3M

Technical Brief

Novec™ 1230
Fire Protection Fluid

Environmental properties of Novec 1230 Fluid

3M™ Novec™ 1230 Fire Protection Fluid was developed as an environmentally responsible extinguishing agent. This total flooding clean agent is the first halogenated halon alternative to address not only the concerns of stratospheric ozone depletion but also those related to climate change (i.e., global warming).

Definitions

When speaking of halogenated compounds, several terms relating to their environmental impact are commonly used. The following provides a brief explanation of what these terms mean.

Ozone Depletion Potential (ODP)—An index that provides a relative measure of the effect a compound has on the stratospheric ozone layer. The halogens bromine and chlorine are known to cause depletion of the ozone layer. Each atom of these halogens can react with thousands of ozone molecules, collectively contributing to a thinning of the ozone layer. The halogen fluorine, however, has been shown to have no effect on the ozone layer. Novec 1230 fluid is a highly fluorinated ketone containing no chlorine or bromine. As a result, the ODP for Novec 1230 fluid is zero, meaning it has no effect on stratospheric ozone.

Global Warming Potential (GWP)— A parameter that provides a relative measure of the possible climate impact due to the presence in the atmosphere of a compound that acts as a greenhouse gas. The two primary characteristics that determine whether a compound will act as a greenhouse gas are absorption of infrared energy and persistence in the atmosphere.

All organic compounds absorb infrared energy. Compounds that contain carbon-fluorine bonds typically exhibit strong infrared absorption. If these compounds are also atmospherically long-lived, the material will have a high GWP. What sets Novec 1230 fluid apart from the first generation of halogenated halon alternatives is its extremely short atmospheric lifetime.

The previous halon replacements are long-lived in the atmosphere–taking tens, hundreds or even thousands of years to degrade after they are emitted. In contrast, Novec 1230 fluid degrades very rapidly when released to the atmosphere. Exposure to natural sunlight causes this material to break up in a matter of several days. However, this unique material remains stable in normal storage conditions as a component of a fire protection system.

How Global Warming Potential is Calculated

The GWP of a compound, as defined by the Intergovernmental Panel on Climate Change (IPCC) [1], is calculated as the integrated radiative forcing due to the release of 1 kilogram of that compound relative to the warming due to 1 kilogram of CO_2 over a specified period of time (the integration time horizon (ITH)):

$$GWP_x = \frac{\int_0^{ITH} F_x C_{xo} \exp(-t/\tau_x)\, dt}{\int_0^{ITH} F_{CO_2}\, C_{CO_2}(t)\, dt}$$

F is the radiative forcing per unit mass of a compound (the change in the flux of radiation through the atmosphere due to the IR absorbance of that compound), C is the atmospheric concentration of a compound, τ is the atmospheric lifetime of a compound, t is time and x is the compound of interest [1].

The commonly accepted ITH used for comparative purposes is 100 years, representing a compromise between short-term effects (20 years) and longer-term effects (500 years or longer). The concentration of an organic compound, x, in the atmosphere is assumed to follow pseudo first order kinetics (i.e., exponential decay). The concentration of CO_2 over that same time interval incorporates a more complex model for the exchange and removal of CO_2 from the atmosphere (the Bern carbon cycle model).

Atmospheric Lifetime of Novec 1230 Fluid

A study conducted by Taniguchi and colleagues [2] examined the atmospheric loss mechanisms for $C_2F_5C(O)CF(CF_3)_2$ commercially known as 3M™ Novec™ 1230 Fire Protection Fluid. The authors of this study determined that this compound does not react with hydroxyl radical (OH) but that substantial decay occurs when exposed to UV radiation. The authors measured the UV cross-section for Novec 1230 fluid, finding a maximum wavelength of absorbance at 306 nm. Because this compound shows significant absorbance at wavelengths above 300 nm, a wavelength higher than that required for UV light to reach the ground, photolysis in the lower atmosphere will be a significant removal mechanism or sink for this compound.

The rate of photolysis under atmospheric conditions and the mechanism of decomposition of this compound were investigated by Taniguchi, et al. The rate of photolysis of Novec 1230 fluid was measured relative to that of Acetaldehyde (CH_3CHO), which has a known atmospheric lifetime by photolysis of 3 to 4 days. The photolysis rate of the Novec 1230 fluid leads to an atmospheric lifetime of 4.5 to 15 days or “approximately 1-2 weeks”. The authors of this study have concluded that their work is consistent with a previous study conducted by 3M, which found the atmospheric lifetime of Novec 1230 fluid to be on the order of 5 days or about one week [3].

Impact on Climate Change

The potential for 3M™ Novec™ 1230 fluid to have an impact on the radiative balance in the atmosphere (i.e., climate change) is limited by its very short atmospheric lifetime and low global warming potential. The quantitative IR cross-section of Novec 1230 fluid was measured in accordance with section 4.6 of the U.S. EPA FTIR Protocol [4]. The IR measurements were made with a 0.5 cm-1 spectral resolution at 293K on a MIDAC (Model I2001) FTIR spectrometer, which employs a mercury-cadmium-telluride infrared detector maintained at 77 K. The experimental setup used a nominal 4 m path length, which was calibrated using certified ethylene gas standards.

Using the measured IR cross-section and the method of Pinnock et al. [5] the instantaneous radiative forcing for Novec 1230 fluid is calculated to be 0.50 $Wm^{-2}ppbv^{-1}$. This radiative forcing value and a one-week atmospheric lifetime results in GWP values as shown below using the IPCC 2001 method [1]. The most commonly cited GWP value is that calculated using a 100-year integration time horizon.

Compound	Atmospheric lifetime (years)	Radiative Forcing (Wm-2ppbv-1)	20 year ITH	100 year ITH	500 year ITH
$C_2F_5C(O)CF(CF_3)_2$ Novec 1230 fluid	0.014	0.50	4	1	0

This GWP calculation and the method of Pinnock et al. use the assumption that the compound emitted to the atmosphere will be well mixed throughout the troposphere. A material as short lived as Novec 1230 fluid cannot reasonably meet this condition due to its rapid removal from the atmosphere. As a result, this calculation overestimates the GWP for this compound. For this reason, Taniguchi et al. have concluded that "with an atmospheric lifetime of 1-2 weeks, $CF_3CF_2C(O)CF(CF_3)_2$ will have a global warming potential that, for all practical purposes, is negligible."

Direct vs. Indirect Global Warming Potential

The GWP calculated thus far is the direct GWP, which accounts for the potential warming effects due to the parent compound released to the atmosphere. In some cases, it is possible to calculate an indirect GWP in an attempt to account for the potential warming effects due to the atmospheric degradation products from that compound. While IPCC has indicated that these indirect GWPs are much less certain [1], it is possible to estimate an indirect GWP for Novec 1230 fluid since its atmospheric chemistry is well understood.

The decomposition mechanism determined by Taniguchi et al. indicates Novec 1230 fluid produces fluorinated degradation products, which are atmospherically short-lived [6], resulting in negligible GWP. However, this decomposition mechanism indicates that one mole of Novec 1230 fluid will produce 4 moles of CO_2. Since the direct GWPs are calculated on a mass basis, the indirect GWPs need to be calculated on this basis as well. Therefore, release of 1 kg of Novec 1230 fluid to the atmosphere will produce 0.56 kg of CO_2.

1000 g Novec 1230 fluid/(316 g/mol)(4 mols CO_2/mol Novec 1230 fluid)(44 g/mol) = 556 g CO_2

This results in an indirect GWP of 0.56, regardless of the time horizon chosen. Therefore, both the direct and indirect GWP for Novec 1230 fluid are less than one. Clearly, compounds with such low GWP are not of concern with respect to potential climate change.

Comparison to other Halocarbons

Highly fluorinated compounds typically have a GWP of 1000 or more, meaning that 1 kg of that compound has the same climate effect as one ton or more of CO_2. For example, the GWPs of HFC-227ea, HFC-125 and HFC-23, all first generation halon replacements, are 3500, 3400 and 12,000, respectively. Due to the exceptionally short atmospheric lifetime of Novec 1230 fluid, its GWP is extremely low – only one, the equivalent to that of CO_2. Such a low GWP is virtually unprecedented for a fluorochemical, making Novec 1230 fluid a unique and sustainable alternative technology to halon and the first generation of replacements.

References

1. IPCC (Intergovernmental Panel on Climate Change), *Climate Change 2001: The Scientific Basis*, edited by J. T. Houghton, et al., Cambridge University Press, Cambridge, U.K., 2001.
2. Taniguchi, N., Wallington, T.J., Hurley, M.D., Guschin, A.G., Molina, L.T., Molina, M.J., *Journal of Physical Chemistry A*, 107(15), 2674-2679, 2003.
3. Plummer, G., "Laboratory measurements and calculations related to the photo-dissassociation of L-15566 in the Earth's lower atmosphere," 3M Environmental Laboratory Report Number E01-0549, 2001.
4. Addendum to Method 320 – Protocol for the Use of Extractive Fourier Transform Infrared (FTIR) Spectrometry for the Analyses of Gaseous Emissions from Stationary Sources (40 CFR Part 63).
5. Pinnock, S., Hurley, M.D., Shine, K.P., Wallington, T.J., Smyth, T.J., *J. Geophys. Res.*, 100, 23227, 1995.
6. Wallington, T.J., Schneider, W.F., Worsnop, D.R., Nielsen, O.J., Sehested, J., Debruyn, W.J., Shorter, J.A., *Environ. Sci. Technol.*, 28, 320, 1994.

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