

FORANE[®]
BLOWING AGENT

Fluorochemicals

Forane[®] FBA 1233zD
Blowing Agent
Technical Profile





INTRODUCTION

Energy is critical for the economy. In recent years, concerns about energy costs have increased, and standards for energy efficiency have become more stringent to ensure quality of life and sustain a green environment. Of the energy we consume today, a significant amount is lost due to poor insulation. Rigid foams, including polyurethane (PUR) foams and polyisocyanurate (PIR) foams, are commonly used for thermal insulation in appliances and in residential and commercial buildings because they help provide higher energy efficiency. Blowing agents are vital components and are responsible for the outstanding thermal performance rigid foams.

Arkema's Forane® FBA 1233zd, trans-1-chloro-3,3,3-trifluoropropene is a non-flammable, liquid blowing agent with a boiling point close to room temperature. Forane® FBA 1233zd low global warming potential (GWP) blowing agent is designed for most PUR applications, including appliances, pour-in-place, spray, and PIR boardstock. Arkema has granted patents on 1233zd use in Foam applications throughout the world.

TABLE 1: PROPERTIES OF FORANE® FBA 1233zd BLOWING AGENT

CHEMICAL NAME	trans-1-chloro-3,3,3-trifluoropropene
CAS NUMBER	102687-65-0
FORMULA	CHCl=CH-CF ₃ (E)
MOLECULAR WEIGHT (g/mol)	130.5
BOILING POINT (°C/°F)	18.6/65.5
VAPOR THERMAL CONDUCTIVITY ¹ mW/(m.K) or (BTU.in)/(ft ² .hr.°F) AT 20°C/68°F	9.94/0.0689
LIQUID THERMAL CONDUCTIVITY ¹ mW/(m.K) or (BTU.in)/(ft ² .hr.°F) AT 20°C/68°F	88.35/0.6127
VAPOR DENSITY ¹ (kg/m ³) AT 20°C/68°F	6.10
LIQUID DENSITY ¹ (g/cm ³) AT 20°C/68°F	1.27
VAPOR PRESSURE ¹ (mmHg) AT 20°C/68°F	809
VAPOR VISCOSITY ¹ (cP) AT 20°C/68°F	0.010
LIQUID VISCOSITY ¹ (cP) AT 20°C/68°F	0.319
SURFACE TENSION ¹ (dyne/cm) AT 20°C/68°F	14.039
LATENT HEAT OF VAPORIZATION AT ¹ 20°C/68°F (kJ/kg/BTU/lb)	193.3/83.1
ATMOSPHERIC LIFE ² (DAY)	26
GWP ²	1
ODP ³	~ 0
FLASH POINT ⁴	None
FLAMMABILITY LIMIT ⁵ (VOL. %) LFL/UFL	None/None
KAURI-BUTANOL ⁶ (KB) VALUE	27

TABLE 2: REGULATORY INFORMATION OF FORANE® FBA 1233zd BLOWING AGENT

US EPA SNAP STATUS	Approved
US TSCA CHEMICAL INVENTORY STATUS	Listed

TABLE 3: TRANSPORTATION INFORMATION OF FORANE® FBA 1233zd BLOWING AGENT

UN NUMBER	3163
PROPER SHIPPING NAME	Liquefied gas, n.o.s
TECHNICAL NAME	trans-1-chloro-3,3,3-trifluoropropene
CLASS	2.2
MARINE POLLUTANT	no

PROPERTIES

Arkema evaluated a range of new blowing agents, formerly known as the "AFA series," designed for most polyurethane (PUR) applications, including appliances, pour-in-place (PIP), spray, and polyisocyanurate (PIR) boardstock. The AFA series includes both liquid and gas blowing agents that possess very low GWP and negligible ozone depletion potential. We selected Forane® FBA 1233zd as our choice of a 4th generation, low GWP liquid blowing agent because of its physical, environmental, and toxicology properties, as summarized in Tables 1 and 2.

TRANSPORTATION

Based on the properties of Forane® FBA 1233zd blowing agent, Arkema has established the following guidelines for transport (Table 3).

TABLE 4: METALS COMPATIBILITY OF FORANE® FBA 1233zd BLOWING AGENT

METAL	COMPATIBILITY
Steel	✓
Stainless steel	✓
Magnesium	✓
Aluminum	✓
Zinc	✓
Silver	✓
Copper	✓
Phosphorus bronze	✓
Brass	✓
Tin	✓
Solder	✓
Tin plate	✓
Cadmium plated	✓
Nickel plated	✓

TABLE 5: PLASTICS COMPATIBILITY OF FORANE® FBA 1233zd BLOWING AGENT

METAL	COMPATIBILITY
PBT (polybutylene terephthalate)	✓
PTFE (polytetrafluoroethylene)	✓
PVC	✓
Zytel® (polyamide 6)	✓

TABLE 6: ELASTOMER COMPATIBILITY OF FORANE® FBA 1233zd BLOWING AGENT

ELASTOMER	COMPATIBILITY
Neoprene	✓
Polyacrylate	
Viton® (fluoroelastomer)	
EPDM (ethylene propylene diene M-class rubber)	✓
Hypalon® (chlorosulfonated polyethylene)	✓
Natural rubber	
Silicone rubber	
SBR (styrene-butadiene rubber)	✓
NBR (nitrile butadiene rubber)	✓

ENVIRONMENTAL

Forane® FBA 1233zd blowing agent was designed to meet the requirement of a 4th generation, low GWP product. The global warming potential² of Forane® FBA 1233zd blowing agent is 1.

Similar to hydrofluorocarbons (HFCs), Forane® FBA 1233zd blowing agent should not be considered a VOC molecule due to its low maximum incremental reactivity (MIR). However, as a member of Responsible Care®, Arkema aims to minimize any releases into the environment. Any disposal or treatment of wastes containing Forane® FBA 1233zd blowing agent should be undertaken within the guidelines set by Responsible Care®.

TOXICITY

Forane® FBA 1233zd blowing agent has been approved for polyurethane foam uses by the U.S. EPA under its SNAP program. As a part of the SNAP requirements, an Occupational Exposure Limit (OEL) has been established for handling the material during foam preparation or manufacturing. A user of a chemical should always read the label and thoroughly review its Safety Data Sheet before use.

STABILITY

Forane® FBA 1233zd was studied at 100°C for 15 days, no chemical reaction or degradation was observed. It is therefore considered stable for storage and use.

COMPATIBILITY WITH METALS

The exposure of various metals to Forane® FBA 1233zd blowing agent was evaluated; measuring the weight change or the extent to which the metal coupons have been dissolved determines the corrosivity of Forane® FBA 1233zd blowing agent. The study shows that Forane® FBA 1233zd blowing agent is compatible with stainless steel, carbon steel, copper, brass, aluminum, and The test procedure followed ASTM G31-72 (Reapproved 2004) – Standard Practice for Laboratory Immersion Corrosion Testing of Metals. Three cleaned metal coupons were placed into the test vessel: one completely submerged in the solution, one half submerged in the solution, and one exposed only to the vapor phase. Forane® FBA 1233zd blowing agent was added to the test vessel, which was then sealed and connected to the reflux condenser. Once the temperature reached the boiling point of Forane® FBA 1233zd blowing agent, testing continued for 168 hours, after which the coupons were analyzed for corrosion.

COMPATIBILITY WITH PLASTICS AND ELASTOMERS

Arkema used the following procedures to determine compatibility of Forane® FBA 1233zd blowing agent with plastics and elastomers. Three dog-bone shaped samples were prepared from each of the materials shown just in tables 5 and 6; typical dimensions of the dog-bone were 75 mm x 4 mm x 2 mm (length x width x thickness). Each piece was introduced into a test tube filled with Forane® FBA 1233zd blowing agent. The tube was sealed and placed in a water bath kept at a temperature slightly above the boiling point of Forane® FBA 1233zd blowing agent for 5 minutes, 24 hours, or 100 hours. At the end of each designated time period, the elastomer or plastic was removed from the test tube and measured for dimensions and weight. The sample was then subjected to a tensile test with crosshead speed of 50 mm/min and the distance between grips set at 30 mm.

All four plastic substrates tested are compatible with Forane® FBA 1233zd blowing agent. HFO 1233zd blowing agent is compatible with neoprene, EPDM, Hypalon®, SBR and NPR. It is not recommended to be in contact with polyacrylate, Viton®, natural rubber, and silicone rubber. Among the compatible elastomers, EPDM is preferred due to its lowest loss of weight after 100 hours of immersion in Forane® FBA 1233zd blowing agent.



STORAGE AND HANDLING

Forane® FBA 1233zd blowing agent should only be stored in an approved cylinder that is in a cool and well ventilated area. If Forane® FBA 1233zd blowing agent needs to be repacked into any vessel different from the original shipping package Arkema's Technical Service Department should be contacted in advance to ensure the new container meets all requirements. The container and its outlet fitting(s) should be protected from physical damage, such as puncturing and denting, and should never be exposed to flame, excessive heat, or direct sunlight. The container valve(s) should be closed if the container is not in use.

Forane® FBA 1233zd blowing agent should not be pressurized in the presence of air and oxygen. If pressurization is necessary, it is recommended that dry nitrogen be used. If any additional information is needed, please contact the Arkema Inc. Technical Service Department.

APPLICATION

Forane® FBA 1233zd blowing agent is a cost effective and comprehensive solution to meet stricter energy standards with low environmental impact. It has been tested in applications such as, but not limited to, appliance, pour-in-place, panels, and spray foam using existing equipment and tooling and requiring no modifications to the current foam process. Foams blown with Forane® FBA 1233zd blowing agent typically have very good insulation and other properties.

TABLE 7: VAPOR PRESSURE OF FORANE® FBA 1233zd BLOWING AGENT AT DIFFERENT TEMPERATURES

TEMPERATURE		PRESSURE
(°C)	(°F)	(bar)
-15	5	0.23
-10	14	0.30
-5	23	0.38
0	32	0.48
5	41	0.59
10	50	0.73
15	59	0.89
20	68	1.08
25	77	1.30
30	86	1.55
35	95	1.83
40	104	2.16
45	113	2.53
50	122	2.94
55	131	3.40
60	140	3.92
65	149	4.50
70	158	5.13

Figure 1: Temperature (°F/°C) vs. Vapor Pressure of Forane® FBA 1233zd Blowing Agent

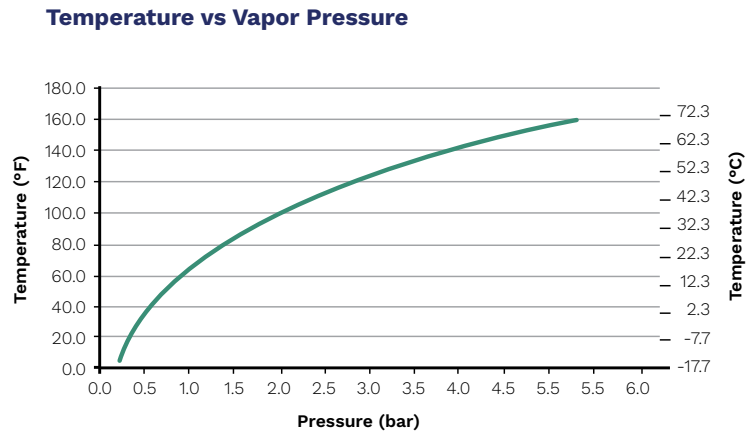


Figure 2: Temperature (°F/°C) vs. Density of Forane® FBA 1233zd Blowing Agent

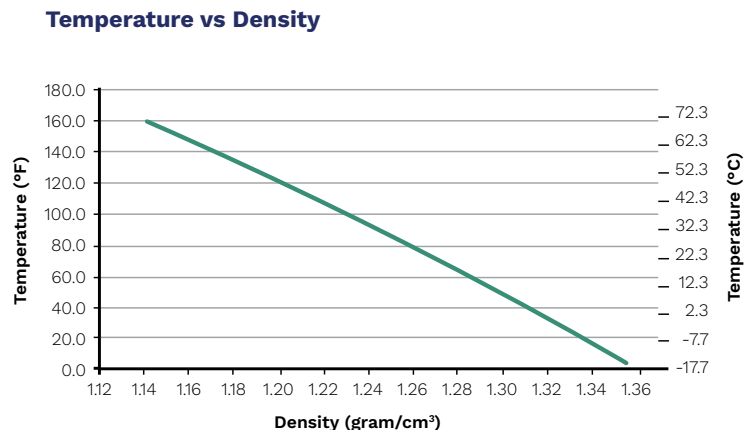


TABLE 8: DENSITY FORANE® FBA 1233zd BLOWING AGENT AT DIFFERENT TEMPERATURES

TEMPERATURE		DENSITY
(°C)	(°F)	(gram/cm ³)
-15	5	1.35
-10	14	1.34
-5	23	1.33
0	32	1.32
5	41	1.31
10	50	1.30
15	59	1.28
20	68	1.27
25	77	1.26
30	86	1.25
35	95	1.24
40	104	1.22
45	113	1.21
50	122	1.20
55	131	1.18
60	140	1.17
65	149	1.16
70	158	1.14

MISCIBILITY

Table 9 lists the various polyols and isocyanates examined for miscibility with Forane® FBA 1233zd blowing agent. Blends were prepared by adding a predetermined weight of polyol to a 125ml (~4 oz.) clear Boston Round bottle with Taperseal lined cap. Forane® FBA 1233zd blowing agent was then added to the appropriate weight of polyol to obtain 5, 10, 15, 20, 25 or 30 weight percent of blowing agent, i.e. one bottle for each polyol and weight percent level of blowing agent.

Weights of both components were adjusted in order to maintain a similar volume and headspace in each bottle. Bottles were immediately capped and placed on a roller mixer for several minutes until thoroughly mixed. The blends were allowed to stand for 24 hours before being reweighed to ensure no loss of blowing agent. Visual observations were made of the blend condition, i.e., stable solution (clear), stable emulsion (cloudy, but not separated), or if the material showed signs of separation. Observations were repeated after one week at room temperature.

TABLE 9: MISCIBILITY FORANE® FBA 1233zd BLOWING AGENT IN POLYOLS AND ISOCYANATES

	OH Value*	Viscosity**	Maximum Wt%***
GLYCERINE BASED POLYETHER POLYOLS			
Carpol® GP-700	230-250	250	30
Carpol® GP-725	230-250	250	30
Carpol® GP-4000	39-42	700	30
Carpol® GP-4520	34-38	890	30
AMINE BASED POLYETHER POLYOLS			
Carpol® TEAP-265	625-645	470	30
Carpol® EDAP-770	757-783	56,000	30
Jeffol® AD-310	310	2,400	30
SUCROSE BASED POLYETHER POLYOLS			
Jeffol® SG-360	360	3,500	30
Jeffol® SD-361	360	2,500	30
Jeffol® SG-522	520	27,000	30
Voranol® 490	490	5,500	30
Carpol® SPA-357	335-365	2,500	30
MANNICH BASED POLYETHER POLYOLS			
Jeffol® R-425X	425	4,500	30
Jeffol® R-470X	470	8,200	30
SORBITOL BASED POLYETHER POLYOLS			
Jeffol® S-490	490	9,000	30
AROMATIC POLYESTER POLYOLS			
Terate® 5100	295	6,000	20
Terate® 2541	240	3,200	30
Terate® 3510	240	6,000	30
Stepanpol® PS-2352	240	3,000	20
Terol® TR-925	295-315	11,000	30
POLYMERIC MDI			
Rubinate® M	31.2	190	30
Papi™ 580N	30.8	700	30

*Per manufactures' literature

**Centipoise at 25°C per manufacturer's literature

***Maximum level tested

Reference:

¹ Arkema Internal Studies

²Reference: Phys. Chem. Chem. Phys., 2012, 14, 1735-1748, Atmospheric chemistry of t-CF₃CHQCHCl: products and mechanisms of the gas-phase reactions with chlorine atoms and hydroxyl radicals; M. P. T. J. Wallington

³Atmospheric Lifetime Determination for the Hydrochlorofluoroolefin" Research work by National Institute of Science and Technology (NIST), Gaithersburg, Maryland under CRADA CN-5094 in 2008

⁴Arkema Internal Studies, determined by ASTM D 3278-96

⁵Arkema Internal Studies, determined by ASTM E681

⁶Arkema internal Studies, determined by ASTM D1133 KB

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Global warming potential (GWP) values are relative to carbon dioxide on a 100-year basis and were obtained for the Fifth Assessment Report (AR5) of the Intergovernmental Panel on Climate Change (IPCC).

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