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Abstract. This paper offers a detailed explanation of aqueous film-forming foam concentrate, its formulations and properties. This paper also illustrates deficiencies of this fire extinguishing agents and offers a newly born product which could compensate the drawbacks of the subject product. The new product is still under research process and needs more experiment.

1. Introduction

Aqueous film-forming foam extinguishing agent (AFFF) is a kind of fire extinguishing agent which could form a film on the surface of hydrocarbon liquid. Water is the most commonly used and main content in fire extinguishing agents. By adding additives in the water, the physical and chemical performance of the liquid could be improved in extinguishing fire. The main additives of water-based fire extinguishing agent are surfactant additives (including fluorocarbon surfactants and hydrocarbon surfactants), flame retardants, emulsifiers, thickeners, antifreeze and other additives. A small amount of additives added in water will have some but very limited influences on fire fighting performance. In alternative way in explaining, the additives should be added in scientific way and sound ratio.

2. Main contents in AFFF

Aqueous film-forming foam extinguishing agents have been constituted by various chemical ingredients.

2.1 Fluorocarbon surfactant

Fluorocarbon surfactant is a kind of chemical compound which reduces the surface extension of solvent by adding little surfactants with low concentration.

Fluorocarbon surfactant is a key element in film-forming foam extinguishing agent. The prominent function is to reduce surface extension of solution of water and fire extinguishing agent, and elevate oleophobic performance of foam and form a film on the surface of hydrocarbon fuel together with hydrocarbon surfactants.

2.2 Hydrocarbon surfactant

Hydrocarbon surfactant could be used with a view to improve film forming ability and foam performance of liquid. Combining application of hydrocarbon and fluorocarbon surfactants could generate the ability of the fire agents with emulsification performance and reduce surface expansion of the foam agents.

Expansion ratio is a term to test the expansion performance of one liquid which is on the surface of another liquid.

Expansion formula is as follows:

$$S = \gamma_f - \gamma_A - \gamma_i$$

Where

S—Expansion ratio

γ_i—surface extension of lower level liquid(fuel)

γ_a—surface extension of upper level liquid(foam solution)

γ_f—interfacial extension between two liquids

When S is a positive value, upper liquid rationally could form a film and expand on the surface of the lower level liquid. While S is a negative or zero, upper liquid then will not film form on the surface of the lower level but will sink on the bottom of the liquid because of its high density.

Hydrocarbon surfactant is a very small constituent in producing aqueous film-forming foam concentrate and generally will not surpass 15 percent of the total amount.

2.3 Stabilizer

Fluorocarbon surfactant and hydrocarbon surfactant are used to reduce surface extension of water with a view to form a film on the surface of the fuel. But generally, the film is not stable and does not have sound burn-back performance. The application of stabilizer just has the function of elevate this burn-back performance.

The common stabilizers used in aqueous film-forming foam concentrate are BCS, butyl diglycol acetate, polyoxyethylene, sodium alginate tech grade and polyacrylamide etc. Stabilizer could also be used to form even-sized foam in foam generating process.

2.4 Other additives

In order to improve performance of foam agents in low temperature environment, generally coolant will be added. In some cases, some buffering agents will be added in order to control the PH value of foam agent in certain field.

3. Chemical performance of the subject fire extinguishing agent

The foam agent is a composition of surface active agent and additive of adapting foam performance. The synthetic surface-active agent could make the foam surface extension down to 18mN/m below. The agent will not only push the foam flow more quickly on the surface of oil but also form a layer on the surface of the oil so as to realize the double effect of foam and water film.

Film-forming foam agent has the characteristics of sound fluidity, fast speed of fire extinguishing, good closure ability, not easy to reignite, and easy to store. The foam agent has the best performance among lots of foam agents. But the foam agent has a fairly high price, which is roughly more than 10 to 15 times compared with the common foam agent in the market. The foam agent has the ability of film-forming ability, and self-curing ability. It has strong anti reignition ability, long storage time (20 years roughly), while common foam agent could only be stored to 2 years.

The foam agent is suitable to non-aspirating foam nozzle equipment. It is suitable to large scale of fluidity of foam solution. It has precise proportioning ration, and is suitable to 3% and 6% foam concentrates. It could be jointly applied to automatic fire extinguishing systems and could realize the foam solution supply by using the pressure from water source and will not need other foam power source.

4. Limitation of AFFF and newly developed AFFF agent without polyfluorinated surfactants

Foam agents compounded with PFOS surfactants are mainly film-formed foam agent. Among these film-formed foam agents, aqueous film-formed foam agents have occupied a significant percentage. Aqueous film-formed foam agents have very effective fire performance and fire protection capability. It has the characteristics of fast speed of fire protection, excellent closure ability, and anti after combustion ability. Aqueous film-formed foam extinguishing agents have already been regarded as the most effective foam extinguishing agents in the world in putting out liquid fires. But they show a negative environmental behaviour because of the imperatively contained polyfluorinated surfactants

(PFS). PFS are generally known for their chemical stability and their high persistent in nature. Due to the approved situation that PFS is increasingly restricted by low and is bio-accumulative and toxic, the use of PFS is increasingly restricted by law in most countries.

In search of environmentally acceptable alternatives, some western researchers have been working on a PFC-free siloxane-based AFFF for military fuels application and have many test data.

Table 1. Surface tensions of important fuels

Fuel	**Surface tension （24℃）**
FAME (Biodiesel)	31.5mN/m
Diesel	28.3mN/m
Jet fuel	26.7mN/m
F-34	25.8mN/m
Gasoline	20.7mN/m

Based on the search of literature, it is indicated that this product is still in developing process and has only been tested using military fuels and test method is not applicable as the same in general national or international standards. But it is surely a good direction which will lead researchers to dig more by conducting more experiments with a view to offer a brand-new product which has sound extinguishing and burn-back ability with no toxic and negative environmental behaviour.

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