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## ЭКОЛОГИЧНАЯ ХИМИЯ ДЛЯ ЭКОЛОГИЧНОЙ ПРОМЫШЛЕННОСТИ SUSTAINABLE CHEMISTRY FOR SUSTAINABLE INDUSTRY

ДЖ. РИЦЦУТО, Ф. БУЧЕЛЛИ, М. ШАККАЛУГА, О. АВАТАНЕО,  
*Foundry Alfe CHEM s.r.l., Турин, Италия*

G. RIZZUTO, F. BUCELLI, M. SCIACCALUGA, O. AVATANEО,  
*Foundry Alfe CHEM s.r.l., Turin, Italy*

*Foundry Alfe Chem является промышленной компанией, работающей в области смазочных материалов и химических добавок для производственных процессов. Работа проходит в рамках находящейся на стадии становления программы «зеленой химии», которая приобретает все большее значение. Цель компании – разработка более экологически безопасных продуктов, используя сырьевые материалы из возобновляемых ресурсов. В частности, Foundry Alfe Chem имеет программу самообеспечения, которая предполагает, в обозримом будущем, прямое производство возобновляемого сырья. Компания разработала новую специализированную систему Olitema, целью которой является предложить новые высокотехнологические решения с полной экологической устойчивостью. В связи с этим Foundry Alfe CHEM создала новый продукт, который представляет собой открытие среди гидравлических жидкостей класса HFC: Ecosafe Plus представляет собой пожаробезопасную биоразлагаемую гидравлическую жидкость с прекрасными инженерно-техническими характеристиками, с высокой экологической устойчивостью и с лучшими гарантиями безопасности на рабочих местах. Его формула не содержит гликоль, что обеспечивает более легкую переработку отработанной жидкости по сравнению с традиционными гидравлическими жидкостями HFC на водно-гликолевой основе. Относительно технологических свойств Ecosafe Plus был подвергнут трибологическим испытаниям в аккредитованных лабораториях (4 Ball wear test ASTM D 4172, Ball on disc test ASTM 6425, Brugger test DIN 51347, Vickers test ASTM D 2882) вместе с тестом на совместимость эластомеров (ASTM D 471) и с тестом на биоразлагаемость (OECD 310 F).*

*Foundry Alfe Chem is an industrial reality working in the field of lubrication and chemical auxiliaries for industrial processes, which falls within the framework of the emerging and increasingly important «green chemistry». The goal of the company is to develop products that are more environmentally friendly by using raw materials from renewable sources; specifically, Foundry Alfe Chem has a program of self-sustainability that contemplates, for the foreseeable future, the direct production of renewable raw materials. The company has developed a new dedicated product line, Olitema, whose purpose is to offer highly technological solutions with complete environmental sustainability. In this context, Foundry Alfe CHEM has created a new product which represents a breakthrough in the class of HFC hydraulic fluids: Ecosafe Plus is a biodegradable fire-resistant hydraulic fluid with high engineering and technological performances, high environmental sustainability and the best security guarantees in workplaces. Its formulation is glycols-free, and it allows for easier disposal of the exhausted fluid, compared to a traditional water/glycol-based HFC hydraulic fluid. For what concern the technological properties, Ecosafe Plus has been tested by accredited laboratories with tribological trials (4 Ball wear test ASTM D 4172, Ball on disc test ASTM 6425, Brugger test DIN 51347, Vickers test ASTM D 2882), with elastomer compatibility test (ASTM D 471) and biodegradability test (OECD 310 F).*

**Ключевые слова.** Гидравлические жидкости класса HFC, биоразлагаемость, процесс смазки, устойчивая переработка, экологическая устойчивость, возобновляемость.

**Keywords.** HFC hydraulic fluid HFC class, biodegradability, lubrication, sustainable disposal, environmental sustainability, renewability.

### Introduction

Foundry Alfe Chem is an industrial reality, working in the field of lubrication and chemical auxiliaries for industrial manufacturing and processes, which falls within the framework of the emerging and increasingly important sector of «green chemistry».

The purpose of the company is to develop more eco-friendly products using raw materials from renewable sources. Foundry Alfe Chem has a self-sustainability program that provides for direct production of renewable raw materials at its own biorefinery.

In this context, the company, with headquarters and research center in Turin and production units in Turin, Milan and Brindisi, has developed a new dedicated product line, Olitema, whose purpose is to offer highly technological solutions with complete environmental sustainability. Foundry Alfe Chem thus offers a portfolio of innovative eco-compatible products, suitable for different types of process and intended for various industrial sectors, in particular foundry and metalworking.

The processing of metals involves hundreds of lubricants and chemical auxiliaries all along the production chain, from manufacturing of the lubricant to its use in metal processing and down to the final user, and even more raw materials. The metal, thus, comes into contact with different substances: if they present a danger, the danger can get to the final consumer.

Moreover, the increasingly more strict legislation imposes the abandonment of some of these hazardous substances, even drafting «black lists» of products the use of which should be avoided. It is therefore crucial that metal processing companies adopt highly performing products under a technological and safety profile.

Within this reality, there is space for a very innovative product that represents the highest expression of Foundry Alfe Chem industrial policies: Ecosafe Plus, a fire-resistant water-based hydraulic fluid, exempt from glycols, biodegradable and eco-friendly, which was awarded as «Product Innovation» during Metef 2014 [1].

### Olitema

Foundry Alfe Chem company aims to develop products that are more environmentally friendly by using raw materials from renewable sources; specifically, Foundry Alfe Chem has a program of self-sustainability that contemplates, for the foreseeable future, the direct production of renewable raw materials.

The corporate facilities include a biorefinery where many processes are developed to turn resources into products with the aim to switch from a petrochemical system to a technological choice increasingly based on the use of vegetal products both in terms of raw materials and chemical auxiliaries.

The project's ultimate goal is not only the production of renewable substances, but also the installation and the starting up of an industrial reality highly sustainable for the territory.

Thanks to the availability of 300–500 hectares of arable land, Foundry Alfe Chem realizes a complete cycle of production and processing of agricultural products with their transformation into materials directly usable as lubricants, chemical auxiliaries and industrial coatings or raw materials for the production of small artifacts.

Another purpose of Foundry Alfe Chem is to produce raw materials taking into account the need not to alter the appearance of the landscape, encouraging the tradition and the predisposition of local crops.

Foundry Alfe Chem is pursuing the following targets:

- Creation of a production chain that fully exploits land and aims to a controlled farming with as many as three bi-yearly harvests of non conventional crops – different from those used for the production of vegetal oils or biodiesel – that can be used as raw materials to meet the technological needs of the metalworking industry. Raw materials later undergo a secondary processing to be converted into chemical compounds for the industrial sector or chemical molecules for further processing (chemical-physical or enzymatic transformations, and/or subsequent organic synthesis).

- Reduction of the CO<sub>2</sub> emissions into the atmosphere in order to reach a negative balance between the CO<sub>2</sub> produced and that absorbed via chlorophyll photosynthesis.

- In-house production of electrical and thermal energy by means of photovoltaic panels, endothermic motors fed by biogas, lean gas and cooling water.

- Replacement of oil-based products with products from renewable sources as much as possible.

The biorefinery plant can be subdivided in 7 different lines:

1. Treatment of oilseeds with the production oil.
2. Treatment of green and sugary biomass with the production of sugars and cellulose.
3. Treatment of cattle waste with production of biogas and digested sludge.
4. Treatment of pruning, threshing residues and internal residues with production of syngas and poor gas.
5. Tertiary treatment for the processing of the obtained raw materials with production of lubricating oil, biodiesel, ethanol, bioplastics and other products derived from internal research.
6. Production of electricity and heat from biogas and poor gas.
7. Treatment of syngas to produce hydrogen and methane.

It is also possible to get polylactic acid and its comonomers to produce plastics destined mainly for the packaging industry, and special polyesters, based on the use of hydroxy acids or diols as comonomers, both obtained by fermentation.

Moreover, through anaerobic digestion processes is possible to obtain biogas to fuel engines for the production of electricity and heat, and compost to fertilize the soil.

### Negative balance on CO<sub>2</sub> emissions

To complete the design of environmental sustainability, Foundry Alfe Chem has committed itself to reduce its emissions of carbon dioxide in the planning and development of its biorefinery.

Its purpose is the stabilization of concentrations of greenhouse gases in the atmosphere at a level that would prevent anthropogenic interference with the climate system, and the reduction of greenhouse gas emissions.

The involved amount of energy and of carbon dioxide released are described in Table 1:

Table 1. CO<sub>2</sub> Balance

	Produced energy MWh/y	Absorbed energy MWh/y	Biomass ton/y	CO <sub>2</sub> absorbed for photosynthesis t/y	CO <sub>2</sub> released t/y
TOTAL	13,775	522	18000	46164	6390

The plant absorbs more carbon dioxide than the emitted quantity, so it is possible to conclude that all the processes of Foundry Alfe Chem biorefinery can be considered sustainable and environmentally acceptable.

To better understand the difference of the impact between the renewable resources and the petrochemical products, we can consider the following ratio, assuming as a comparison a CO<sub>2</sub> emission value of 100 for the petrochemical derivatives:

- Impact of the use of Olitema lubricants: -30
- Impact of the use of traditional lubricants: 100

Also considering the economical side, it is possible to notice that Olitema is absolutely competitive with petrochemical products; assuming as comparison term the cost of petroleum-based products with a value of 1, it is possible to establish the following ratio:

- Cost of Olitema sustainable products: 0,8
- Cost of petroleum-based products: 1

What emerges from these considerations is the evidence that the sustainability is not an additional cost, but it represents a resource to improve both the technological performances and the environmental impact of the industrial processes.

### Ecosafe plus

The product that best represents the philosophy and the commitment of Foundry Alfe Chem in the «green chemistry» is Ecosafe Plus, a new product which represents a breakthrough in the class of fire-resistant hydraulic fluids. Ecosafe Plus is a biodegradable and eco-friendly water-based hydraulic fluid (Type HFC and Viscosity Class ISO 46 and ISO 68), completely glycols-free.

Hydraulic systems often operate in difficult industrial processes and environments such as steel plants, molding, plastic deformations, die casting, handling of large products and foundries, in the presence of hot surfaces, molten metal or naked flames. In case of breakage of hydraulic circuits, the escape of high-pressure hydraulic fluid is a potential risk for fire and environmental contamination. Precisely for these severe applications, Foundry Alfe Chem has developed Ecosafe Plus; Ecosafe Plus is particularly suitable to be used in hydraulic circuits located near sources of heat, thanks to its complete non-flammability and security guarantees in case of fire.

Ecosafe Plus confirms the commitment of Foundry Alfe Chem in developing lubricants and auxiliary chemicals with high engineering and technological performances, high environmental sustainability and the best security guarantees in workplaces.

The formulation of this innovative product is based on a mixture of polymers and biopolymers and unlike conventional HFC hydraulic fluids, it is free from glycols (monoethylenic, diethylenic and others). This composition gives particular technological characteristics to the product and compared to traditional water/glycol based HFC hydraulic fluids allows greater ease of waste fluid disposal and higher environmental safety.

In addition, Ecosafe Plus has been subjected to various tests, carried out by accredited laboratories in order to evaluate and confirm its excellent performances combined with high environmental sustainability: fire-resistance, excellent performances during laboratory tests and during operation, high lubrication and resistance, high biodegradability, environmentally sustainable disposal, compatibility with elastomers.

Moreover, according to Italian and international regulations the product is not subject to any labeling [2], and the strict rules concerning transport by sea and the resulting restrictions for hydraulic fluids do not concern Ecosafe Plus [3].

### Lubricating performance

Ecosafe Plus has been tested by accredited laboratories, and has been compared with a traditional water/glycol product, in order to evaluate its lubricant characteristics.

The first test was performed with «Vickers pump» (test from ASTM D 2882 regulation [4]), where Ecosafe Plus wear-resistance was compared with that of a market leader water/glycol security hydraulic fluid. The test lasted 600 hours, after which Ecosafe Plus showed vanes, rotor and stator wearing equal to 25% of that measured after the same operating period for traditional products currently on the market and containing glycols.

Therefore, Ecosafe Plus has lubricating and wear-resistant performances that are four times higher than glycol-based products that have been on the market for years. The conditions under which Vickers test was carried out and the results of the test are summarized in tables 2 and 3.

Table 2. Operating conditions of Vickers test

Test Conditions	
Test Length, (hours)	600
Discharge Pressure, (psi)	2000
Inlet Fluid Temperature, (°C)	65
Pump Speed, (rpm)	1200
Outlet Volume, (GPM)	7,5

Table 3. Vickers test results about Ecosafe Plus compared with a market leader water/glycol-based hydraulic fluid

TEST RESULTS				
Weight loss (g)				
	Rotor	Vanes	Stator	Total weight loss (g)
Traditional Fluid	0,402	0,045	4,159	4,606
Ecosafe Plus	0,050	0,104	1,523	1,677

Moreover, «Vane on flat» test was conducted on Ecosafe Plus, comparing it with a HFDU fluid of reference: the product completed the 8h of testing without any noticeable failure; the friction and temperature were lower than the HFDU fluid of reference. The surface damage was slightly better than the reference, and the mass loss of the disc was less pronounced with Ecosafe Plus compared to the HFDU fluid (Fig. 1).

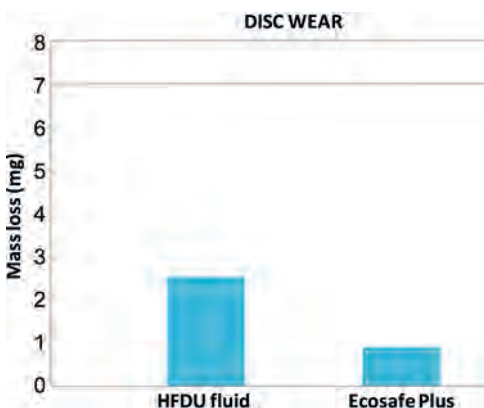


Figure 1. Mass loss of Ecosafe Plus compared to HFDU fluid after 8h of Vane Pump Test

Surface damage can also be noticed considering the roughness variation in vanes and disc (Ra surface parameter); the Ra surface parameter indicated that with Ecosafe Plus contacting surfaces are must polish compared to a HFDU fluid of reference, since Ra parameter decreased in all the cases (vanes and disc).

High lubricant performances also result in lower heat production due to wear and friction phenomena, therefore, Ecosafe Plus operating temperatures are more constant and tend to be lower than those of traditional products. Always in relation with what has been previously said, water evaporation is less noticeable and therefore, the value of product viscosity is more constant.

This results in even greater stability of the pH value, with less need of continuous and periodic analytical controls and refilling of water to compensate the evaporation phenomenon.

### Brugger test confirms high lubricity

Ecosafe Plus was tested also by Brugger test (DIN 51347 regulation [5]), in which it has clearly shown higher performance than the traditional product.

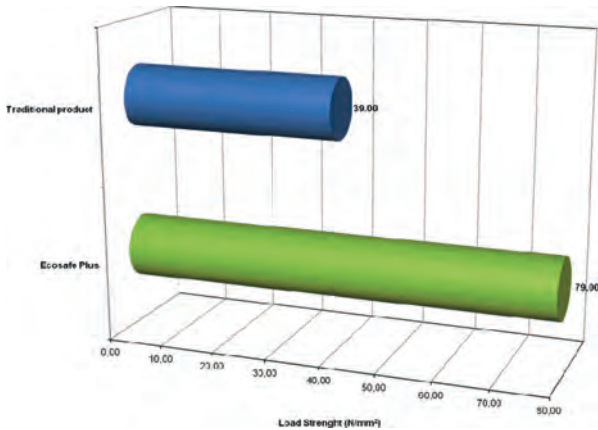


Figure 2. Brugger Test; Ecosafe Plus compared with a conventional market leader water/glycol-based hydraulic fluid

For what concern Ecosafe Plus, the test showed a load resistance equal to 79 N/mm<sup>2</sup>, double than traditional hydraulic fluid of reference (39 N/mm<sup>2</sup>) (Fig. 2).

Tribological tests carried out on the product confirm its physical and chemical stability during long operating applications and its high lubricity.

Ecosafe Plus has high resistance to chemical alterations and great reduction of deposits formation. This feature allows using Ecosafe Plus for a long time, as long as external contaminations are removed with an efficient filtration system.

Ecosafe Plus has chemical and physical characteristics that are highly constant during exercise (% H<sub>2</sub>O, viscosity, pH, etc.), thanks to its excellent lubricity and high stability of the raw materials of its composition (Table 4).

Table 4. Physical/chemical properties of Ecosafe Plus

Appearance:	clear liquid
Color:	red
Odor:	typical
pH:	8,5–9
Relative density (20 °C, g/ml):	1,05–1,10
Viscosity (40 °C, cSt):	41,0–50,6
Solubility:	water soluble
Flash point (°C):	none
Pour point (°C):	–20
Cloud point (°C):	≥70
Working temperature (°C):	40–70
Working pressure (bar):	up to 250 and more
<b>Filtration system (µm):</b>	5–10 min

### Fire resistance and FM Approval

Ecosafe Plus has also been tested with flammability trials, in order to evaluate its fire resistance properties and thus its safety during operation. Ecosafe Plus meets the requirements and therefore passes the following tests:

- Wick Test (ISO 14935): it measure the fire resistance of fluid when soaked into absorbent or flammable materials and the extent to which the fluids will propagate fire [6].
- Hot Manifold Test (ISO 20823): it reproduces a loss of fluid at low pressure on a surface at 700 °C [7].
- Spray Ignition test (ISO 15029): the fluid mist is sprayed on an oxy-acetylene flame [8].

As a further confirmation of its fire-resistance properties, Ecosafe Plus has been certified by the american FM Global, which in turn conducted several tests of resistance to fire [9].

The registration number of the certification (FM Approval Class 6930) is: 3052383.

### Complete compatibility with elastomers

A particular request that results from the needs of hydraulic oils users and that traditional HFC fluids often don't meet is compatibility with elastomers and seals that are generally used in hydraulic systems. This is the reason why Ecosafe Plus has been tested by accredited external laboratories about elastomers that are commonly used in «O rings», testing in accordance with ASTM D 471 regulation of compatibility with polymers (immersion in fluid for 166 h at 80 °C) [10].



Figure 3. Ecosafe Plus is compatible with elastomers and seals that are generally used in hydraulic systems

The test had an extremely positive outcome: Ecosafe Plus was compatible with red and white Silicon, Viton, Teflon, EPDM, polyurethane and NBR. These conditions are due to the absence of glycol in the product formulation (Fig. 3).

### High biodegradability reduces disposal costs

An important benefit from Ecosafe Plus innovative formulation is its high biodegradability.

The product has passed severe tests and was approved to be biodegradable ( $\geq 70\%$  biodegradation after 28 days) according to OECD 310 F regulation [11], unlike water/glycol hydraulic fluids of normal use ( $\leq 40\%$  biodegradation after 28 days). Biodegradability provides high environmental and work safety to the product, thanks to more environmental compatibility in every stage of the process (Fig. 4).

During the test, the product is not subject to any modification of its chemical-physical characteristics

nor to biological alterations, for which biodegradability does not affect Ecosafe Plus technical properties (Table 4).

Besides, the disposal of the exhausted product at its end life will prove to be easier and cheaper than the traditional hydraulic fluids, being possible to lean to a plant for the biological treatment plant of waste water or similar disposal systems.

Ecosafe Plus is not classified as dangerous and eliminates the costs and the disposal procedures as special waste.

In addition, dispersion or accidental spill of this product in areas that are sensitive to environmental pollution are easier to be cleaned-up and have lower reclamation costs.

Another very important point in favor of Ecosafe Plus is represented by its great ability to separate pollutants such as hydraulic oils, greases, various auxiliary chemicals, release agents and other products that can accumulate in the hydraulic fluid during operating conditions. This is mainly because Ecosafe Plus is glycols-free. This peculiarity enables an easier regeneration of Ecosafe Plus after a certain running time.

### Industrial tests confirm the advantages of Ecosafe Plus

In the light of what has been seen so far, it is possible to conclude that Ecosafe Plus meets the requirements of the main pump and system components manufacturers, as well as end users of the product.

Its performances are confirmed by the industrial tests on high-pressure aluminium injection presses, hydraulic controls for furnaces, continuous casting of steel and aluminium. In particular, we are mentioning the case study about an industrial test carried out between February 2013 and February 2014, at one of the major die-casting plants of Northern Italy.

The test compared the operating and disposal costs between the use of a traditional water/glycol-based product and the use of Ecosafe Plus.

The result of this study is that Ecosafe Plus does not require any pretreatment before being sent to a biological disposal plant, even if it is possible to use a concentrator, thanks to low COD value of exhausted product ( $< 500 \text{ mg O}_2/\text{l}$ ) and because, according to CER classification, it is not considered as hazardous waste; in addition, the evaporated product resulting from a possible distiller can be readily reused. Traditional water/glycol hydraulic fluid, instead, must be disposed as hazardous waste according to CER classification, after pre-treatment with a concentrator, and the resulting evaporated product is not readily available for new use.

As a result, cost and management difficulties are definitely higher than those of Ecosafe Plus.

The selected raw materials, the high biodegradability and the non-toxic nature of Ecosafe Plus make this product an excellent choice to combine the best technical performance with a sustainable vision for the environment. In particular, its excellent results in tribological tests and its compatibility with the most commonly used elastomers, combined with its biodegradability, make this product a true technological innovation.

### Conclusions

An R&D activity focused on the utmost integration of raw materials derived from renewable sources has led Foundry Alfe Chem to the creation of lubricants and chemical auxiliaries for the processing of metals, ensuring excellent conditions of hygiene and safety in the workplace, as well as the protection and respect for the environment. These innovative products will allow users to remarkably optimize the production both in terms of technological performance and of reduced consumption, without compromising sustainability.

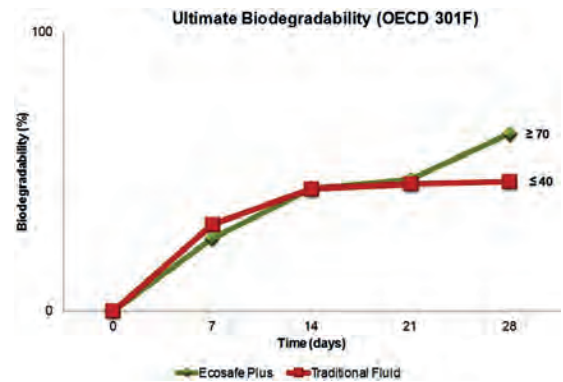


Figure 4. Biodegradability of Ecosafe Plus compared with a market leader water/glycol-based hydraulic fluid

In conclusion, we can say that although the current market and economic conditions in general are not positive, this should not divert the industry from the objectives of research and development for innovation in both products and processes. We are therefore convinced that, also and especially with a proper research and application of new technologies, it is possible to resume the path of economic growth in a context of proven compatibility and environmental sustainability.

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### Сведения об авторах

*Джанни Риццито*, управляющий директор, Foundry Alfe Chem s. r. l., корсо Брешиа, 77, 10155, г. Турин, Италия, <http://www.foundrychem.it/home/>, [info@foundrychem.it](mailto:info@foundrychem.it), + 39 011.2478204.

*Фьоренцо Бучелли*, управляющий директор, Foundry Alfe Chem s. r. l., корсо Брешиа, 77, 10155, г. Турин, Италия.

*Марко Шаккалуга*, директор R&D, Foundry Alfe Chem s. r. l., корсо Брешиа, 77, 10155, г. Турин, Италия.

*Оттавия Аватанео*, ассистент R&D, Foundry Alfe Chem s. r. l., корсо Брешиа, 77, 10155, г. Турин, Италия.

### Information about the authors

*Gianni Rizzuto*, Managing Director, Foundry Alfe CHEM s. r. l., C. so Brescia 77, 10155, Turin, Italy, <http://www.foundrychem.it/home/>, [info@foundrychem.it](mailto:info@foundrychem.it), + 39 011.2478204.

*Fiorenzo Bucelli*, Managing Director, Foundry Alfe CHEM s. r. l., C. so Brescia 77, 10155, Turin, Italy.

*Marco Sciaccaluga*, R&D Director, Foundry Alfe CHEM s. r. l., C. so Brescia 77, 10155, Turin, Italy.

*Ottavia Avataneo*, R&D Assistant, Foundry Alfe CHEM s. r. l., C. so Brescia 77, 10155, Turin, Italy.