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Subject: Effect of PFAS (AFFF) on Durability of HDPE Geomembrane Containment Systems

Forward:

This study reports on the effect of PFAS (AFFF) on Durability of HDPE Geomembrane Containment systems and in particular with regard their stress cracking response.

1. Introduction

ANSULITE™ and HYDRAL™ are fluorosynthetic film forming liquids based on PFAS commonly known as Aqueous film forming foam (AFFF) which is a highly efficient type of fire suppressant agent, used to attack flammable liquid pool fires. AFFF available in three concentrations: 1%, 3%, and 6% (v/v). The numbers refer to the concentration percentage of the foam concentration mixed with either fresh or sea water by a proportion nozzle. AFFF is effective against a wide variety of corrosion. Generally, increased corrosion resistance can only be obtained at increased cost. At a fundamental level , corrosion resistance materials often tend to be more susceptible to localized corrosion which is often difficult to detect and to monitor effectively. AFFF concentrates used for fighting fires on hydrophobic liquids are generally diluted with water at a 3-part concentrate to 97-part water ratio. This dilution step is called proportioning. The resulting mixture is then mixed with air and the resulting foam is then applied to the burning hydrophobic liquid. A concentrate which is effective at a 3% dilution level is desired over a weaker concentrate, such as a concentrate which is diluted at a 6 part concentrate to 94 part water ratio .

The AFFF coats a pool of hydrocarbon fuel with a layer of foam, which acts as a thermal and evaporation barrier to inhibit and eventually extinguish combustion. The "film-forming" characteristic refers to the fact that, even after the foam has dissipated,the aqueous layer formed from the water/concentrate mixture can coat a liquid hydrocarbon surface. Three fire extinguishments mechanisms are in effect when using ANSULITE 3% (AFC-3A) AFFF Concentrate. First, an aqueous film is formed which works to help prevent the release of fuel vapor. Second, the foam blanket from which the film-forming liquid drains effectively excludes oxygen from the fuel surface. Third, the water content of the foam provides a cooling effect.

Despite their excellent properties as fire fighting foams, ANSULITE™ and HYDRAL™ have been implicated in causing premature failure of HDPE tanks and geomembrane liners by environmental stress cracking (ESC). This study examines their effect on common HDPE geomembrane liner systems for containment of AFFF water.

2. PFAS AFFF Manufacturer Recommendations

Synthetic foam concentrates

ARAFFF, AFFF, Fluorine Free, High Expansion, Class-A foams.

316 Stainless steel tanks are very reliable for this application provided the concentrate has a low chloride level. Since 3M stopped manufacturing AFFF's there are not likely to be many synthetic foam concentrates with high chloride levels but you should verify this with the manufacturer. In ocean environments external corrosion of stainless steel tanks may be a more serious issue.

Glass reinforced polyester tanks are very reliable provided chemical resistant resins (isophthalic) are used and the gel coat must be isophthalic.

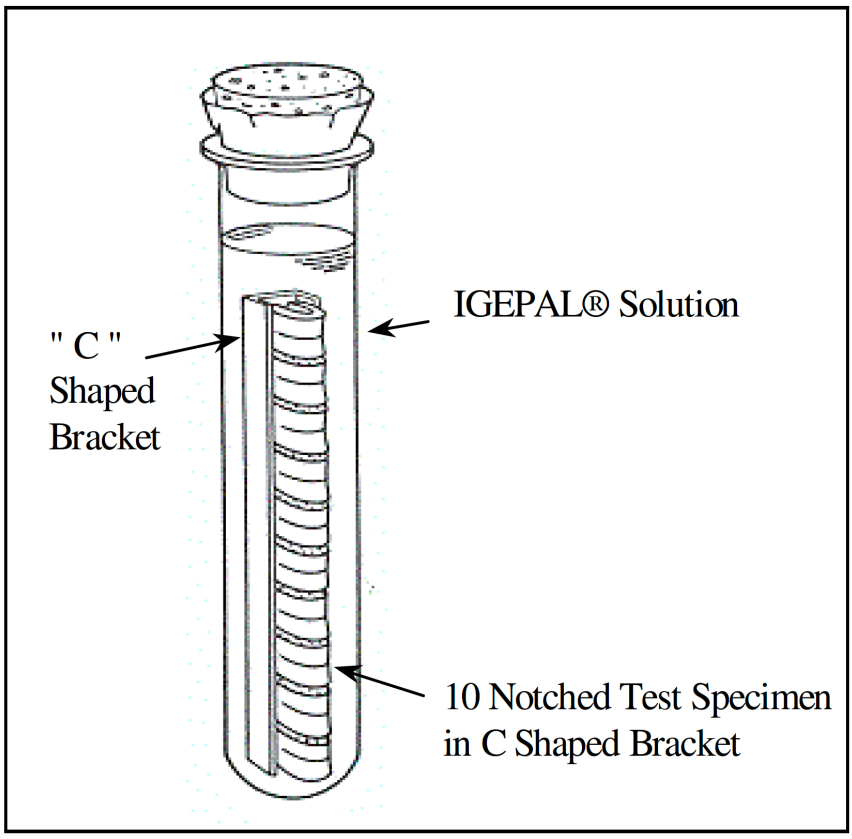
High density polyethylene tanks are not recommended. While that are low cost there are actually very few tanks made of true high density polyethylene and there is a large risk that the resin is not sufficiently chemical resistant for long term storage of fire-fighting foams. We have seen more failures than successes. In general they do not have an expansion dome and can only be used for ARAFFF if sealer oil is applied to the top of the foam concentrate. Since sealer oil requires careful application and periodic maintenance it is likely that the long term savings from using these tanks are probably not realised by many customers as either the tanks fail of the foam concentrate life is significantly shortened. High density polyethylene tanks are not recommended for outdoor use.

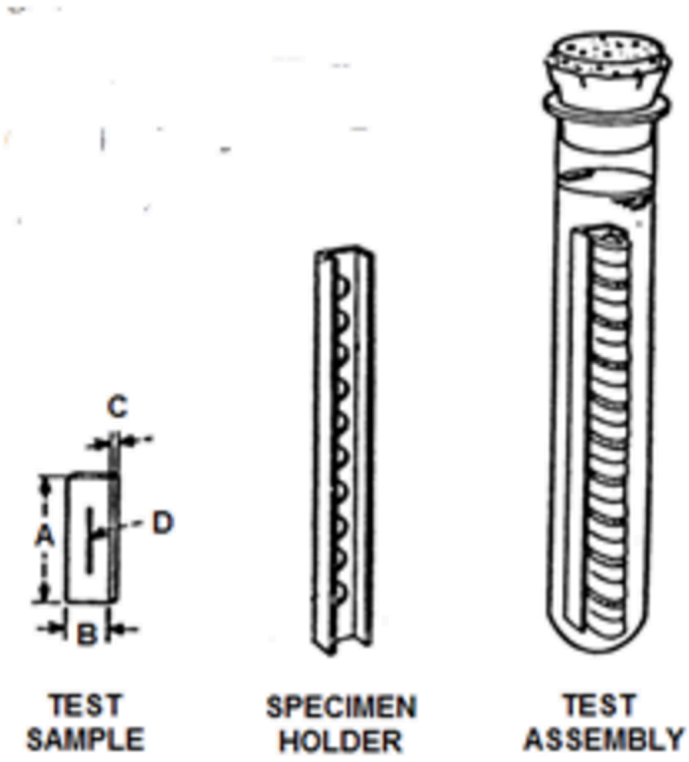
3. Testing Methodology

The stress cracking potential of AFFF on HDPE was determined using the Bent Strip ESCR Test (ASTM D1693).

ASTM D1693 requires each of the ten specimens from a specimen set to be cut with a controlled notch and be bent into a “U” shape to induce stress in the specimen (see Figures below). The notch allows cracks to form at specific positions if the material is susceptible to environmental stress cracking.

Figure 1 - ASTM D 1693 – Bent Strip ESCR Test





Sets of notched specimens, sets of un-notched specimens and specimens that were not to be bent into a “U” shape were prepared.

One set of notched specimens, one set of un-notched specimens and one set of un-stressed specimens were placed into tubes containing 6% Ansulite AFFF solution.

One set of notched specimens, one set of un-notched specimens and one set of un-stressed specimens were placed into tubes containing 10% Igepal CO 630 solution (a standard stress crack inducing reagent).

All the solutions were placed in an oven at 50°C and monitored at regular intervals.

6. Results

The table below sets out the ESC results observed.

Time /Date	*Elapsed Time/ Condition*	*Notched 10% Igepal CO630*	*Notched 6% Ansulite AFFF*	*Un-notched 10% Igepal CO630*	*Un-notched 6% Ansulite AFFF*	*Un-notched Not Bent 10% Igepal CO630*	*Un-notched Not Bent 6% Ansulite AFFF*
1600 24/3	0 hours	No Cracks	No Cracks	No Cracks	No Cracks	No Cracks	No Cracks
1000 27/3	70 hours	No Cracks	No Cracks	No Cracks	No Cracks	No Cracks	No Cracks
1000 28/3	94 hours	3 Cracks	No Cracks	No Cracks	No Cracks	No Cracks	No Cracks
1000 29/3	118 hours	7 Cracks	5 Cracks	1 Crack	No Cracks	No Cracks	No Cracks
1600 31/3	172 hours	10 Cracks	7 Cracks	2 Cracks	No Cracks	No Cracks	No Cracks
1000 3/4	238 hours	10 Cracks	9 Cracks	3 Cracks	1 Crack	No Cracks	No Cracks

Note: while 6% AFFF was used for the above studies, further work is showing more dilute solutions of AFFF actually exert higher stress cracking potential on HDPE due to higher levels of micellation and ionization in solution. The maximum rate of stress cracking of HDPE was found to correlate with the critical micelation concentration (CMC) of the AFFF.

Remainder of Report: Redacted.