

Class I Spray Foams for Wall Insulation Application using R-245fa

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ABSTRACT

Formulating HFC-245fa blown wall spray systems poses numerous challenges to formulators. The three greatest challenges are dealing with the high vapor pressure of this material, achieving ASTM E84 Class I rating at 4.0 inches, and the prohibitive cost. We propose to solve these issues by limiting the loading of HFC-245fa to 8% of the B-side. The remaining blowing agent will be water. By doing so we will introduce dimensional stability and flammability issues into the system.

In order to create a dimensionally stable, ASTM E84 Class I rated system with only 8% HFC-245fa in the B-side we needed to approach the problem from a new direction. We will show how increasing the overall functionality of the polyol mixture improves dimensional stability in the presence of increased water levels. Also, since higher loadings of the polyester polyol are required to achieve ASTM E84 Class I rating, a new high functionality polyol was developed and tested.

INTRODUCTION

At the end of 2004, the polyurethane industry was forced to discontinue use of HCFC-141b as a blowing agent. There are several possibilities to replace HCFC-141b. For interior wall spray applications, the most logical alternative is HFC-245fa. With HFC-245fa there is no need for costly equipment modifications, as with pentanes or gaseous blowing alternatives.

However, this particular blowing agent poses many challenges to polyurethane (PU) formulators. The most fundamental problem that arises from HFC-245fa formulating is the low boiling point of this material, less than 60°F. The low boiling point causes problems with

material handling and vapor pressure in drums. While the lack of chlorine and additional carbon/hydrogen content helps reduce global warming potential and ozone depletion, it diminishes the fire properties of the molecule with respect to HCFC-141b. Another drawback of this material is the cost. HFC-245fa is appreciably more expensive than HCFC-141b.

Table 1. Blowing Agent Properties [1]

	HCFC-141b	HFC-245fa
Molecular Formula	CCl ₂ FCH ₃	CHF ₂ CH ₂ CF ₃
Molecular Weight (g/mol)	117	134
Boiling Point (°C)	32.2	15.3
Vapor Pressure at 20°C (PSIA)	10.0	17.8
Vapor Pressure at 54°C (PSIA)	29.9	56.3

In this study we will limit the loading of HFC-245fa to 8-9% of the total resin blend. The remaining blowing agent will be water. By limiting the loading of HFC-245fa we solve issues with vapor pressure. However, by replacing the HFC-245fa with water we introduce dimensional stability issues.

One mole of water reacts with two moles of isocyanate to produce a polyurea and one mole of CO₂, which in turn blows the foam. Water is very efficient in lowering foam density. However, in the presence of large amounts of CO₂ problems with dimensional stability occur. If the polyurethane matrix lacks significant resistance to CO₂ diffusion, while possessing relatively good resistance to air infiltration, cell collapse usually occurs.

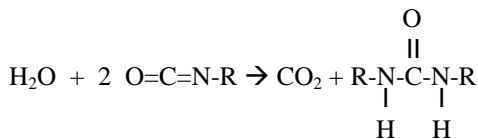


Figure 1. Isocyanate – water reaction

In PU foams with significant amounts of CO₂ generated foam cells experience a loss of internal pressure as the CO₂ escapes and nothing displaces its volume. If the cell matrix is not sufficiently strong, the result will be major cell collapse. With time the external air will slowly diffuse into the cells restoring the initial volume [2].

In this paper we propose to solve this problem by using a higher functional polyol mixture. The increased crosslinking is used to prevent major cell collapse and thus produce a dimensionally stable system. Furthermore, we will introduce a new Terol polyol with higher functionality that allows for greater polyester loading than current technology provides.

DIMENSIONAL STABILITY

Screening for the optimal polyol mixture to yield a dimensionally stable system was done with laboratory samples. Laboratory conditions sometimes included lower catalyst levels and cooling samples below room temperature. Samples were mixed with a commercial drink mixer and poured into cake boxes. The samples

were cured 1 day before cutting. Samples were aged in a humidity cabinet, 158°F and 95% relative humidity, for only 1 day. In our experience the first few days are the critical period as to whether the foam sample will pass or fail.

We initially attempted to fit HFC-245fa into similar technology as one would use with HCFC-141b. However, as all formulators soon realized HFC-245fa was not a direct drop-in for HCFC-141b. The limiting parameter of 8% HFC-245fa required a closer examination of the effect of CO₂ on dimensional stability.

Our initial studies on the effect of CO₂ toward dimensional stability utilized the CO₂ to HFC-245fa molar ratio. Theoretically one mole of water will produce one mole of CO₂; it is therefore possible to calculate the theoretical molar ratio. The following figure shows the calculation used to determine this quantity:

$$\text{mole CO}_2 / \text{mole HFC-245fa} = (\text{pbw H}_2\text{O} / 18 \text{ g}^*\text{mol}^{-1}) / (\text{pbw HFC-245fa} / 134 \text{ g}^*\text{mol}^{-1})$$

Figure 2. Molar ratio calculation

The following table shows the effect of increasing the CO₂ to HFC-245fa molar ratio on dimensional stability in the humidity cabinet after 1 day.

Table 2. Effect of CO ₂ :HFC 245fa Molar Ratio on Dimensional Stability					
Formulations	Pbw 1	Pbw 2	Pbw 3	Pbw 4	Pbw 5
Terol 256, f = 2.3	45.00	45.00	45.00	45.00	45.00
Jeffol R-466X, f = 3.3 ¹	45.00	45.00	45.00	45.00	45.00
Sucrose Polyether, f = 4.7	10.00	10.00	10.00	10.00	10.00
RB-79 / TMCP ²	20.00	20.00	20.00	20.00	20.00
Surfactant	1.60	1.60	1.60	1.60	1.60
Catalysts	7.00	7.00	7.00	7.00	7.00
Index	1.15	1.15	1.15	1.15	1.15
Nominal Functionality of Resin	2.97	2.97	2.97	2.97	2.97
Average Core Density (pcf)	2.0	2.0	2.0	2.0	2.0
CO ₂ :HFC-245fa Molar Ratio	1.4	1.6	1.8	2.0	2.4
%Shrinkage in Humid Chamber	3	4	5	16	21

All experimental parameters were held constant except HFC-245fa and water levels. In doing so, only the effects of the molar ratio were measured. As one would expect the greater the CO₂ to HFC-245fa molar ratio the more pronounced the distortion in the humidity chamber.

To achieve an applied density of 2.0 pcf while maintaining only 8% loading of HFC-245fa the water loading needs to be 2.6%. This level of blowing agents results in a bench free rise density of 1.6 pcf. Also, this loading level results in a CO₂ to HFC-245fa molar ratio of 2.4. As seen in table 2, a molar ratio of 2.4 causes major distortion of the sample when the polyol loading levels are similar to HCFC-141b technology.

The overall functionality of the system plays an important role in the strength and stability of the system. In systems with high CO₂ to HFC-245fa molar ratios the crosslinking and crosslinking density of the system are two of the critical factors in determining whether the system will pass or fail the humid chamber. There are only two ways to increase the functionality of the system: increase functionality of the isocyanate or increase the functionality of the resin. Changing to a higher functional isocyanate would result in a higher viscosity; so we decided to take a cursory look at this option. Changing the nominal functionality of the resin is much easier to do, and we decided to examine this option more closely.

For the discussion about changing nominal functionality of the resin we will only consider the contributions of the polyols. For simplicity we will leave out contributions from other reactive and non reactive species present. As long as the formulations do not change appreciably we feel this assumption is valid. Functionality was calculated on a molar basis. In order to change the functionality of the resin we must change the types and proportions of the polyester, the sucrose and the mannich polyols.

The polyesters for this study were chosen for high aromatic content and high functionality. Terol 256 was originally developed for pour-in-place applications where higher polyester loading was necessary for improved fire properties.

OH (mg KOH/g)	265
Viscosity at 25°C (cps)	11000
Nominal Functionality	2.30
HFC-245fa Solubility	21%

Commercially available mannich polyether polyols range in functionality from 3 to 4. In terms of contribution to overall functionality of the system, changing to a high functional mannich polyol offers little in return. Typically, higher functional mannich polyols are often limited by high viscosity. For these reasons we looked at two common mannich polyols: Jeffol R-466X and Jeffol R-425X.

	Jeffol R-466X	Jeffol R-425X
OH (mg KOH/g)	470	425
Viscosity at 25°C (cps)	11000	4500
Nominal Functionality	3.30	3.20

In our preliminary investigations, we looked at a glycerin initiated sucrose polyol such as R-360 which has a functionality of 4.7 and manageable viscosity of 4500 cps. However, during the course of our investigation we decided to look at higher functional sucrose polyols and higher than normal loadings. With sucrose polyols it is possible to increase the overall functionality of the system to a greater degree than by changing the polyester or the mannich polyols.

In a subsequent experiment we decided to confirm the effect of increasing the sucrose loading on the dimensional stability of the foam. The following table shows the experiment that we conducted:

Formulations	Pbw 1	Pbw 2	Pbw 3
Terol 256, f = 2.3	45.00	45.00	45.00
Jeffol R-466X, f = 3.3 ¹	45.00	45.00	45.00
Sucrose Polyether, f = 4.7	5.00	10.00	15.00
RB-79 / TMCP ²	20.00	20.00	20.00
Surfactant	1.60	1.60	1.60
Catalysts	7.00	7.00	7.00
Index	1.15	1.15	1.15
CO ₂ :HFC-245fa Molar Ratio	1.9	1.9	1.9
Average Core Density (pcf)	2.0	2.0	2.0
Average Functionality	2.91	2.97	3.02
%Shrinkage in Humid Chamber	7	5	4

As with the previous experiment, all parameters were held constant as the level of sucrose was changed from 5 parts by weight to 15 parts by weight. The nominal functionality changed from 2.91 to 3.02. The result of this experiment confirmed what we expected: higher nominal functionality diminished shrinkage in the humidity cabinet. In this experiment the molar ratio of CO₂ to HFC-245fa was only 1.9. As mentioned before, the molar ratio needs to be 2.4 to have an applied density of 2.0 pcf.

To overcome the dimensional stability problems at a 2.4 molar ratio we needed to use a higher than normal sucrose loading or a higher functional sucrose. We decided to explore both options as they would allow us to increase polyester loading relative to the mannich polyol. Our investigations led us to a sucrose polyol with a nominal functionality of 7. Due to the higher functionality the viscosity of this material increased to 31,000 cps

To determine the optimal combination of polyols we used a laboratory screening process. We used the full loading of blowing agents to get low density so as to exaggerate the effects of the humidity cabinet. Table 6 summarizes the results from our screening experiments:

Sample number 1 was our control system; it most closely represents a HCFC-141b system. The blowing level was 12% HFC-245fa and 1.9% water. At the lower water level the system performed well after 1 day age in the humidity cabinet. However, 12% HFC-245fa is not feasible, as the vapor pressure in the drums will be too high.

At 8% HFC-245fa and 2.7% water, to get a minimal pass we needed to have a nominal functionality above 3 and a sucrose loading above 13% of the resin. Best dimensional stability data was obtained when sucrose loading was at least 20% and polyester loading was below 40%. In order to get optimal fire performance we decided to increase sucrose loading at the expense of the mannich polyol, not the polyester.

Using these findings we developed the formulation permutations for the ASTM E84 trials.

Table 6. Dimensional Stability Screening, Overview

Formulations	Pbw 1	Pbw 2	Pbw 3	Pbw 4	Pbw 5	Pbw 6	Pbw 7	Pbw 8	Pbw 9
Terol 256	29.48	40.75	40.75	40.75	47.54	44.14	37.35	27.16	44.14
Jeffol R-425X ¹	29.48	13.58	10.19	6.79	10.19	16.98	20.37	30.56	6.79
Sucrose polyol, f = 7	6.55	13.58	16.98	20.37	10.19	6.79	10.19	10.19	16.98
Surfactant	0.98	1.02	1.02	1.02	1.02	1.02	1.02	1.02	1.02
RB-7001 ²	13.10	13.58	13.58	13.58	13.58	13.58	13.58	13.58	13.58
TMCP ²	3.28	3.40	3.40	3.40	3.40	3.40	3.40	3.40	3.40
Catalysts	3.01	3.12	3.12	3.12	3.12	3.12	3.12	3.12	3.12
Water	1.90	2.72	2.72	2.72	2.72	2.72	2.72	2.72	2.72
a-methyl styrene	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
HFC-245fa ³	12.12	8.15	8.15	8.15	8.15	8.15	8.15	8.15	8.15
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Nominal Functionality of B-Component	2.97	2.99	3.08	3.18	2.81	2.78	2.96	3.10	3.03
Index	1.16	1.04	1.04	1.04	1.05	1.04	1.03	1.00	1.05
M20 ⁴	103.96	102.47	102.29	102.11	101.45	102.23	103.24	105.01	101.69
Core Density (pcf)	1.71	1.73	1.61	1.62	1.64	1.66	1.55	1.57	1.65
Humid Age Distortion (1-3)	3	2	3	3	1	2	1	2	2

1=Extreme, 2=Modest, 3=No visual distortion

ASTM E84 CLASSIFICATION

Our ASTM E84 tunnel samples were prepared at Albemarle Coporation’s technical center in Baton Rouge, Louisiana. Our processing conditions are listed in table 7:

Our first set of formulations is summarized in table 8:

In our initial trials we decided to look at changing the MDI, changing the fire retardant, changing the fire retardant levels and then finally increasing both fire retardant level and polyester level while introducing *trans* 1, 2 dichloroethylene (1,2-TDCE).

Formulation number 1 and 2 are the same formulation, but with different Isocyanates. We wanted to determine if changing Isocyanate functionality would have benefits to dimensional

Spray Unit	Gusmer VH3000	B Temperature, °F	125-135
Spray Gun	Gusmer Gap gun	B Tank Pressure, psi	80
Spray Module	No. 2	B Dynamic Pressure, psi	1200-1400
A Temperature, °F	125-135	Nominal Sample Thickness, in	4
A Tank Pressure, psi	80	Nominal Pass Thickness, in	2
A Dynamic Pressure, psi	1200-1400	Number of Passes	2
		Nominal Sample Density, pcf	1.93-2.08

Formulations	No. 1	No. 2 *	No. 3	No. 4	No. 5
Terol 256	39.40	39.40	39.40	36.96	48.06
Jeffol R-425X ¹	6.56	6.56	6.56	6.16	6.01
Sucrose polyol, f = 7	19.69	19.69	19.69	18.48	6.01
Surfactant	0.98	0.98	0.98	0.92	0.90
XP-7382 ²	16.41	16.41	-	21.56	-
RB-7001 ²	-	-	16.41	-	-
TMCP ²	-	-	-	-	9.61
RB-79 ²	-	-	-	-	8.41
Catalysts	6.35	6.35	6.35	5.97	5.95
Water	2.63	2.63	2.63	2.46	1.74
α-methyl styrene	0.10	0.10	0.10	0.09	0.09
1,2 TDCE ³	-	-	-	-	5.11
HFC-245fa ⁴	7.88	7.88	7.88	7.40	8.11
Total	100.00	100.00	100.00	100.00	100.00
Index	1.04	1.01	1.04	1.07	1.31
Lupranate M20 ⁵	103.00	103.00	103.00	103.00	103.00
ASTM E84 ⁶					
Flame Spread	15	20 / 20 **	20	20	20 / 20 **
Smoke Index	500	500 / 550 **	450	550	350 / 400 **
Dim Stab %ΔVol					
2 Day Age					
158°F, 95% RH	2.83	7.86	0.80	6.23	5.85
28 Day Age					
158°F, 95% RH	6.87	4.25	11.47	4.90	27.39

* - sample No. 2 was prepared with 700 cps Isocyanate
 ** - " / " indicates duplicate test

stability or fire properties. Fire properties and dimensional stability for both trials were comparable. We did not find any benefit from changing Isocyanates.

In formulations number 1 and 3 we decided to compare two fire retardants recommended by Albemarle Corporation: XP-7283 and RB-7001. Both of these fire retardants are blends of brominated aromatic esters and chlorinated phosphates. XP-7283 has a curative agent that allows for quicker “greening.” RB-7001 yielded better smoke values but XP-7283 yielded lower flame spread. In future formulations RB-7001 was our fire retardant of choice because smoke obscuration was the problem area. Formulation number 3 yielded a Class I rating.

In formulations 1 and 4 we looked at fire retardant loading. Formulation number 4 had a greater fire retardant loading, but had slightly higher smoke index. In this set of tests we found that changing fire retardant level did not substantially affect the flame spread or smoke values.

Formulation number 5 saw the introduction of 1,2-TDCE from Arkema, Inc. This material is marketed as a fire retardant, but due to its low boiling point (48°C) it has some blowing characteristics [3]. We wanted to take advantage of the chlorine

and the alkene bond in this molecule for flammability purposes. And if we got some blowing effects it would be considered a bonus. Though, from our experience it did not blow with great efficiency. Also, the material is flammable and a terrific solvent. The solvent effects on the foam were evident during spraying. Initially, the foam was very soft. This indicated that it was well plasticized. Also, formulation number 5 had tremendous growth in the humidity cabinet. As a result, we decided that in future trials we would limit the amount of TDCE to less than 4% of the total resin. Formulation number 5 yielded the best E84 results and we attribute this to the increased polyester loading and the lowered water loading.

OH (mg KOH/g)	310
Viscosity at 25°C (cps)	11000
Nominal Functionality	2.45
HFC-245fa Solubility	21%

We decided to take the successes from the first trial and make

Formulations	No. 6	No. 7	No. 8	No. 9	No. 10
Terol 256	37.87	39.23	-	39.20	42.70
Terol 925	-	-	42.70	-	-
Jeffol R-425X ¹	6.31	6.54	6.10	6.53	6.10
Sucrose polyol, f = 7	18.93	19.61	12.20	19.60	12.20
Surfactant	0.95	0.98	0.91	0.98	0.91
RB-7001 ²	15.78	13.08	18.30	16.33	18.30
Catalysts	6.25	6.47	6.03	6.47	6.03
Water	1.83	1.90	1.77	2.61	1.77
α -methyl styrene	0.09	0.10	0.10	0.10	0.10
1,2 TDCE ³	3.79	3.92	3.66	-	3.66
HFC-245fa ⁴	8.20	8.17	8.23	8.18	8.23
Total	100.00	100.00	100.00	100.00	100.00
Index	1.21	1.18	1.19	1.04	1.26
Lupranate M20 ⁵	103.00	103.00	103.00	103.00	103.00
ASTM E84 ⁶					
Flame Spread	25	25	25	25	25
Smoke Index	500	500	400	550	450
Dim Stab % Δ Vol					
2 Day Age					
158°F, 95% RH	4.61	6.46	4.01	8.76	6.75
28 Day Age					
158°F, 95% RH	1.86	3.55	19.20	7.84	15.84

some modifications for a second round of testing. In the second round of testing we decided to evaluate Terol 925. Terol 925 was developed for similar applications as Terol 256. However, Terol 925 has a greater nominal functionality and hydroxyl value than Terol 256.

Table 10 shows the summary of the second trial:

Formulation number 9 is a duplication of formulation number 3. However, we were not able to duplicate the ASTM E84 Class I rating from the initial trials; we were close at 550 smoke obscuration index. Dimensional stability was comparable between formulations 3 and 9.

Formulation number 6 is similar to formulation number 9. However, in formulation number 6 the water level was lowered to 1.83% and we introduced 3.79% 1,2-TDCE. The results from the E84 tunnel were comparable. Flame spread was 25 for both and smoke index was 500 and 550, for formulations 6 and 9, respectively.

In formulation number 7, we wanted to determine the effect of reduced fire retardant loading on smoke index. Formulations 6 and 7 are similar except for fire retardant loading levels. The result was that there was no significant benefit from changing the fire retardant level. This finding corroborates an earlier experiment between formulations 1 and 4.

In formulation numbers 8 and 10, we decided to compare Terol 256 and Terol 925. In these formulations, we increased polyester loading at the expense of the sucrose polyol and increased the fire retardant level to 18%, while maintaining less than 4% 1,2-TDCE. The result was ASTM E84 Class I rating for both Terol 925 and Terol 256. The dimensional stability for Terol 925 was slightly worse, but we feel that it is within experimental variation.

CONCLUSIONS

HFC-245fa is a difficult blowing agent to formulate with because of its very nature. The material has a high vapor pressure at ambient temperature, it has less fire retarding character than HCFC-141b and is relatively more expensive than HCFC-141b. However, by choosing polyol mixtures to maximize overall functionality and polyester polyol loading it is possible to produce a dimensionally stable system with ASTM E84 Class I rating at 4.0 inches.

We feel that the strongest contributor to lower smoke numbers is higher polyester loading and lower water loading. Our experiments verify these findings. We noticed that when polyester level was above 42% and water was below 2% of the resin, we obtained the lowest smoke obscuration numbers. We feel that Terol 925 is a product with great potential because of the greater nominal functionality of this material. With greater functionality we feel that Terol 925 loading levels could

approach 45% of the resin. This is an area for future development.

We have presented two formulations based on Terol polyols that we have been able to give reasonably good dimensional stability while yielding ASTM E84 Class I rating at 4.0 inches.

FUTURE AND PENDING WORK

The formulations presented here were developed to meet two criteria: form a dimensionally stable system and yield ASTM E84 Class I rating at nominal 4.0 inch thickness. During the course of our trials we noticed three looming problems associated with these formulations.

The first issue was noted when the system was applied on a 32°F substrate. We applied the system to a stud wall in a cold room and noticed that there was separation from the stud wall within hours. With high levels of water adhesion is always a concern. The increased crosslinking of these systems also contributes to the friability and thus poor adhesion of the foam. We are now investigating catalysis and other additives to help mitigate this phenomenon.

The second problem deals with the shelf stability of the system. We obtained retain samples of the trialed systems for observation. There was precipitation in some of the formulations. In systems with high polyester and high water levels it is inevitable that some precipitation will be noticed. It is a matter of delaying the equilibrium that will establish itself. We are examining catalyst selections that will help this problem.

The final issue associated with these systems involved the viscosity of the system. Some systems had measured viscosities of 800 to 1000 cps. 1,2-TDCE was very efficient at reducing viscosity. At 3-4% loading the viscosity of the system dropped 300-400 cps. There are other additives that we are examining to help with this problem.

Currently, we are working with Tosoh Corporation to choose catalysts that will help with adhesion in cold environments and permit longer system stability. And we will continue to find look for alternatives to help lower viscosity.

Our future formulation development work will concentrate on Terol 925 as we believe that we can develop systems with even greater polyester loading. We believe that the resin should contain as much polyester as possible without sacrificing dimensional stability to achieve ASTM E84 Class I rating. Furthermore, at Oxid we believe that we can increase the functionality of our Terols even higher. Future polyol research will be done in this area.

ACKNOWLEDGMENTS

The authors of this paper would like to acknowledge Jeremy Leteff and Richard Donald of Oxid, L.P. for

assistance with sample preparation and testing. We would also like to acknowledge the Albemarle Corporation for allowing us to use their spraying apparatus.

We would also like to acknowledge the following companies for assistance with reagent procurement:

- Foam Enterprises, LLC
- BASF Corporation
- Albemarle Corporation
- Huntsman Polyurethanes
- Arkema Inc.
- Honeywell Corporation

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3. Arkema Corporation. MSDS of Transcend (TM) Additive, November 2004.

IMPORTANT NOTES

1. HUNTSMAN POLYURETHANES: JEFFOL R-466X, OHV = 470 mg KOH/g, viscosity = 11,000 cps, nominal functionality = 3.3; JEFFOL R-425X, OHV = 425 mg KOH/g, viscosity = 4500 cps, nominal functionality = 3.2.
2. ALBEMARLE CORPORATION: TMCP = tris (2-chloro-isopropyl) phosphate; SAYTEX RB-79, OHV = 218 mg KOH/g, viscosity = 107,500 cps, %Br = 48; SAYTEX RB-7001, OHV = 100 mg KOH/g, viscosity = 585 cps, %Halogen = 39, %Phosphorus = 5.1; XP-7382, OHV = 90 mg KOH/g, viscosity = 375 cps, %Halogen = 34.5, %Phosphorus = 4.5.
3. ARKEMA INC: *trans* 1, 2 dichloroethylene (1,2-TDCE, Transcend™)
4. HONEYWELL CORPORATION: HFC-245fa (Enovate 3000)
5. BASF CORPORATION: Lupranate M20S, %NCO = 31.5, viscosity = 200 cps, nominal functionality = 2.7

6. ASTM E84 Testing done at Omega Point Laboratories in Elmendorf, Texas.

BIOGRAPHIES

Jose Luna

Jose Luna is a Research Chemist at Oxid, L.P. Jose joined Oxid in 2002 as laboratory technician and upon graduation he joined Oxid as a full time Chemist. He is responsible for polyester polyol synthesis as well as development of PUR/PIR foam systems. He holds two BA degrees from the University of Houston at Clear Lake and is currently working toward completion of his MS degree.

David Shieh

As Manager of R & D for Terol polyols, David Shieh is responsible for both polyester polyol development as well as PUR/PIR foam development, using these polyols. Prior to joining Oxid in 1990, David was a Research Chemist at Chardonol, where he developed numerous polyester polyols for use in foams. He holds several patents in the field of Polyester polyol, and he is recognized as an authority in this field. He holds a BS degree in Chemistry from the Catholic University of Taiwan, and graduate degrees from the University of Houston and the University of Mississippi.

Al DeLeon

Al DeLeon is the VP of R & D for Oxid L.P. He began his career in 1970 working at Jim Walter Research Corp., where he was involved in the development of isocyanurate chemistry. After fourteen years there, he became Technical Director of Flexible Products Company where he stayed for four years, directing their R & D as well as TS & D efforts. In 1988, Al joined Oxid in his current position. He holds numerous patents in urethanes, and is the author of numerous publications. Al holds BS and MS degrees in Chemistry from the University of Miami (FL). He is a member of Sigma XI and ACS.