DuPont™ Formacel®

foam blowing agents

DuPont™ Formacel® S for Polyurethane/ Polyisocyanurate Foams

Introduction

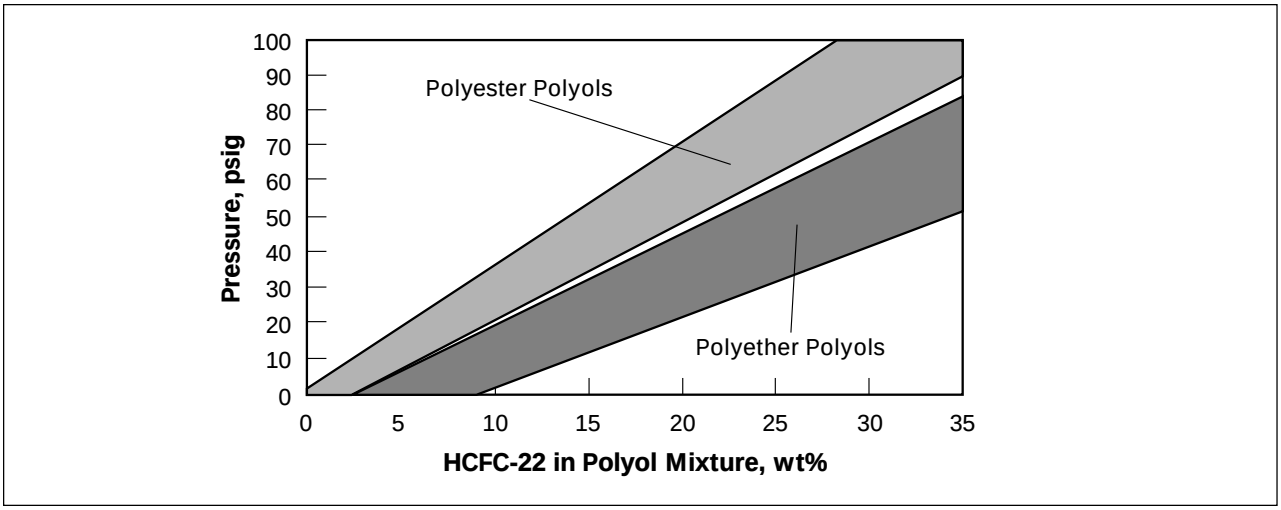
In evaluating alternative blowing agents for polyurethane foams, DuPont™ Formacel® S (HCFC-22) offers some unique characteristics that will allow it to be used as a replacement for CFC-11. The affinity of Formacel® S for polyol systems reduces its vapor pressure, which makes it easier to handle than might be expected from its low boiling point. Additionally, Formacel® S is nonflammable, with known toxicity (equivalent to CFC-11), and is commercially available. Its low molecular weight suggests reduced usage over CFC-11.

Vapor Pressure Studies

Because of the affinity of Formacel® S for polyols, Formacel® S/polyol solutions exhibit lower than expected vapor pressures. For example, even though the vapor pressure of Formacel® S is 121 psig at 21°C (70°F), polyol solutions of up to 30 wt% Formacel® S can exhibit vapor pressures as low as 50–60 psig, depending on the type of polyol.

To help evaluate equipment pressure-handling capabilities, vapor pressure vs. temperature data can be developed for Formacel® S in different polyurethane (PUR) and polyisocyanurate (PIR) polyols. The available data show that Formacel® S has a greater attraction for polyether polyols than for polyester polyols (see **Figure 1**). There are also variations within each class of polyol, a situation which suggests that other polyol properties affect attraction for Formacel® S.

Figure 1. Vapor Pressure of DuPont™ Formacel® S/Polyol Mixtures at 21°C (70°F)



Vapor pressure measurements are made primarily on Formacel® S/polyol mixtures alone. In comparison, catalysts and surfactants in the mixtures appeared to have no effect on the affinity of Formacel® S for polyols. However, other additives, such as water, may affect the bonding of Formacel® S in the polyol. Water will compete with Formacel® S for the polyol bonding sites and, thus in some cases, release Formacel® S from the mixture.

Formacel® S Stability

As with other HCFC alternatives, the stability of Formacel® S in B-side systems and foams must be considered. Aerosol experience with HCFC-22 has shown that HCFC-22 will degrade in alkaline environments, especially in the presence of water. Sealed-tube testing was used to measure Formacel® S degradation and to analyze by-product formation in B-sides and foams. Test data obtained suggest that the stability of Formacel® S depends on the alkalinity of the system. Amine polyols and amine catalysts, which increase alkalinity, showed the most degradation of Formacel® S. This degradation is significantly reduced in the cases where alkalinity is reduced. In fact, in catalyst comparison tests, amine catalysts that were neutralized with a carboxylic acid showed no Formacel® S degradation (see **Table 1**). Even in severe cases, however, the degradation is slow: in the range of 0–1% Formacel® S loss per month.

In all cases, the only by-products detected were acids, which interfere with foam processing. No other decomposition by-products of concern were observed.

Viscosity

One important function served by the blowing agent is to reduce the B-side viscosity to levels within the pumping capabilities of the processing equipment. Formacel® S accomplishes this as well as CFC-11.

As an estimate of the dilution ability of Formacel® S, viscosities were measured for polyols with the amount of Formacel® S that would dissolve at atmospheric pressure. The data are summarized in **Table 2**.

Table 1
DuPont™ Formacel® S Degradation in Catalyst/ PPG Solutions During 40-day Exposure at Temperatures Up to 60°C (140°F)

	HCFC-22 Degradation, %
Amine Catalysts	0.2–2.0
"Blocked" Amine Catalysts	0
Potassium Catalyst	0.5
Tin Catalyst	0
Silicone Surfactant	0
Polypropylene Glycol (PPG)	0

Formacel® S Conversions

Formacel® S is already used as a blowing agent in such commercial foam applications as refrigeration, refrigerated transport, marine flotation, and insulation board.

Formacel® S can be used alone or in blends with higher boiling blowing agents. Foam produced with Formacel® S exhibits better low-temperature insulation value and better dimensional stability (see U.S. Patent #4927863).

Areas where development work is necessary to begin using Formacel® S include:

- Evaluating the pressure capabilities of the mixing and blending equipment,
- Developing a Formacel® S addition procedure,
- Tailoring the foam formulation to Formacel® S, and
- Dispensing and distributing the foaming mixture, while managing the Formacel® S pressure let-down.

The investment required to begin using Formacel® S is typically small. In some cases, where appropriate equipment is already in place, the investment is essentially zero (i.e., some minor maintenance costs).

Table 2
Polyol Viscosities with DuPont™ Formacel® S Dissolved at Atmospheric Pressure

	Viscosity, cPs	
	Without HCFC-22	With HCFC-22 Soluble at Atmospheric Pressure
Polyether Polyol at 21°C (70°F)	8,000	2,000
Polyester Polyol at 21°C (70°F)	3,200	1,700
Polyester Polyol at 38°C (100°F)	1,200	800

Table 3
Properties of CFC Blowing Agents and Possible Alternatives

	CFC-11	HCFC-141b	CFC-12	HCFC-22	HFC-134a	HCFC-142b	HFC-152a
Formula	CCl_3F	CCl_2FCH_3	CCl_2F_2	$CHClF_2$	CH_2FCF_3	$CClF_2CH_3$	CHF_2CH_3
Molecular Weight	137.4	117.0	120.9	86.5	102.0	100.5	66.0
Boiling Point, °C °F	23.8 74.9	32.0 89.6	–29.8 –21.6	–40.8 –41.4	–26.1 –15.0	–9.8 14.4	–24.2 –11.5
Vapor Pressure at 21°C (70°F), psig bars	0 0	0 0	70 5.8	121 9.4	71 5.9	29 3.0	63 5.4
Ozone Depletion Potential	1.0	0.11	1.0	0.055	0	0.065	0
Global Warning Potential (GNP) 100 YR ITH, CO_2 = 1	4,000	630	8,500	1,700	1,300	2,000	140
Vapor Thermal Conductivity, at 25°C (77°F), mW/(m·K) Btu·ft/hr·ft²·°F	7.8 0.0045	10.6 0.0061	9.7 0.0056	11.4 0.0084	14.6 0.0084	13.0 0.0075	14.7 0.0085
Flammability Limits in Air, vol%	none	7.3–16.0	none	none	none	6.7–14.9	3.9–16.9
Latent Heat at Boiling Point, Cal/g Btu/lb	43.1 77.5	53.3 95.9	39.4 71.0	55.8 100.5	51.9 93.4	53.3 95.9	78.6 141.5
Liquid Density at 25°C (77°F), g/cc	1.48	1.23	1.31	1.19	1.20	1.11	0.90
Toxicity,* ppm	1,000 (TLV)	500 (AEL)	1,000 (TLV)	1,000 (TLV)	1,000 (AEL)	1,000 (AEL)	1,000 (AEL)

* An Acceptable Exposure Limit (AEL) is the recommended time-weighted average concentration of an airborne chemical to which nearly all workers may be exposed during an 8-hr day, 40-hr week without adverse effect, as determined by DuPont for compounds that do not have a TLV.

Summary

As progress toward replacing CFC blowing agents continues, Formacel® S arises as an unexpected, but promising candidate for polyurethane foams. Formacel® S is attractive because it:

- Is a commercially available product,
- Is nonflammable,
- Has low toxicity (TLV = 1,000 ppm),
- Has improved environmental properties compared to CFCs, and
- Improves low-temperature performance of the foam.

It exhibits special properties when blended in B-side systems; however, these properties vary with different formulations. Conversion from CFC-11 to Formacel® S is easily done, but care must be taken to properly evaluate the potential safety implications of pressure containment, blowing agent degradation, and elastomer compatibility.

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