Ecomate – A Revolutionary yet Economical New Blowing Agent

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Ecomate is a patented Blowing Agent useful for rigid and semi-rigid urethane foams. It will allow the formulator to produce foams which are very nearly like those obtained with HCFC-141b.

In order for any potential blowing agent to make a niche in the market it must offer the good physicals properties, be superior in some ways, and be economically priced. As you read further, you will see this is the case for ecomate.

1. Physical Properties

Ecomate is a true liquid blowing agent designed to replace HCFCs, HFCs, and HCs, which has many similar properties to HCFC-141b. As one can see from Table 1, ecomate is quite similar to HCFC-141b in many critical physical properties, such as boiling point, solubility and gas lambda value. This means that it will have similar foaming characteristics [initiation speed or CT [crème time], density potential, and thermal resistance]. Its upper and lower explosion limits [UEL/LEL] are slightly broader than those for 141b, which is understandable since ecomate has no halogen content.

Table 1	ecomate	141b	HFC 245fa	HFC 365mfc	365/227 93/7	n-pentane	Cyclo-pentane
Molecular Wt	60	117	134	148	149,6	72	70
Boiling Point, °C	31,5	32	15,3	40,2	30	36	49
Sp Gr	0,982	1,24	1,32	1,25	1,28**	0,62	0,75
Lambda, gas @ 25C	10,7	10	12,2	10,6	10.7	14*	11*
LEL/UEL,%	5 - 23	7,6-17,7	n/a	n/a	n/a	1,4-17,8	1,4-8,0

*gas@20C ** liquid @20C

The fact that ecomate has a molecular weight about half that of 141b means that it is nearly twice as effective at blowing the same density foam, which is an obvious economic advantage. Thus it has the right balance of boiling point and molecular weight to make it very enticing to the formulator. What one doesn't see from this table is its superior solubility in all rigid foam raw materials [Table 4].

2. Environmental Properties

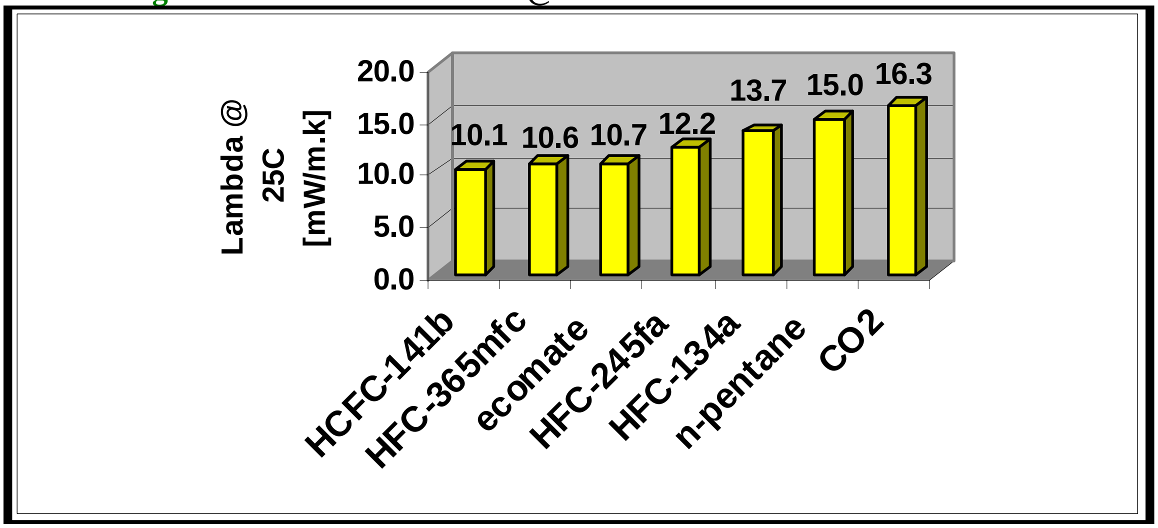
Ecomate is the **only** physical blowing agent on the market today which is zero ODP, zero GWP and a VOC exempt compound [Table 2]:

Table 2	ODP	GWP	VOC
ecomate	**0**	**0**	**NO**
HCFC 141b	0.1	700	NO
HCFC 22	0.05	1700	NO
HCFC 124	0.02	480	NO
HCFC 142b	0.06	2000	NO
HFC 134a	0	1300	NO
HFC 245fa	0	820	NO
HFC 365/227 (93/7)	0	1049	NO
Cyclo-pentane	0	11	YES

3. **Thermal Efficiency**

ECOMATE has the potential for very good foam lambda values based on its relatively low gas lambda values [Figure 1]. It is nearly the same as HCFC-141b and HFC-365mfc, and much better than the other perspective blowing agents available today. It is nearly one third better than pentane.

Figure 1: BA Lambda values @ 25 °C



In addition to having a low molecular weight, a liquid boiling point almost identical to HCFC 141b, excellent gas thermal insulation values, and no environmental penalties, what else does ecomate bring to the table? Cost efficiency and solubility!

4. **Economic Efficiency**

What we mean by economic (or cost) efficiency is what it costs to blow foam to a given target density. In general, it takes the same molar concentration of any blowing agent to blow the same density of foam.

This of course ignores two potential mitigating factors of the blowing agent: high volatility [low boiling point temperature] and poor solubility. Both will cause more of the blowing agent to escape before doing what it was intended to do – blow and insulate. Thus they become less cost efficient because of those two factors.

However, let us look at current BA candidates on just a molar cost basis [Table 3]. In this table we derive a factor for equivalent molar concentration of each material by dividing each individual molecular weight by the molecular weight of 141b. That factor is then multiplied by its cost per kilo to obtain a relative cost per mole of the blowing agent. The table illustrates that ecomate is very cost efficient in blowing foam.

Table 3: Cost efficiency of BAs

Blowing Agent	€/kg	Mol Wt	Wt Factor	€/mole
HCFC-141b	**	117	1.00	Ref
HFC-245fa	******	134	1.15	+380%
HFC-365/227	****	149	1.27	+280%
cC5	*	70	0.60	-70%
nC5	*	72	0.60	-75%
Ecomate	**	60	0.51	-60%

5. Solvency

The two mitigating factors mentioned earlier, low boiling point and solubility are NOT relevant for ecomate. It boils just below 32 °C, so there are no boil-off issues; and it is very soluble in all urethane raw materials [Table 4].

Table 4: ecomate Solubility

INGREDIENT	Aspect with 20% ecomate
POLYESTER Polyol	CLEAR
SUCROSE GLYCERINE Polyol	CLEAR
AMINE Polyol	CLEAR
MANNICH Polyol	CLEAR
ISOCYANATE	CLEAR
DEG	CLEAR
TCPP	CLEAR
Br FRA	CLEAR
PROPYLENE CARBONATE	CLEAR
WATER	CLEAR

This solubility includes water and ester polyols, as well as the isocyanate, fire retardants, and plasticizers one may use. This means that the formulator can freely use any polyester, especially DMT- and PET- derived esters without having to resort to an emulsion step. This means less work, less hassle, and in the long run, more consistent densities.

6. Other Benefits

The improved solubility one obtains with ecomate affords three other benefits:

1) very low system vapor pressures [both in the polyol-component and in the iso-component, Figures 2 & 3];
2) excellent low system viscosities [allowing higher functionality polyols and isocyanates to be utilized]; and
3) very low emissions of ecomate [Figure 4].

Figure 2: Vapor pressure in Polyol Component

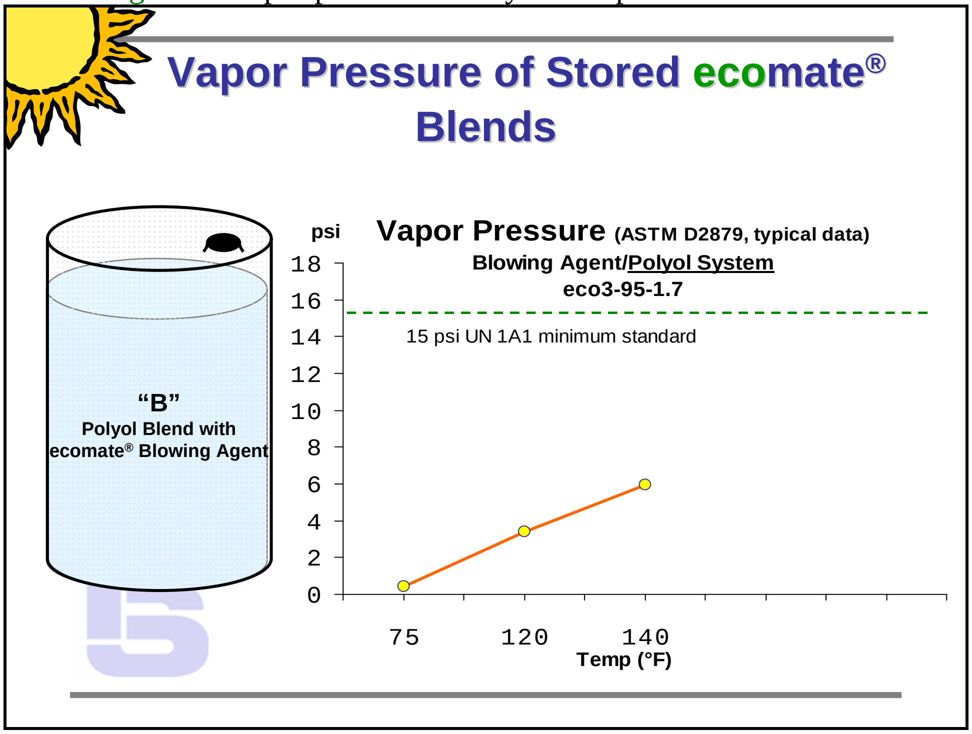
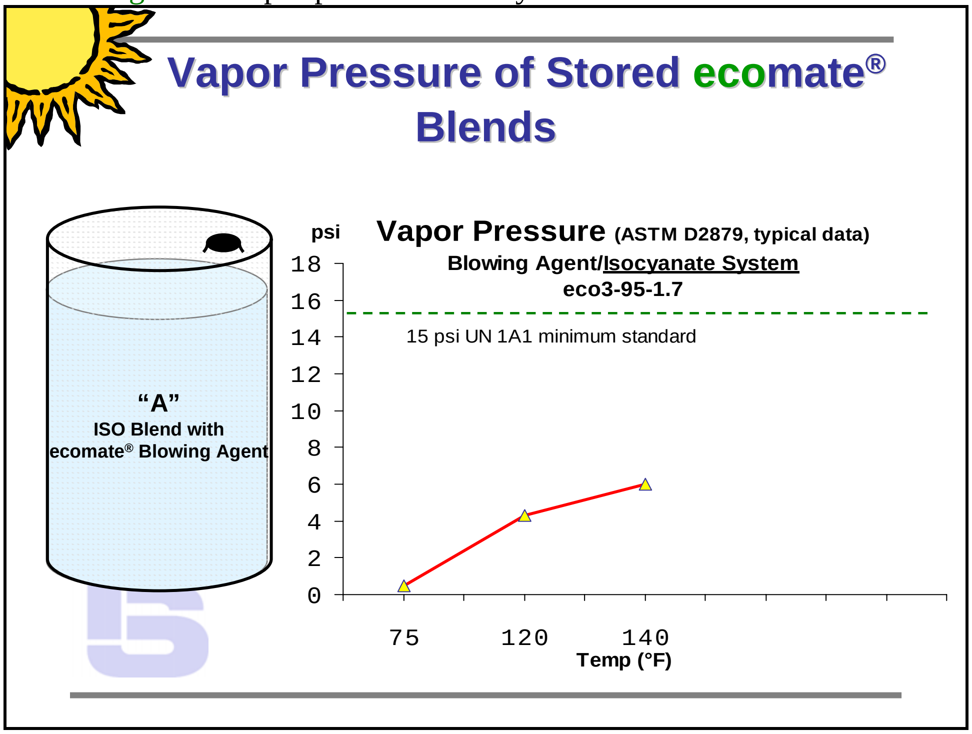


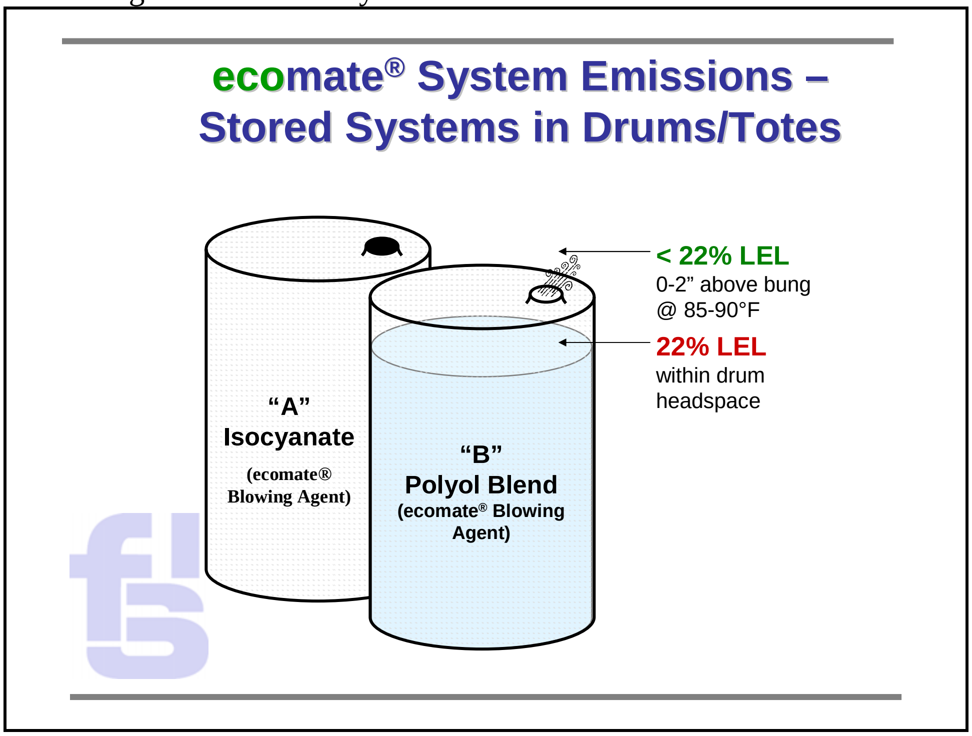
Figure 3: Vapor pressure in Isocyanate Blend



Low emissions of ecomate are critical for two reasons: **1) it allows one to safely use ecomate at substantial concentrations without exceeding the LEL**. Our testing shows that ecomate levels were only 22% of the LEL (less than 1% by volume) within 2.5 cm of the liquid level in a closed drum; and less than 22% of the LEL zero to 5 cm above the bung of an open drum at 29 – 32 °C.; and **2) it allows one to ship drum or larger quantities of ecomate systems without exceeding Transportation flammability**

regulations. The safe levels of ecomate usage in foam formulations depend on the foam raw materials and their proportions used. We recommend that any new formulation using ecomate be checked for flashpoint using a SETA closed cup testing apparatus prior to use or shipping.

Figure 4: ecomate System Emissions



7. Ecomate in Pour Systems

Ecomate has been successfully used commercially for the past 4 years as a blowing agent in many pour-in-place systems because of the good physical properties it imparts to the finished foam. For example, Table 5 highlights some of the excellent physical properties obtainable with this blowing agent in two such systems: a non-rated foam and a UL-94 HF1 listed product. Note the **excellent thermal properties** obtained with ecomate.

Table 5: Ecomate Systems Physical Properties

	Eco3-95-1.7	**Eco2-90-1.7**
Density, *kg/m3*	36.8	33.6
Comp Strength //, *kPa*	317	283
Comp Strength _|_, *kPa*	214	186
Dim Stability		
Cold, 7d	-0.06 %	-0.06 %
Humid, 7d	2.0 %	-0.21 %
Lambda, *mW/mK*	20.9	20.1

8. Ecomate in Integral Skinned foams

Ecomate is useful in many different types of foam. It can be used not only in rigid foams, but also in integral skinned elastomers, and flexible foams as well. What makes it unique in integral skinned foams is a combination of: 1) its ability to solvate all of the polyester and polyether polyols currently in use with HCFC141b blown elastomers; and 2) its perfectly suited boiling point, just above ambient [similar to 141b], which allows good skin formation without expensive cooling. The fact that it has half the molecular weight of 141b, therefore requiring half its weight for equivalent density, and that it is very economically situated make it very appealing to this segment of the industry. Needless to say, patents are pending for this application.

In addition ecomate has **SNAP** approval for use in integral skin polyurethanes as an alternate to CFCs and HCFCs. While HFC 245fa has similar approval, it has much poorer solubility, a sub-ambient boiling point, higher molecular weight and higher cost than ecomate. At the time of this writing, neither HFC 365mfc nor the HFC 365mfc/227ea blends have been approved for integral skinned foams. Even if they were to gain such approval, they are not available for use in North America, and their MW & costs should well make them economically prohibitive.

It also has been used successfully in pour-in-place, spray, and isocyanurate foams. Let us focus on the latter to demonstrate its usefulness, and some application pitfalls you may want to avoid.

9. Ecomate in PIR Formulations

In our PIR studies we looked at high and low index [I=375 vs 225], with and without fire retardant [TCPP @ 0, 2.7%], and with the three different types of esters on the market [DMT, PET, and PA based]. Our target density range was 29 to 36 kg/m3. Our reaction profile was Crème Time = 6-8 sec; Gel 18-22 sec; and Tack Free 20-30 sec.

Ecomate was completely compatible in all formulations trialed. All mixtures were crystal clear and without haze. There was no need to emulsify the blowing agent into the polyester mix. Viscosities were all very low, ranging from 300 cps to as low as 70 cps with all ecomate blown formulations.

10. The Study

Table 6	FORMULA WT
ESTER 1	10.2
FRA	2.7
CAT BLEND	2.6
SURFACTANT	0.7
WATER	0.8
ECOMATE	2.0
ISOCYANATE	81.0
	100.0

Our typical formulations are built on the entire system being 100% – polyol and isocyanate included [Table 6]. In this manner we can keep select ingredients [such as surfactant, catalysts, and especially fire retardants] constant in the formulation during resin or index changes.

The study began with several 375 Index formulations blown solely with ecomate, using a DMT based polyol, with and without fire retardant [Table 7]. Our fire testing is done on a modified Monsanto tunnel equipped for monitoring smoke; in addition we monitor the weight loss of the panels during burning. The tunnel is calibrated with a commercial PIR board with consistent FS and smoke. Smoke values >16 here will be >450 smoke in the full tunnel. Without FRA, naturally the flame spread, smoke, and weight loss are much worse. Both panels showed some shrinkage when fabricated to fit the tunnel. Flame Spread readings are from small scale tests that may indicate what happens in full scale tesing.

Table 7: Effect of FRA		
I=375	39-4	39-10
ESTER 1	21.35	22.11
FRA	2.67	0
Water	0	0
Ecomate	7.56	7.56
RATIO / 100 A	54	49
FLAME SPREAD	15	50
SMOKE	1	29.2
% WT LOSS	3	14
SHRINK	YES	YES

A second trial run at the same index, again without FRA, demonstrates that a slightly higher density [33.6 vs. 28.8 kg/m^3] via a slightly lower level of ecomate eliminates shrinkage and has little effect on flame spread, smoke or weight loss. [Table 8].

Table 8: Effect of Density		
I=375	39-12	39-10
ESTER 1	22.61	22.11
FRA	0	0
Water	0	0
Ecomate	5.67	7.56
RATIO / 100 A	46	49
Density	**2.1**	**1.8**
FS	50	50
Smoke	26.5	29.2
%Wt Loss	16	14
Shrink	NO	YES

Another experiment was completed at the same Index, but with FRA and with replacement of some of the ecomate with some water [Table 9]. One can see that the inclusion of some water in the formulation has little effect on flame spread, but the smoke and the burned weight loss is increased. In addition, the ratio becomes more severe with the inclusion of water, but this level of water eliminates shrinkage.

Table 9: Results of FRA		
I=375	39-3	39-4
ESTER 1	10.2	21.35
FRA	2.67	2.67
Water	0.8	0
Ecomate	2.0	7.56
RATIO / 100 A	23.7	54
FS	15	15
Smoke	10.2	1
%Wt Loss	5.4	3.3
Shrink	NO	YES

Table 10: Effect of H2O /Ecomate Levels				
I=375	39-14	39-13	39-8	39-9
ESTER 1	16.0	13.3	10.74	10.96
FRA	0	0	0	0
Water	0.2	0.4	**0.6**	0.8
Ecomate	7.0	5.6	**4.4**	2.0
RATIO / 100 A	36.6	29.8	24.0	20.6
FS	40	40	**30**	25
Smoke	26	28	**10**	22
%Wt Loss	11	11	**7**	8
Shrink	YES	SLT	**NO**	NO

A fourth set of experiments at the same index, again without FRA, was run to determine an ideal loading of ecomate/water to maintain density and to minimize both shrinkage and the effect on fire properties [Table 10]. As water increases, the A/B weight ratio becomes more skewed. However, flame spread, weight loss and shrinkage improve with the addition. From this data there seems an optimal level at about 0.6% water / 4.4% ecomate in the entire system. Beyond this level properties begin to degrade.

A 375 Index is quite high for many applications, so a comparison of 375 vs. 225 Indices were made, again without FRA, but with the new ecomate / water levels [Table 11]. As expected, the weight ratio improves at the lower index; but the FS, smoke, and weight loss all get worse. NO shrinkage indicates minimal effect of index on shrinkage.

Table 11: Index Effects		
INDEX VARIABLE	39-8	44-1
ESTER 1	10.74	25.7
FRA	0	0
WATER	0.6	0.6
ECOMATE	4.4	4.4
RATIO / 100 A	24.0	51.6
INDEX	**375**	**225**
FS	30	35
SMOKE	10	23
% WT LOSS	7	18
SHRINK	NO	NO

One of the reasons to examine systems ***without FRA*** is to discern the best polyol for the task without masking its deficiencies. It is well known that many a system has passed small screening fire tests only to fail in full scale testing. While there may be many causes for this, at least one may be a marginal polyol masked by FRA. In [Table 12] three esters are investigated without FRA, at a 225 Index and with 0.6% water. Again there was no shrinkage, indicating that ester changes do not exacerbate shrinkage. The esters vary markedly in properties, with Ester 3 having substantially worse FS and weight loss than the other two. Ester 2 seems marginally better than Ester 1.

Table 12: Ester Effects			
I=225	44-1	44-4	44-2
ESTER 1	25.8		
ESTER 2		23.2	
ESTER 3			29.2
FRA	0	0	0
Water	0.6	0.6	0.6
Ecomate	4.4	4.4	4.4
Ratio / 100 A	51.6	45.9	59.9
FS	35	30	>75
Smoke	23	25	34
% Wt Loss	18	17	27
Shrink	NO	NO	NO

In [Table 13], the effects are more subtle using the same three esters under the same conditions with the addition of FRA. Here Ester 3 seems equivalent to Ester 1. Ester 2 still seems marginally better than the other two in fire resistance properties.

Table 13: Ester Effects			
I=225	44-5	44-6	44-7
ESTER 1	24.9		
ESTER 2		22.4	
ESTER 3			28.2
FRA	2.25	2.25	2.25
Water	0.6	0.6	0.6
Ecomate	4.4	4.4	4.4
Ratio / 100 A	54.9	49.1	63.3
FS	30	25	30
Smoke	10	8	10
% Wt Loss	7.8	6.2	7.7
Shrink	NO	NO	NO

It is very possible that Ester 3 might fail a full scale fire test, and highly probable that Ester 2 would pass, perhaps even with a FRA cut-back saving additional expense.

What is unique about ecomate in these formulations is its ability to be readily soluble in esters which is very difficult for hydrocarbons. This allows the formulator to continue to use those esters previously used with HCFC-141b, and at the lower levels of fire retardant previously used. They can be very cost advantageous.

We examined another ester, Ester 4, based on PA [phthalic anhydride], for its solubility in ecomate and its resistance to fire. We discovered that it was highly soluble in ecomate and produced an excellent piece of foam [Table 14]. But when we tested it for fire properties, at the above index w/o any FRA, it exhibited a horrific FS and smoke scenario. Both FS and smoke were nearly beyond the capacity of our equipment. The flame burned out the end of the tunnel within 10sec of ignition, and the smoke reached 100% obscurity shortly thereafter. All esters are not created equal.

Finally, we produced a boardstock formula [Table 14, Formula 55-7] at a 250 index with 5% fire retardant with Ester 4 to replicate what may be generic in the US today using hydrocarbon BAs and to demonstrate that good foam can be made even with inferior polyols if one adds sufficient FRA and raises the index sufficiently. It is left to the reader to compare costs of the Ester 2 formulation in Table 13 to the ester 4 formulation in this table, with its higher index and more than double the amount of FRA.

11. Conclusions

In conclusion, we believe that ecomate is an excellent alternative BA for rigid PIR foams, especially where excellent solubility of raw materials is an issue. There is no need to emulsify blowing agents into systems when using ecomate. With ecomate the formulator has the broadest range of polyols from which to choose without any viscosity or solubility constraints. One can obtain good physical properties, perhaps superior properties, with the right choice of polyols. As we have demonstrated, the choice of esters severely affects burn and other physical properties.

Table 14: Ester effects	55-2	44-4	55-7
	I=250	I=225	I=250
ESTER 4	23.0		25.1
ESTER 2		29.2	
FRA	0	0	5
Water	0.6	0.6	0.6
Ecomate	4.4	4.4	4.4
Ratio / 100 A	46.9	45.9	65.5
FS	>75	30	25
Smoke	54	25	5
% Wt Loss	28	17	4
Shrink	NO	NO	NO

Ecomate offers the following advantages:

- It is a true Liquid Blowing Agent
- It is SNAP approved, Monreal and Kyoto protocol compliant;
- It is zero ODP, zero GWP, and VOC exempt
- It has superior solubility
- Low volatility
- Produces foams with good properties, including thermal resistance,
- Is available world-wide
- Compatible with isocyanate and polyol blends
- Is compatible with all other Blowing Agents,
- And is cost competitive [i.e. advantageous]!
- Try it . . . . You'll like it!

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