluated can be considered to possess complete aqueous miscibility (Table 2). Exceptions do exist within the isomeric butyl alcohols and among particular glycol monoether acetates. EB solvent, a frequently used coupling agent for nonpolar organic phases, has restricted water miscibility above 122°F (Figure 4).

The temperature dependence of water solubility of a coupling agent should be well defined if the coupling agent is to be operative over an extended temperature range. Otherwise, surprising results may emerge at an inopportune time and place. The components of a waterborne paint, although properly coupled in the paint, may not remain coupled when the coating is applied to a preheated substrate or passed through a baking oven at the processing plant.

Nonpolar components were coupled most easily by adding EB solvent. Matching the polarity of the coupling agent with that of the multiphase composition appeared to be an important consideration. The polarity of the coupling agent can be altered by blending the various cosolvents or by logical choice of chemical structure.

An extensive series of coupling solvent compositions are compared in Table 3 on page 9. Polar and nonpolar organic phases were represented by isobutyl isobutyrate (IBIB) and mineral spirits, respectively. The addition of any water-insoluble solvent fraction would be expected to reduce the coupling efficiency of the EB solvent.

Table 2

**Miscibility of Glycol Ethers and Water at Varying Temperatures (20% Glycol Ether/80% Water)**

Glycol Ether	Miscibility	
	21°C (70°F)	77°C (170°F)
EGME Solvent	Miscible	Miscible
EGEE Solvent	Miscible	Miscible
Eastman EB Solvent	Miscible	Immiscible
Eastman DM Solvent	Miscible	Miscible
Eastman DE Solvent	Miscible	Miscible
Eastman DB Solvent	Miscible	Miscible
PnP Solvent	Miscible	Immiscible

Figure 4

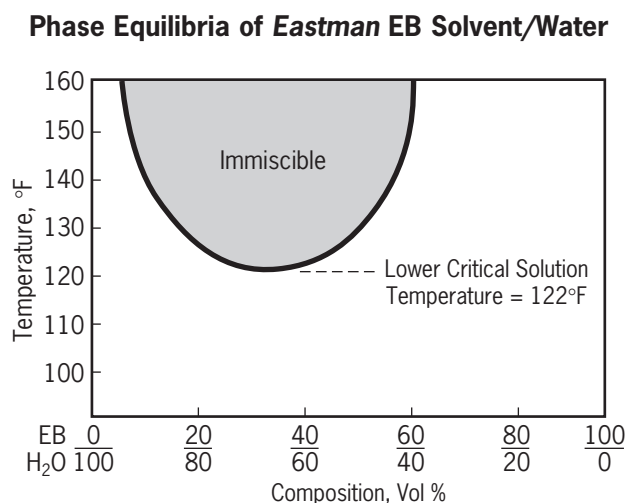


Table 3

## Coupling Efficiency

Coupling Solvent	Vol % to Couple 50/50 Mixture		Coupling Solvent	Vol % to Couple 50/50 Mixture	
	Mineral Spirits/ H <sub>2</sub> O	IBIB/ H <sub>2</sub> O		Mineral Spirits/ H <sub>2</sub> O	IBIB/ H <sub>2</sub> O
EGME Solvent	89	64.5	<i>Eastman EB solvent plus 30 vol % of the following solvents:</i>	Methyl Alcohol	74 54
EGEE Solvent	80	55.6		Tecsol C (anhy) Ethyl Alcohol	65 55.5
<i>Eastman EP Solvent</i>	70.5	50		n-Propyl Alcohol	60 60
<i>Eastman EB Solvent</i>	57.5	61.6		n-Butyl Alcohol	64 64.3
EH Solvent	77	77.8		n-Pentyl Alcohol	69 68.7
<i>Eastman DM Solvent</i>	92	68.7		n-Hexyl Alcohol	72 71.8
<i>Eastman DE Solvent</i>	86	60.8		t-Butyl Alcohol	58 60.8
<i>Eastman DP Solvent</i>	78	51.2		EGME Solvent	71 55.6
<i>Eastman DB Solvent</i>	68	41.2		EGEE Solvent	65 53.5
DH Solvent	61.5	63		<i>Eastman EP Solvent</i>	58 56.5
<i>Eastman PM Solvent</i>	80	56.5		<i>Eastman EB Solvent</i>	57.5 61.6
PnP Solvent	71	70		EH Solvent	65.5 67.2
PnB Solvent	81	81.8		<i>Eastman DM Solvent</i>	— 56.5
DPM Solvent	79	61.6		<i>Eastman DE Solvent</i>	— 53.5
Methyl Alcohol	>85	60		<i>Eastman DP Solvent</i>	— 52.4
Tecsol C (anhy) Ethyl Alcohol	80	50		<i>Eastman DB Solvent</i>	— 55.6
n-Propyl Alcohol	67	55.6		DH Solvent	— 63.0
n-Butyl Alcohol	78	75.9		EGEEA	64 —
n-Pentyl Alcohol	>85	>83.3		Ethylene Glycol Diacetate	69 —
n-Hexyl Alcohol	>85	>83.3		2-Ethylhexyl Acetate	75 —
t-Butyl Alcohol	61.5	60		IBIB	79 —
EGEEA	>85	—		Tecsol C (anhy) Ethyl Alcohol/ n-Propyl Alcohol, 50/50	63 —
<i>Eastman DE Acetate</i>	83	—		Tecsol C (anhy) Ethyl Alcohol/ n-Butyl Alcohol, 50/50	57.5 —
Ethylene Glycol Diacetate	>85	—	Tecsol C (anhy) Ethyl Alcohol/ t-Butyl Alcohol, 50/50	59.2 —	
2-Ethylhexyl Acetate	>85	—	n-Propyl Alcohol/ n-Butyl Alcohol, 50/50	61.5 —	
IBIB	>85	—	n-Propyl Alcohol/ t-Butyl Alcohol, 50/50	57.5 —	
Acetone	—	67.7	n-Butyl Alcohol/ t-Butyl Alcohol, 50/50	57.5 —	
Methyl Ethyl Ketone	—	>83.3			
Methyl-n-Propyl Ketone	—	>83.3			
Methyl-n-Amyl Ketone	—	>83.3			

# Concentration Relationship

The structural characteristics of the multiphase model components were shown to influence the choice of coupling agent most appropriate for the biphase system. A series of experiments examined the concentration relationship within the multicomponent system. Systems were prepared with relative amounts of organic phase to aqueous phase present during the selection of the coupling agent. The test model selected was 2,2,4-trimethylpentanediol-1,3-monoisobutyrate/water system. The volumetric concentration of this system was varied at 90/10, 75/25, 50/50, 25/75, and 10/90 levels. Each composition was titrated with the specified coupling agents.

The  $\Delta$  values were plotted on ternary phase diagrams (Figures 5, 6, and 7) and then connected to generate the ambient-temperature phase boundary displayed in each figure. The region below each curve represents a multiphase region, or immiscible compositions. The region above each curve represents single-phase, homogeneous mixtures, or miscible systems. The phase boundary depicts the compositions at which coupling occurs for various ratios of organic to aqueous phases.

Curve crossing was evident among coupling agents, revealing that the ratio of organic phase to water

must be considered during the selection of the cosolvent. There was obviously greater difference between coupling agents in regions of high aqueous concentration. The curves spread apart from left to right on each ternary diagram (Figures 5 and 6). Diethylene- and ethylene-glycol-based monoethers of the same alkoxy moiety possessed very similar coupling efficiency numbers (Figure 7). In the high aqueous regions, a change in the alkoxy moiety significantly altered the efficiency of the coupling agent.

Figure 6

**Relative Efficiency of Diethylene-Glycol-Based Monoethers**

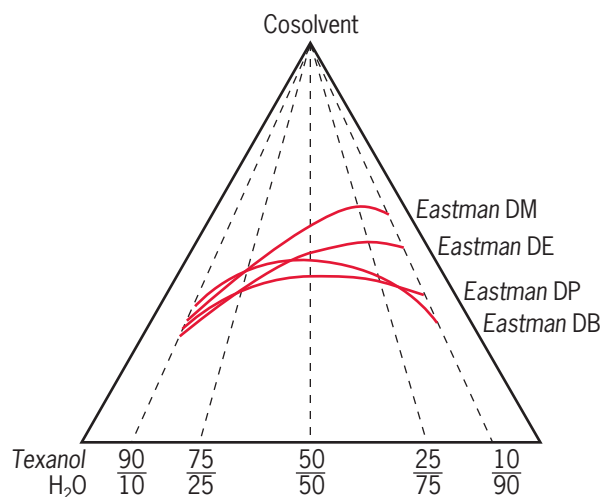


Figure 5

**Relative Efficiency of Ethylene-Glycol-Based Monoethers**

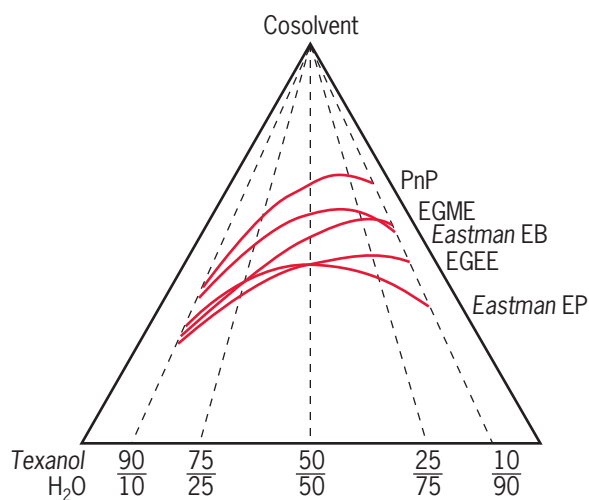
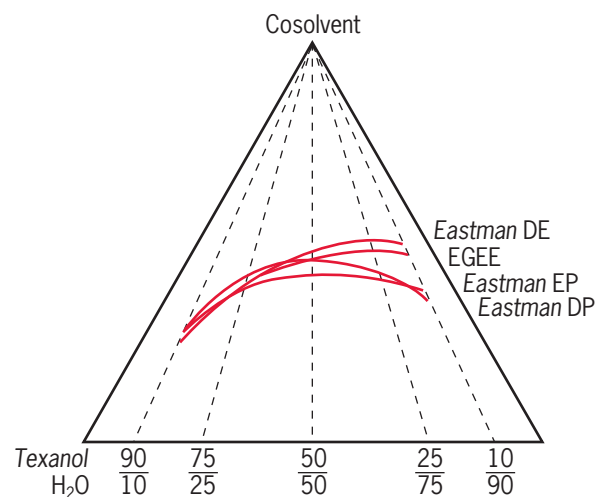


Figure 7

**Effect of Alkoxy Group vs. Type of Glycol Base**



# Blends of Coupling Agents

Often, blends of cosolvents offered advantages that could not be obtained using a single coupling agent. The coupling efficiency of EB solvent was modified by adding 30 vol % of a homologous series of alkyl alcohols (Figure 8). The effect on coupling efficiency was not necessarily positive, as can be seen with the multiphase models of mineral spirits or IBIB combined with water. The coupling activity of EB solvent for IBIB was enhanced by adding 30 vol % of *Tecsol C* anhydrous proprietary ethyl alcohol solvent to the cosolvent portion of the mixture.

Two cosolvents, each contributing relatively poor coupling ability when used alone, were combined at a select volume ratio. Their mixture displayed exceptionally good coupling activity. A 50/50 volume mixture of EGEE solvent and EH solvent produced approximately the same coupling activity as EB solvent for the multiphase model of mineral spirits and distilled water (Figure 9). It was suspected that, for this phenomenon to occur, the “partition preference” of each cosolvent between the organic phase and the water phase must be in direct opposition.

This principle is employed in the development of surfactant molecules having various levels of hydrophilic and hydrophobic nature within the same chemical structure. One component of the cosolvent blend should prefer the aqueous phase, and the other should prefer the organic phase. In the case demonstrated in Figure 9, EGEE solvent preferred the water, and EH solvent preferred the mineral spirits (as revealed by a study of partition preference data discussed later).

Figure 8

**Effect of Chain Length of Alkyl Alcohol on Coupling Efficiency**

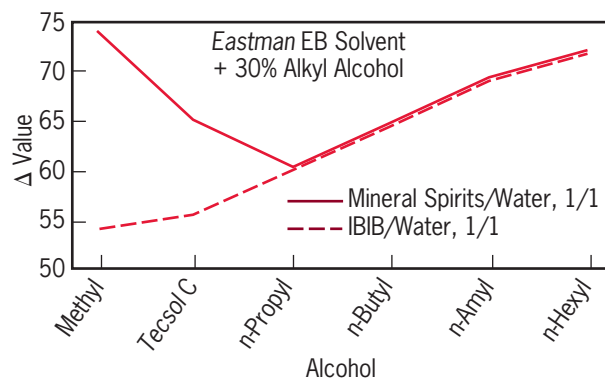
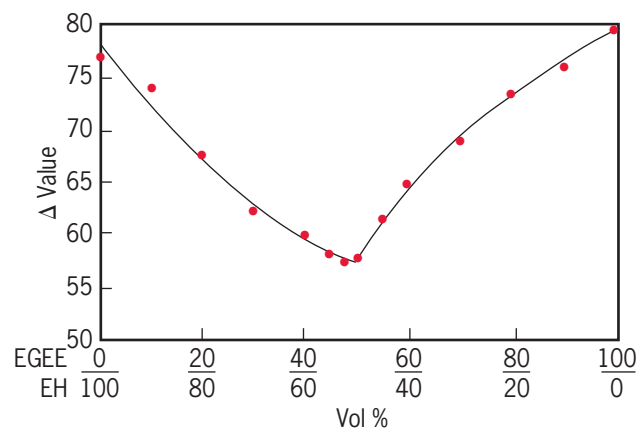


Figure 9

**Coupling Efficiency of EGEE/EH for Mineral Spirits/Water, 1/1**



# Thermal Influence

Thermal rise might be expected to enhance the ability of the coupling agent to operate efficiently. The thermal influence assumed positive and negative deviation modes (Figure 10). In some cases, heat improved the coupling activity, but in others, efficiency was markedly reduced (Table 4). EGEE solvent, when coupling a 50/50 volume ratio of mineral spirits and water, improved efficiency as the temperature varied from 21° to 66°C (70° to 150°F). EB solvent for the same multiphase model showed a decline in coupling activity as the temperature of the system was raised. This loss of efficiency was correlative to the diminished water solubility [4] of EB solvent at temperatures above 50°C (122°F), its lower critical solution temperature. DE solvent showed a dramatic efficiency increase

(drop in the  $\Delta$  value) when used to couple the multiphase system of IBIB/water at the 50/50 volume ratio. DB solvent showed an opposite effect of almost an identical numerical shift in the  $\Delta$  value (Table 5).

Figure 10

## Thermal Influence on Coupling

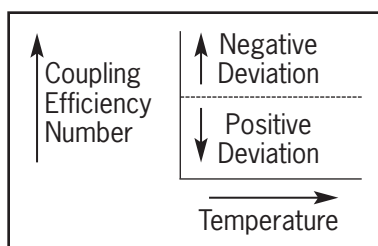


Table 4

### Effect of Temperature on the Coupling Efficiency of Glycol Ethers for Mineral Spirits/Water (50/50) Mixture

Coupling Solvent	Vol % Giving Miscibility @			
	21°C (70°F)	38°C (100°F)	52°C (125°F)	66°C (150°F)
EGME Solvent	>83	>83	>83	>83
EGEE Solvent	80.0	78.7	77.3	76.5
Eastman EP Solvent	70.5	71.0	71.8	72.2
Eastman EB Solvent	57.5	63.0	64.9	66.1
EH Solvent	77.0	80.4	81.5	81.8
PnP Solvent	71.0	74.7	75.9	76.2
Eastman DM Solvent	NA <sup>a</sup>	NA	NA	NA
Eastman DE Solvent	>83	>83	>82.8	>81.5
Eastman DP Solvent	78.3	78.3	76.5	75.0
Eastman DB Solvent	67.7	71.0	71.0	71.8
DH Solvent	61.5	67.7	70.6	73.3
Eastman EB Solvent	57.5	63.0	64.9	66.1
Eastman EB Solvent/n-Butyl Alcohol, 70/30	64.9	67.7	69.7	70.1
Eastman EB Solvent/Eastman DE Solvent 70/30	63.6	63.6	62.3	61.5

<sup>a</sup>Not Available

Table 5

**Effect of Temperature on the Coupling Efficiency of Glycol Ethers  
for IBIB/Water (50/50) Mixture**

Coupling Solvent	Vol % Giving Miscibility @			
	21°C (70°F)	38°C (100°F)	52°C (125°F)	66°C (150°F)
EGME Solvent	64.5	64.3	63.0	60.8
EGEE Solvent	56.5	53.5	51.2	48.7
Eastman EP Solvent	50.0	50.0	51.2	53.5
Eastman EB Solvent	61.5	64.9	64.9	65.5
EH Solvent	77.8	79.6	81.1	82.0
PnP Solvent	70.0	73.3	74.0	74.7
Eastman DM Solvent	NA <sup>a</sup>	NA	NA	NA
Eastman DE Solvent	60.8	60.8	56.5	44.4
Eastman DP Solvent	51.2	51.2	47.4	47.4
Eastman DB Solvent	41.2	51.2	55.6	59.2
DH Solvent	63.0	71.0	72.6	73.3

<sup>a</sup>Not Available

## Partition/Distribution Tendency

When a coupling agent is placed in a multiphase system, it will selectively partition between the organic and aqueous phases. The cosolvent's affinity for each phase determines the partition preference of the cosolvent in the system. If the cosolvent is miscible with the organic phase and water in all proportions, then, as small amounts are added, it will be distributed between the two phases [6]. Thus, two ternary solutions consisting of cosolvent, organic phase, and water are in equilibrium with one another, provided the gross composition of the mixture resides in the immiscible region of the phase diagram. As additional cosolvent is added, the two ternary phases become more similar, and the "tie lines" of the system become shorter. At the critical point, the compositions of the two solutions become identical, resulting in the formation of a single homogeneous phase at the phase boundary.

In studying the relationship between partition preference and coupling efficiency experiments, a small amount of the cosolvent (premature to the

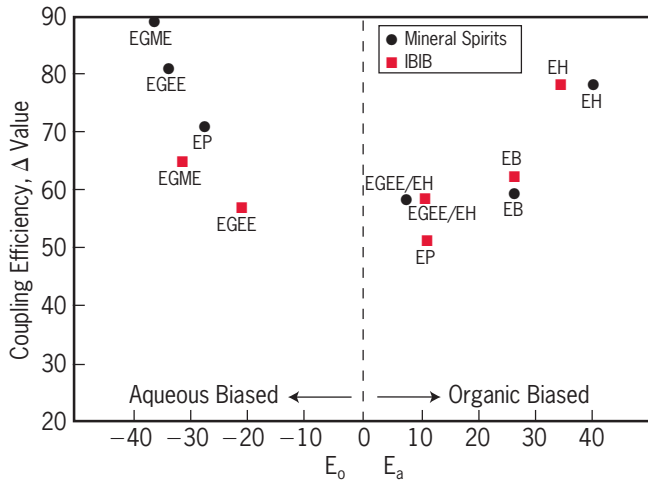
$\Delta$  value) was added to the organic/aqueous two-phase system in question.

After the cosolvent had distributed itself between the two phases, the phases were separated and gas chromatography was used to measure the concentration of coupling agent in each phase. The concentrations of the glycol ether in the organic and the aqueous phases were designated as  $E_o$  and  $E_a$ , respectively. The mathematical difference ( $E_o - E_a$ ) represented the partition preference value. A positive value for  $E_o - E_a$  represents a solvent that prefers the organic phase and is thus referred to as *organic biased*; a negative value represents a cosolvent that prefers the aqueous phase and is referred to as *aqueous biased*. If the value is zero, the cosolvent is partitioned in approximately equal amounts to both phases.

Graphical representation of partition preference numbers versus coupling efficiency numbers for various ternary systems is shown in Figures 11, 12, and 13.

Figure 11

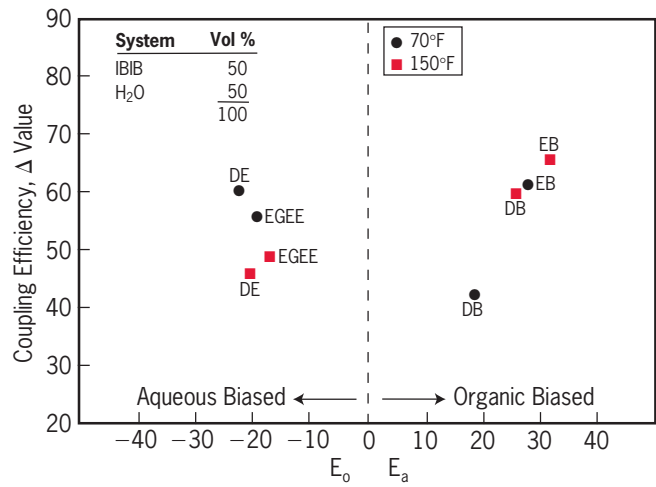
**Coupling Efficiency vs. Distribution for Glycol Ethers**



$E_o$  = Glycol ether in organic phase, wt %  
 $E_a$  = Glycol ether in aqueous phase, wt %  
 EGEE/EH = 50/50 Volume blend

Figure 13

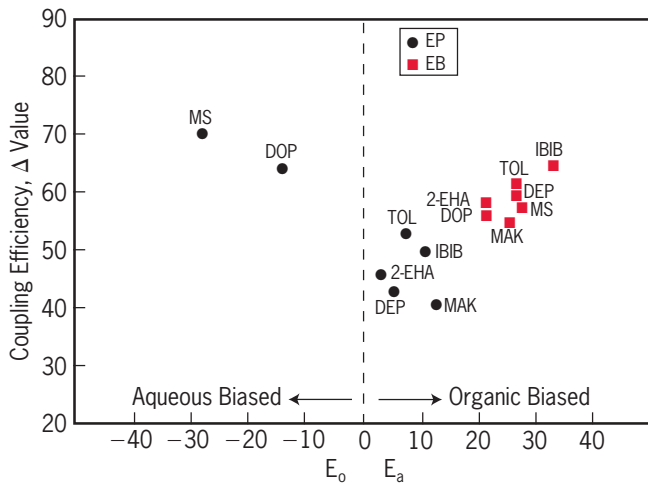
**Temperature Effect on Coupling Efficiency vs. Distribution**



$E_o$  = Glycol ether in organic phase, wt %  
 $E_a$  = Glycol ether in aqueous phase, wt %

Figure 12

**Coupling Efficiency vs. Distribution for Organic Phase**



$E_o$  = Glycol ether in organic phase, wt %  
 $E_a$  = Glycol ether in aqueous phase, wt %  
 MS = Mineral spirits  
 DOP = Dioctyl phthalate  
 TOL = Toluene  
 IBIB = Isobutyl isobutyrate  
 2-EHA = 2-Ethylhexyl acetate  
 DEP = Diethyl phthalate  
 MAK = Methyl amyl ketone

# Conclusion

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As a result of this study, the following concepts regarding coupling agents have been formed:

- In aqueous/organic systems, inherent water miscibility of all phases must be considered over the temperature range of interest.
- The chemical nature of the multiphase ingredients must be understood in terms of their degree of polar versus nonpolar character.
- The concentration relationship within the multiphase composition must be evaluated over the range encountered in the end-use application. Because of the presence of curve-crossing tendencies, blends of cosolvents may prove to be more appropriate than a single coupling agent.
- The temperature range over which the coupling agent must function should be tested. Some agents will improve in efficiency with an increase in temperature while others lose efficiency.
- Partition data should be correlated with the generation of coupling efficiency numbers because partition preference may explain many observations gained from coupling data that would otherwise remain a mystery.
- The principles considered in the selection of a coupling agent must be balanced against the other performance factors and economics required of the total system.

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