VISCOPLEX® cold flow improvers (CFIs)

LOW-TEMPERATURE SOLUTIONS FOR FUEL CHALLENGES
The Oil Additives specialists at Evonik are global leaders in the development of high-performance fuel and lubricant additives for use in automotive, hydraulic and industrial applications. State-of-the-art regional technology centers and manufacturing facilities linked through a global supply chain enable Evonik to reliably provide high-quality customized products and solutions to customers worldwide. Evonik’s team of fuel and lubricant specialists is poised to help OEMs, formulators and oil marketers get an edge and boost efficiency in a range of applications.

Biodiesel is a fuel composed of monoalkyl esters of long chain fatty acids derived from vegetable oil or animal fats, designated as B100. An example of the mechanism of biodiesel formation is shown in Figure 1. It is also commonly referred to as fatty acid methyl esters (FAMEs). It can be derived from different sources, such as rapeseed, soy, palm, tallow and used cooking oil. Each source also consists of a mixture of long-chain fatty acid esters, each differing in carbon chain length and degree of saturation. Thus, the biodiesel mixture can have components with a wide range of temperature properties. These properties, such as pour point (PP), cold filter plugging point (CFPP), etc., are quite varied, as indicated in Figure 2.

The primary negative influence on biodiesel cold flow properties comes from the crystallization of long-chain saturated fatty acid methyl esters. Failure to address this issue results in the inability to fully utilize these alternative fuels. Consequently, there is a vital need to improve these properties to meet the performance standards of current fuel specifications.
Evonik has developed VISCOPLEX® cold flow improvers (CFIs) for biodiesel fuels. Evonik’s VISCOPLEX® CFIs boost efficiency by:

- Reducing the Cold Filter Plugging Point (CFPP) of biodiesel B100 from different sources such as: rapeseed methyl ester (RME), soy methyl ester (SME), palm methyl ester (PME), tallow methyl ester (TME) and used cooking oil methyl ester (UCOME).

- Enabling blends of fatty acid methyl ester (FAME) feedstocks of various costs and levels of low-temperature performance to achieve an ideal performance/cost ratio.

- Optimizing the CFPP of blends of biodiesel with fossil diesel, meeting or exceeding required fuel specifications.

In order to combat these issues, a customized VISCOPLEX® cold flow improver (CFI) must act at the molecular level to alter the crystallization process and crystal morphology. Therefore, the effectiveness of the CFI depends on the distribution of its wax-interacting side chains along the polymer backbone. When a biodiesel blend containing an appropriate VISCOPLEX® CFI polymer is cooled, the waxy side chains of the CFI co-crystallize with the waxy components in the biodiesel (see illustrations in Figure 4 below). The polymer backbone interferes with the continued growth of the crystals, rendering them smaller in size. VISCOPLEX® CFIs can effectively alter the development of the crystal matrix and extend the temperature range of biodiesel fluidity.

**FIGURE 3: VISCOPLEX® CFI effect on the CFPP of PME+SME blends**

![Graph showing the CFPP effect of VISCOPLEX® CFI on PME+SME blends](image)

**FIGURE 4: How VISCOPLEX® CFIs modify wax crystals as temperature drops**

- **Without VISCOPLEX® CFI**
  - Crystallization of wax molecules below cloud point temperature
  - Mainly lateral growth, forming needles or plates
  - Wax crystal structure continues to grow
  - Large, structured crystal network, diesel fuel ceases to flow

- **With VISCOPLEX® CFI**
  - Co-crystallization occurs between wax molecules and VISCOPLEX® CFI crystalline units
  - VISCOPLEX® CFI modifies wax crystal growth
  - Interlocking of wax crystals is prevented, leading to smaller and more random structure.
  - No aggregation of gel-like wax network. Diesel fuel continues to flow through the filter.

**IMPROVE BIODIESEL PERFORMANCE WITH VISCOPLEX® COLD FLOW IMPROVERS**

FAMEs are a clear, solids-free liquid at room temperature and, upon cooling to cloud point (ASTM D2500), defined as the onset temperature of wax crystallization, the waxier components with higher melting points begin to crystallize.

Upon further cooling, the waxy crystals will continue to grow, eventually becoming large and numerous enough to stop or slow down the flow of the FAME through a filter. The highest temperature for 20 mL of fuel fails to pass through a standardized filter within 60 seconds as described by the ASTM D6371 Cold Filter Plugging Point (CFPP) test. As FAME temperature continues to decrease, crystals continue to grow in size, forming a network extending throughout the fluid that prevents it from flowing. The temperature at which the fluid ceases to flow is the Pour Point (PP), measured with the ASTM D97 method. Both CFPP and PP are important for FAME producers and users to prevent plugging from cold biodiesel, which could result in engine shutdown and loss of time and money.
Interaction of VISCOPLEX® CFIs with wax crystals resulting in low-temperature performance improvement

The mechanism is illustrated in the photomicrograph of rapeseed methyl ester crystals (RME) shown in Figure 4.

LOW-TEMPERATURE FILTRATION PERFORMANCE, CFPP

In the photomicrograph above on the left, crystals in the untreated RME sample have grown to ca. 50 microns or more and are large enough to plug diesel fuel filters and fail stringent CFPP requirements. The photomicrograph above and on the right represents the same sample treated with VISCOPLEX® CFI. The crystals are ca. 10 times smaller, enabling this treated biodiesel to more easily pass the CFPP test and to perform satisfactorily in actual service.

In addition to reducing wax crystal size, VISCOPLEX® CFIs can also improve low-temperature performance, demonstrated by the example in Figure 5 on the right. The figure shows a significant improvement of CFPP and PP of RME with only 0.3% of CFI-1. At 0.5% treat rate, a substantial decrease is achieved in CFPP and PP to -25°C and -36°C, respectively.

FIGURE 5: Significant CFPP reduction with VISCOPLEX® CFI
EFFECT ON THE LOW-TEMPERATURE STORAGE STABILITY OF BIODIESEL

The flow performance of biodiesel can deteriorate when stored at low temperature. Wax molecules in storage are given more time to rearrange and form stronger structures. Figure 6 shows the performance of VISCOPLEX® CFIs. Samples of treated and untreated SME were kept for three days at -5°C. Solidification of the untreated samples would likely pose severe problems when attempting to move the material out of a tank.

**Figure 6: VISCOPLEX® CFIs enhance biodiesel low-temperature storage stability**
VISCOPLEX® CFI HANDLING & APPLICATION

VISCOPLEX® CFIs should be added to fuel at temperatures well above the fuel’s cloud point. The dosing can be done in-line when fuel is pumped through pipes from one tank into another, or to the loading station, or directly into a tank that can provide adequate mixing. Before dosing, please make sure the temperature of the fuel is at least 10°C above its cloud point. The recommended VISCOPLEX® CFIs temperature is 40°C.

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Partner with the Oil Additives specialists at Evonik for custom formulation solutions that boost efficiency and future-proof business with a sharp competitive edge.
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