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# Viscosity of Foam Concentrate Products Used for Extinguishing Fires in the Oil Industry

Elisei Dumitru, Ioan Tudor

Universitatea Petrol – Gaze din Ploieşti, Bd. Bucureşti nr. 39, Ploieşti
e-mail: eliseidumitru@yahoo.com
e-mail: itudor@upg-ploiesti.ro

## Abstract

*This paper presents the experimental researches regarding viscosity of foam concentrate products used for extinguishing fires in the oil industry and the dependence between the foam concentrate's dynamic viscosity and it's temperature. In order to perform the experimental research the authors used two distinct equipments - Rheotest 2 rotational viscometer and Brookfield DV-E digital viscometer – and got the results of dynamic viscosity for ten foam concentrate products.*

**Key words:** *viscosity, foam concentrate, jet*

## Introduction

Industry, especially the oil industry, use various raw materials and chemicals, some of which are dangerous from the fire's point of view. It made for fire prevention and extinguishment work to be a concern not only to know the physical-chemical properties of materials used, degree of fire danger but also for the improvement and modernization of equipment and substances used in fire prevention. Fire-fighting foam concentrates are widely used to control fire, extinguish and also to prevent flammable liquids ignition and reigniting.

In terms of optimizing the conditions of formation of foam used for extinguishing fires in the oil industry has proven to be necessary to improve conditions of formation of jets in order to operate from a safe distance, as if such fire thermal radiation around the fireplace area is quite high, so it is important to know both the properties of materials used (viscosity for our case) and how is it's variation with temperature.

## Experimental Tests at Viscosity of Foam Concentrates Products Used for Extinguishing Fires in the Oil Industry

Fire-fighting foam is an aggregate of air filled bubbles formed from aqueous solutions and is lower in density than flammable liquids. The main quality is the ability to form a cohesive floating blanket on flammable and combustible liquids and prevents or extinguishes fire by excluding air and cooling the fuel. It also prevents reigniting by suppressing formation of flammable vapors. It has the property of adhering to surfaces, which provides a degree of exposure protection from adjacent fires. [4]

These foams can be used in combination with other products of extinction, in particular with $CO_2$ and powders.

Generally, a foam system consists of a water supply, a foam concentrate supply, proportioning equipment, piping system, foam makers and discharge devices. In the oil industry the foam concentrates used for protection of hydrocarbon fuels shall be one of the following types:

- protein;
- fluoroprotein;
- aqueous film-forming foam (AFFF);
- film-forming fluoroprotein (FFFP);
- alcohol-resistant.

Main foam concentrate products used in Romania are the following:

- Filfoam 616;
- Filfoam 913;
- Filfoam 916;
- Filfoam A 836;
- Fluorofoam 806;
- Fomtec AFFF 6% A;
- Fomtec ARC 3x6;
- Profoam 806;
- Profoam 806 G;
- Spumax SCM.

To study the variation of the distances as far as it can intervene in the jet of liquid is interesting to study this phenomenon dependent on foam concentrate's viscosity used in the foaming jet.

Viscosity describes a fluid's internal resistance to flow and may be thought of as a measure of fluid friction. The study of viscosity is known as rheology. [2]

Dynamic viscosity (or absolute viscosity) determines the dynamics of an incompressible Newtonian fluid, which is a fluid whose stress versus rate of strain curve is linear and passes through the origin. In common terms, this means the fluid continues to flow, regardless of the forces acting on it. The usual symbol for dynamic viscosity used by mechanical engineers and fluid dynamicity is the Greek letter – $\mu$ and $\eta$ which is also used by chemists. The SI physical unit of dynamic viscosity is the Pascal-second (Pa·s), which is identical to $kg{\cdot}m^{-1}{\cdot}s^{-1}$. [3]

The physical unit for dynamic viscosity is the Poise (P), but it is more commonly expressed, particularly in ASTM standards, as centiPoise (cP). Water at 20 °C has a viscosity of 1.0020 cP.

Fluids behave differently in terms of viscosity's variation dependant on temperature. Gas viscosity increases with the temperature's increasing but in case of fluid process is reversed - to decrease as temperature increases. Viscosity reduction is stronger at lower temperatures than at higher ones (fig. 1) [2].

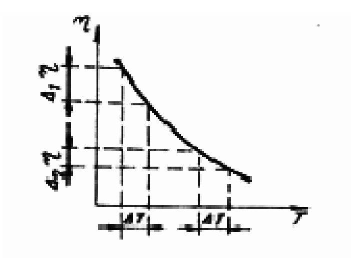
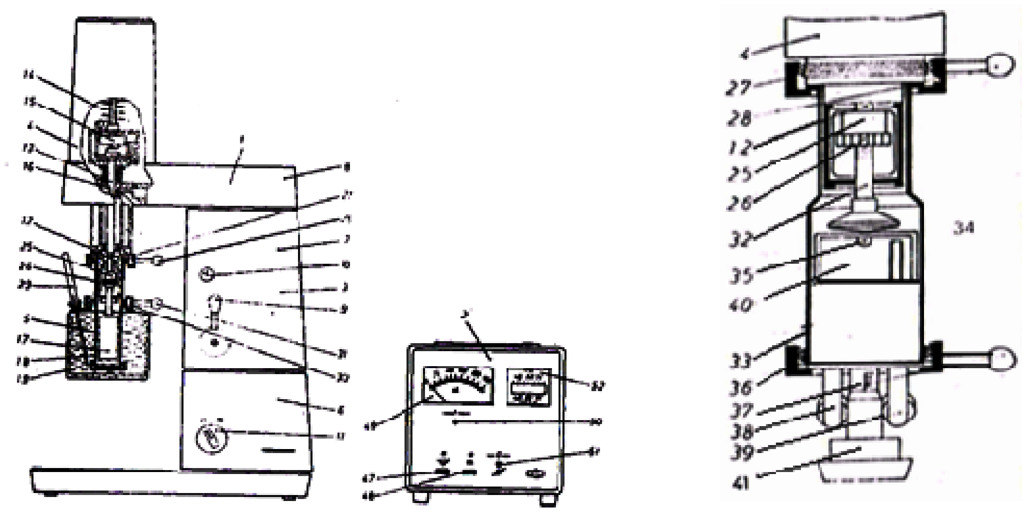


**Fig. 1.** Viscosity's variation dependant on temperature

The first determinations of foam concentrates product's viscosity used for extinguishing fires in the oil industry have been carried out with the Rheotest 2 rotational viscometer (fig. 2) existing in the University "Petrol-Gaze" Ploiesti at the Department of Hydraulics for five foam concentrates products: Fomtec AFFF 6% A, Filfoam 913, Profoam 806, Fomtec ARC 3*6, Filfoam 916 and the experimental data are presented in table 1.

The measuring principle is that the substance to be tested as to it's rheological characteristics is located in a space of co-axial cylinder system. The outer stationary cylinder is for measuring the tested substance. A jacketed heating vessel can be suspended in position around the outer cylinder measuring vessel; the heating vessel is connected to a liquid circulations thermostat.

The inner test cylinder is connected to the measuring shaft which is provided with a cylindrical coil spring. For the determination of torque at the test cylinder it will be measured the deflection of the cylindrical coil spring which is measured by an instrument potentiometer which together with a crossed fields coil system forms the basis of the separate control unit. The indication of the crossed fields system and the torque the shearing force and viscosity are in proportional relation to each other [5].



*a.* *b.*

**Fig. 2.** Rheotest 2 rotational viscometer
*a) general assembly, b) device for measuring*

*1* - viscometer *2* - the measure, *3* - control group, *4* - measurement mechanism, *5* - measurement device with cylinders, *6* - leg, *7* - gearbox, *8* - transmission point, *9* - gear lever, *10* - gradual scale, *11* - switch speed of rotation, *12* - measurement axle, *13* - axle, *14* - dynamometer, *15* - potentiometer, *16* - switch domain measurement, *17* - measuring cylinder, *18* - container measuring, *19* - container setting heat, *20* - tube of the measurement, *21, 22* - closing lids, *23* - inserted piece, *24* - locking nut, *25* - coupler, *26* - nut, *27,30, 36* - bridle, *28, 31, 37* - extension-nut, *29* - thermometer, *32* - with measuring, *33* - guide plate, *34* - board measure, *35* - measure body temperature, *38* - input, *39* - exit, *40* - cell to adjust temperature, *41* - micro-metric screw, *42* – cell, *43* - ball for flexible pipes, *44* - handle, *45* - holding platen, *46* - clamp, *47* - switch (engine), *48* - switch (mechanism for measuring), *49* - indicator *50* - equalization zero point (mechanical), *51* - equalization zero point (electric), *52* - frequency measurements.

Viscosity of foam concentrates products used for extinguishing fires in the oil industry carried out with the Rheotest 2 rotational viscometer was determined by means of the next formula:

$$\mu = \frac{100\, z\alpha}{D_r \dfrac{F}{50}} [cP] \tag{1}$$

where:

- z and $D_r$ are quotients that depend on the kit of component pieces of Rheotest 2 rotational viscometer;
- α is the torque;
- F is frequency.

**Table 1**. Dynamic viscosity for foam concentrate products

| Foam concentrate | $T$ ($^0$C) | $\alpha$ | $z$ | $D_r$ | $F$ (Hz) | μ (cP) | μ (Pa·s) |
|---|---|---|---|---|---|---|---|
| Fomtec AFFF 6% A | 25 | 11 | 3,21 | 1312 | 50 | 2.6913 | $2.6913 \cdot 10^{-3}$ |
| | 19,5 | 12,5 | 3,21 | 1312 | 50 | 3.0583 | $3.0583 \cdot 10^{-3}$ |
| | 15,2 | 14,5 | 3,21 | 1312 | 50 | 3.5476 | $3.5476 \cdot 10^{-3}$ |
| | 10 | 16 | 3,21 | 1312 | 50 | 3.9146 | $3.9146 \cdot 10^{-3}$ |
| Filfoam 913 | 20 | 0,8 | 3,21 | 1312 | 50 | 0,1957 | $0,1957 \cdot 10^{-3}$ |
| | 15 | 1,1 | 3,21 | 1312 | 50 | 0.2691 | $0.2691 \cdot 10^{-3}$ |
| | 10 | 4 | 3,21 | 1312 | 50 | 0.9786 | $0.9786 \cdot 10^{-3}$ |
| | 5 | 6 | 3,21 | 1312 | 50 | 1.4679 | $1.4679 \cdot 10^{-3}$ |
| Profoam 806 | 29 | 12 | 3,21 | 1312 | 50 | 2.9359 | $2.9359 \cdot 10^{-3}$ |
| | 21 | 5 | 3,21 | 1312 | 50 | 1.2233 | $1.2233 \cdot 10^{-3}$ |
| | 15 | 4 | 3,21 | 1312 | 50 | 0.9786 | $0.9786 \cdot 10^{-3}$ |
| | 10 | 3,5 | 3,21 | 1312 | 50 | 0.8563 | $0.8563 \cdot 10^{-3}$ |
| Fomtec ARC 3*6 | 23 | 43 | 3,21 | 1312 | 50 | 10.5205 | $10.5205 \cdot 10^{-3}$ |
| | 19,5 | 47,5 | 3,21 | 1312 | 50 | 11.6215 | $11.6215 \cdot 10^{-3}$ |
| | 15,5 | 50 | 3,21 | 1312 | 50 | 12.2332 | $12.2332 \cdot 10^{-3}$ |
| | 10 | 53 | 3,21 | 1312 | 50 | 12.9672 | $12.9672 \cdot 10^{-3}$ |
| Filfoam 916 | 24 | 8,2 | 3,21 | 1312 | 50 | 2.0062 | $2.0062 \cdot 10^{-3}$ |
| | 19,2 | 18 | 3,21 | 1312 | 50 | 4.4069 | $4.4069 \cdot 10^{-3}$ |
| | 15 | 20,1 | 3,21 | 1312 | 50 | 4.9177 | $4.9177 \cdot 10^{-3}$ |
| | 8,5 | 24 | 3,21 | 1312 | 50 | 5.8719 | $5.8719 \cdot 10^{-3}$ |

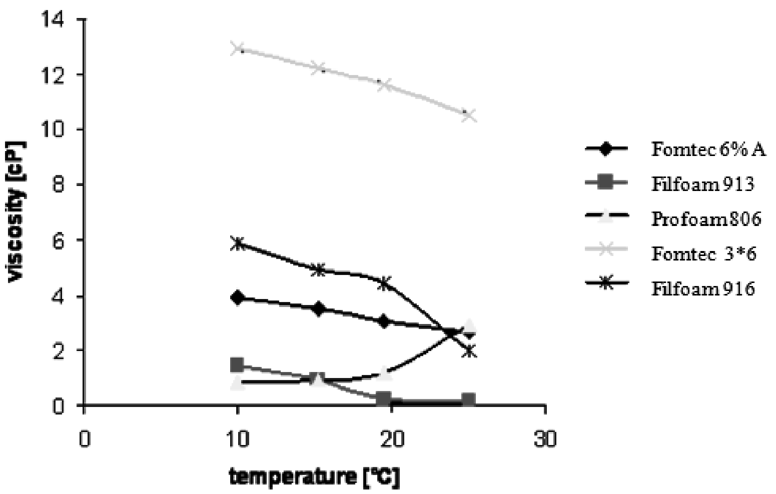



**Fig. 3.** Diagram (μ, t) of experimental results

The second determinations of foam concentrate product's viscosity used for extinguishing fires in the oil industry have been carried out with the Brookfield DV-E digital viscometer (fig. 2) from S.C. Gefil S.R.L. – specialized company in products and services of fire prevention and extinguishment, for other five foam concentrates products: Filfoam A 836, Filfoam 616, Filfoam 916 Kerr, Profoam 806 Gefil, Fluorofoam 806 and the experimental data are also presented in table 2.

All test results are illustrated in (μ, t) diagrams (fig.3 and fig.5), where the curves obtained vary exponentially.


**Fig. 4.** Brookfield DV-E digital viscometer

**Table 2.** Dynamic viscosity for foam concentrate products

| Foam concentrate | Temperature ($^0$C) | Viscosity (cP) | Viscosity (Pa·s) |
|---|---|---|---|
| Filfoam A 836 | 15 | - | - |
| | 20 | 1660 | $1660 \cdot 10^{-3}$ |
| | 25 | 1000 | $1000 \cdot 10^{-3}$ |
| Filfoam 616 | 15 | 4,9 | $4,9 \cdot 10^{-3}$ |
| | 20 | 4,6 | $4,6 \cdot 10^{-3}$ |
| | 25 | 3,9 | $3,9 \cdot 10^{-3}$ |
| Filfoam 916 Kerr | 15 | 4,9 | $4,9 \cdot 10^{-3}$ |
| | 20 | 4,6 | $4,6 \cdot 10^{-3}$ |
| | 25 | 4,1 | $4,1 \cdot 10^{-3}$ |
| Profoam 806 G | 15 | 12 | $12 \cdot 10^{-3}$ |
| | 20 | 11 | $11 \cdot 10^{-3}$ |
| | 25 | 10 | $10 \cdot 10^{-3}$ |
| Fluorofoam 806 | 15 | 6,8 | $6,8 \cdot 10^{-3}$ |
| | 20 | 6,3 | $6,3 \cdot 10^{-3}$ |
| | 25 | 6 | $6 \cdot 10^{-3}$ |

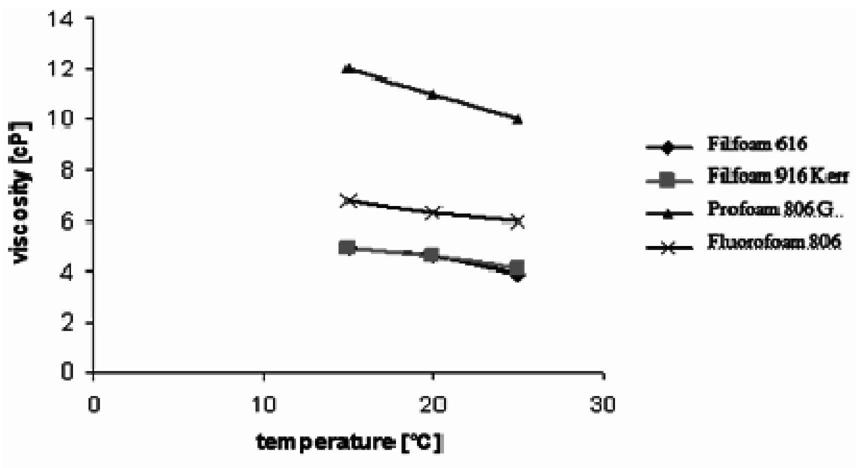



**Fig. 5.** Diagram (μ, t) of experimental results

## Conclusions

The physical-chemical properties of foam concentrate products used for extinguishing fires in the oil industry - especially density and viscosity - are important for jet dynamics, modifying the turbulent motion and should be taken into account for obtaining effective results.

This paper presents several determinations of viscosity in a temperature's scale equivalent to that encountered in extinguishing products from 5°C to 30 °C.

From the point of view of viscosity variation with temperature Filfoam 916 Kerr and Fluorofoam 806 products have the best behaviour . Profoam 806 foam concentrate product has a different behavior, in the sense that along with increasing temperature has been found that the product has become thicker.

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# Vâscozitatea produselor spumante concentrate folosite la stingerea incendiilor din industria petrolieră

## Rezumat

*Articolul de faţă prezintă cercetările experimentale asupra vâscozităţii produselor spumante concentrate folosite la stingerea incendiilor în industria de petrol şi dependenţa între vâscozitatea dinamică a produselor spumante concentrate şi temperatura acestora. Pentru realizarea cercetărilor experimentale, autorii au folosit două echipamente distincte – vâscozimetrul rotaţional Rheotest 2 şi vâscozimetrul digital Brookfield DV-E – şi au obţinut rezultate ale vâscozităţii dinamice pentru zece produse spumante concentrate.*