Development of Low 245fa/High Water Blends for Discontinuous Panel Applications

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ABSTRACT

Following the footsteps of many developed countries, Article V countries have started to phase out the HCFC-141b blowing agent by implementing a consumption freeze on January, 2013, and subsequent phase-out schedule. Foam manufacturers are actively seeking blowing agent alternatives during this transition period. Typically, industry, such as discontinuous metal panel sector, is highly fragmented and typically prefers an easy-to-handle and non-flammable blowing agent with minimal conversion issues. With zero ODP, Honeywell HFC-245fa is a liquid, non-flammable blowing agent which fits these preferences well through this conversion. In this paper, the properties of a Honeywell developed cost effective formulation with low HFC-245fa/high water content are presented. Furthermore, a production trial with this formulation using conventional equipment in existing facility at ambient condition is also showcased.

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INTRODUCTION

In response to the Montreal Protocol on Substances that Deplete the Ozone Layer (the Montreal Protocol), the production of foams containing HCFC-141b has been phased out in several countries, including the United States, Japan and the EU. The use of this blowing agent will also be phased out in the near future in developing, or Article V, countries. The HCFC Phase-out Management Plan (HPMP) for foam applications in Article V countries is currently in effect. For instance, Honeywell found that the total allowable usage volume of HCFC in India has been frozen in 2013 and will be reduced steadily afterwards.

Honeywell has developed and commercialized a zero ozone depletion potential blowing agent, HFC-245fa (i.e. 1,1,1,3,3-pentafluopropane), as a non-flammable, liquid replacement for HCFC-141b in polyurethane and polyisocyanurate foams. Many rigid foam applications that had traditionally used HCFC-141b as the blowing agent, including appliances, spray foam, discontinuous and continuous panels, and others, have converted successfully from HCFC-141b during this phase-out process in developed countries. It is anticipated that a similar conversion to HFC-245fa will also occur in Article V countries as they complete their transitions.

As the HCFC Phase-out Management Plan (HPMP) for foam applications is in effect in Article V countries, OEMs and system houses in these regions have started or are in the process of evaluating blowing agent alternatives for HCFC-141b. Providing equivalent or better performance than HCFC-141b, HFC-245fa is the best option for all segments, in particular discontinuous panel applications. Although HFC-245fa can easily act as a drop-in replacement for HCFC-141b based formulations to meet or exceed desired properties and performances of foam, OEMs and system houses in these regions have frequently found that the cost of the resultant HFC-245fa system is relatively hard to absorb.

Targeting the blowing agent conversion in Article V countries, the development of a performance and other factors balanced formulation with a reduced amount of HFC-245fa and increased level of water is showcased. The physical and thermal properties of this low HFC-245fa/high water formulation are compared to a conventional HCFC-141b formulation that is commonly used in the region. Further to the development study, the results of a production trial of another system with reduced HFC-245fa, 5pbw, is also presented.

PROPERTIES

Table 1 summarizes selected physical properties of various blowing agents for comparison.[1] Similar to CFC-11, HFC-245fa is classified as a non-flammable liquid blowing agent with neither a flash point nor vapor flame limits in air. HFC-245fa is a zero ozone depletion liquid fluorocarbon blowing agent with acceptable global warming potential. If HFC-245fa is released into the atmosphere, it does not break down into any long-lived atmospheric products. Table 2 summarizes the environmental properties of different blowing agents.[1]

Table 1. Selected Physical Properties of Various Blowing Agents

Properties	HFC-245fa	CFC-11	HCFC-141b
Mol. Weight, g/mol	134.0	137.4	116.9
Boiling Point			
°C	15.3	23.8	32.2
°F	59.5	74.8	90.0
Flashpoint			
°C	None	None	None
°F	None	None	None
LFL/UFL (Vol% in Air)	None	None	7.6-17.7

Table 2. Selected Environmental Properties of Various Blowing Agents

Properties	HFC-245fa	CFC-11	HCFC-141b
Atmospheric Lifetime, yrs	8.4	50	9.4
GWP, 100 yrs time horizon	1030	4750	725
VOC Status (US)	No	No	No

DISCONTINUOUS PANEL FOAM EVALUATIONS

LAB EVALUATION

In this evaluation, all foams were prepared by the hand-mixing method with processing conditions given in Table 3. Polyol premix and isocyanate were blended thoroughly and the reactive mixture was poured into a mold at 40°C, and allowed to cure for 15 minutes before demolding. All physical properties and thermal conductivity testing was performed at least 24 hours after foams were prepared.

[1] A mosaic of properties must be satisfied by a blowing agent replacement; the table reports only certain of the properties that must be considered.

Table 3. Hand-Mixing Method – Preparation Parameters and Conditions	
Parameters	**Conditions**
Component Temperature	
Polyol Premix, °C	20
Isocyanate,°C	20
Stirring	
Speed, RPM	5000
Duration, Seconds	5
Mold Dimension, cm^3	7.5 x 40 x 40
Mold Temperature, °C	40

With the aim of balancing cost and performance, a generic formulation was developed with a reduced dosage of HFC-245fa, as low as 7pbw, and an increased level of water, up to 3.5 pbw. This low-HFC-245fa/ high-water generic formulation is showcased in Table 3 below. Note that a typical formulation usually contains about 21phw of HCFC-141b for discontinuous panel application. With a free rise density of about 30±1kg/m^3, the core density of the molded foams is about 40±1kg/m3 after approximately 20% overpack.

Table 3. Generic Formulation with High HFC-245fa/Low Water Dosage Level	
Components	
Polyether Polyol #1	26.45
Polyether Polyol #2	35.00
Polyester Polyol	17.00
Catalyst #1	0.15
Catalyst #2	0.35
Catalyst #3	0.15
Catalyst #4	0.10
Surfactant	2.00
Flame Retardant	8.00
Special Additive	0.30
Water	3.50
HFC-245fa	7.00
Isocyanate	125

It is important to note that the scope of this study is to develop a generic formulation with low HFC-245fa and high water dosage with equivalent physical properties as those of a typical HCFC-141b formulation and with less than 24mW/mK thermal insulation value. Physical properties, such as dimensional stability and compressive strength, of the low HFC-245fa/high water generic formulation and the HCFC-141b formulation are compared in Table 4. Foams were evaluated after 24 hours aging at -30^{o}C and 95^{o}C as per ASTM D-2126-09. Furthermore, the compressive strength of foams was tested at both parallel and perpendicular directions as per ASTM D-1621-10. As shown in Table 4, it is evident that, even with a low dosage of HFC-245fa, the formulation provides comparable compressive strength and dimensional stabilities to those of the typical HCFC-141b formulation. Note that it is understandable that the lambda value of the HCFC-141b formulation is much superior to the low HFC-245fa/high water generic formulation because the former contains three times higher levels of the hydrofluorocarbon blowing agent.

Table 4. Comparison of Foam Properties of the Generic and the HCFC-141b Formulations

Formulation	***HCFC-141b***	***Low 245fa/High Water***
Free Rise Density, kg/m^3	30.0	31.0
Core Density, kg/m^3	37.0	37.1
Lambda, mW/mK		
at 10°C	19.96	23.14
at 24°C	21.75	25.14
Compressive Strength, kPa		
Parallel	135	132
Perpendicular	120	93
Dimensional Stability, %		
at -30°C	<2	<2
at 95°C	<2	<2

PRODUCTION TRIAL EVALUATION

Before the actual production trial, a system house, Bayer made an additional change to the formulation reducing the HFC-245fa dosage level from 7pbw to 5pbw. Surprisingly, there is no significant difference in either thermal or physical properties between the two formulations evaluated. Properties of both formulations, one with 7pbw HFC-245fa and the other with 5pbw, and shown in Table 5.

Table 5. Comparison of Foam Properties of Low 245fa/High Water Formulations		
Formulation	***7 pbw***	***5 pbw****
Foam Density, kg/m^3	39.8	39.1
Lambda, mW/mK		
at 10°C	23.05	N/A
at 25°C	24.80	25.08
at 35°C	26.26	26.50
Compressive Strength, kPa		
Parallel	142	130
Perpendicular	92	80
Dimensional Stability, %		
at -29°C, 24hrs	-0.14	0.20
at 90°C, 24 hrs	1.20	0.06
at 75°C/95%RH, 24 hrs	-4.09	-2.36

- Bayer Formulation

Production trials were conducted in an Article V country, using the formulation with 5pbw HFC-245fa dosage level. A typical high pressure foam machine, which is commonly used in discontinuous panel application, was utilized to prepare foam for evaluation. Detailed physical and thermal properties are listed in Table 6. During the production trial, it was observed that the processing behavior of the system with 5pbw HFC-245fa is comparable to or better than the conventional HCFC-141b system. The system with 5pbw HFC-245fa demonstrates no flowability and demold-time problems to fill a panel more than 8.35m in length. Furthermore, the adhesion strength and foam consistency are also adequate as per customer specifications and comments.

Table 6. Production Trial Evaluation of Formulation with 5pbw HFC-245fa	
Properties	
Foam Density, kg/m^3	41
Core Density, kg/m^3	36
Lambda, mW/mK	
at 25°C	24
at 35°C	25
Compressive Strength, kPa	
Parallel	159
Perpendicular	151
Dimensional Stability, %	
at -20°C, 24hrs	-0.04
at 25°C, 24 hrs	0.09
at 70°C/95%RH, 24 hrs	0.22
Closed Cell Content, %	93.8

EQUIPMENT RECOMMENDATIONS

With no flammability risk related to any of the listed potential ignition sources, we found no modification related to possible ignition source and common static electricity is necessary for processing and discharging equipment when using HFC-245fa. On the other hand, flammable blowing agents, such as hydrocarbons, investments are usually required to modify or upgrade storage vessel, processing equipment and facility ventilation in order to eliminate potential ignition sources and implement stricter safety standards and handling procedures.

It is evident that successful foam production trials of the low HFC-245fa/high water formulation can be conducted using existing or conventional equipment for the HCFC-141b system. Depending on the preferred condition of polyol blend which the OEMs would like to receive from system house, corresponding handling method is required to ensure a smooth production run. As a matter of fact, we found some OEMs prefer to have polyol and blowing agent pre-blend while others may like to blend the blowing agent onsite. Recommendations are provided to further facilitate the processing of the low HFC-245fa/high water system in Article V countries, such as India and those in the Middle East region on different scenarios with either high or low pressure machine. These recommendations and are summarized in Table 7.

Table 7. Equipment Recommendations: Low 245fa/High Water System in Article V Countries

<table>
<tr><th>Scenarios</th><th>High Pressure Machine</th><th>Low Pressure Machine</th></tr>
<tr><td>Polyol Pre-blends
(w/ ≤ 15% HFC-245fa)</td><td>• Chiller is required to cool the polyol and polyol pre-blend tank
• Pressure, up to 1 bar, is necessary to day tank to maintain temperature of <22°C</td><td>• Pressure, up to 1 bar, is necessary to polyol tank
• Low pressure recirculation and cooling are required on polyol</td></tr>
<tr><td>Polyol Pre-blends
(w/ > 15% HFC-245fa)</td><td colspan="2">• Close pumping system with either transfer pump or drum pump is recommended to transfer the polyol preblend to the tank
• Pressure, up to 1 bar, is necessary for the tank
• Only transfer pre-blend when needed.</td></tr>
<tr><td>Blending Polyol and Blowing Agent Onsite</td><td colspan="2">• Pressure, minimum 1 bar, is required for the day tank
• Chiller is required to cool the polyol
• Agitate thoroughly under head pressure</td></tr>
<tr><td>Polyol Pre-blends in Drums</td><td colspan="2">• Use of a closed pumping is recommended, if available to prevent frothing</td></tr>
</table>

CONCLUSIONS

HFC-245fa is a non-flammable, zero ODP blowing agents which produces foams with equivalent or better physical and thermal properties than HCFC-141b. As a sole blowing agent in rigid polyurethane applications, HFC-245fa provides superior performance compared to other available alternatives for the HCFC-141b phase-out. Both lab studies and scale-up field production trial have confirmed that HFC-245fa offers excellent performance for different rigid polyurethane foam applications in many Article V countries when co-blown with high amount of water.

REFERENCES

1. J. Bowman, D. Williams, "HFC-245fa Foam Equipment Considerations" Proceedings of Polyurethane Expo 2001

2. D. Williams, "Enovate 3000 Blowing Agent: A Versatile and Cost Effective Blowing Agent Technology for Rigid Foam" Proceedings of Polyurethane Expo 2002

3. J. Ling, "HFC & Beyond, Energy Efficient Cost Effective HCFC Replacement Technologies for Rigid Polyurethane Foams", Proceeding of PUTECH India 2008

BIOGRAPHY

Pranav Mehta

Pranav holds an M.Sc degree in Applied Chemistry from M.S University of Baroda, India and an M.S degree in Macromolecular Chemistry from University of Detroit-Mercy, Detroit, USA. He is currently working as Foam Applications Leader for EMEAI region for the Honeywell India Tech Centre, in Gurgaon, India. He has worked in all areas of polyurethane foam technology in past 26 years in polyol systems, appliance, automotive, construction and other applications. Pranav joined Honeywell in 2008 and currently leads the R&D efforts of blowing agent in the Honeywell India Tech Centre in India.

Abhijit Borgohain

Abhijit holds a M.Sc. degree in Polymer Chemistry from Tezpur Central University (Assam), India. He is currently associated with Honeywell India Tech Centre in Gurgaon, India as PU foam application specialist. He has gained significant exposure for the last 7 years in rigid polyurethane foam technology, specifically in design and development of formulations and their applications. He has worked extensively with customers across India, Middle East, USA and China. He is deft in execution of line trial and know-how approach to lower formulation cost. He is adept with designing and product development and implementing process initiatives to enhance efficiency and productivity. Abhijit joined Honeywell in 2010.

Jim Y.K. Ling

Jim holds an M.Eng degree in Chemical Engineering and Applied Chemistry from University of Toronto, Canada and an MBA degree from Schulich School of Business, Toronto, Canada. He is also a registered Professional Engineer under PEO in the province of Ontario, Canada. He has worked as a research and development scientist for ShawCor Ltd. in the spray applied rigid polyurethane foam sector for thermal insulation applications. Jim joined Honeywell in 2007 and is currently a global program leader in the blowing agent technical service and development group, with primary responsibility for pour-in-place foam applications of fluorocarbon products.