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# SELECTING ENVIRONMENTALLY ACCEPTABLE HYDRAULIC FLUIDS

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## OFFICIAL COURSE/EXAM

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# MEC-136 EXAM PREVIEW

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## Exam Preview:

1. According to the reference material, environmentally acceptable fluids are composed of two basic items: (1) base fluid, and (2) additives.
  - a. True
  - b. False
2. Which of the following attributes is NOT an environmentally-based factor according to the USACE?
  - a. Sheen generation
  - b. Biodegradability
  - c. Toxicity
  - d. Water Solubility
3. Using Table 1. Comparisons of Various Types of Environmentally Acceptable Fluids, which of the following types of hydraulic fluid has a high renewability content?
  - a. Polyglycol
  - b. Vegetable Oil
  - c. Synthetic Ester
  - d. PAO & Related Hydrocarbon Fluids
4. Using Table 2. USFWS and EPA acute toxicity rating scales for aquatic organisms, which of the following concentrations is the EC50 criteria for highly toxic fluid according to the USFWS?
  - a. 10-100
  - b. 1.0-10.0
  - c. 0.1-1.0
  - d. >1000

5. According to the reference material, the cost of EA fluids can currently range from 1.5-4 times that of a regular-grade, petroleum-based hydraulic fluid.
  - a. True
  - b. False
6. Using Table 1. Comparisons of Various Types of Environmentally Acceptable Fluids, which of the following types of hydraulic fluid has ASTM D 2270 Viscosity Index of 140-160?
  - a. Polyglycol
  - b. Vegetable Oil
  - c. Synthetic Ester
  - d. PAO & Related Hydrocarbon Fluids
7. The CWA and the Oil Pollution Act of 1992 (OPA 92) prohibit the discharge of oil into the waters of the United States in quantities that may be harmful.
  - a. True
  - b. False
8. Using Table 1. Comparisons of Various Types of Environmentally Acceptable Fluids, which of the following types of hydraulic fluid is water soluble?
  - a. Polyglycol
  - b. Vegetable Oil
  - c. Synthetic Ester
  - d. PAO & Related Hydrocarbon Fluids
9. According to the reference material, the fluid performance factor that indicates the point of oil solidification is the low temperature performance.
  - a. True
  - b. False
10. Using Table 3. ASTM aquatic toxicity rating scale, which of the following designation corresponds to a loading rate of 100-10?
  - a. Tw1
  - b. Tw2
  - c. Tw3
  - d. Tw4

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## INTRODUCTION:

On a daily basis, the United States Army Corps of Engineers (USACE) is responsible for operation of hydraulically powered machinery systems. Some of these machinery systems are land-based (installed in land facilities or off-road vehicles such as excavators, bulldozers, backhoes, etc.), while others are installed on floating plants (such as steering systems, winches, capstans, etc.).

Accidental spillage of hydraulic fluid can occur during operation of any machinery system. Estimates for the loss of hydraulic fluids into the environment from mobile hydraulic machinery are as high as 70–80% (Carnes 2004). Spillage of existing mineral oil-based hydraulic fluids into the environment has caused adverse effects on marine life (plants and animals) and soil contamination. These adverse effects have ranged from minor to devastating. USACE has attempted to minimize any adverse effects of its floating plant operations on the environment, through the following means:

- Providing spill containments for design and construction of new vessels
- Where possible, locating the hydraulically powered machinery inside the hull
- Where feasible, considering the use of water-based hydraulic fluid systems
- Providing sludge tanks and oily bilge tanks for the collection and proper disposal of oil-contaminated bilge water
- Performing routine maintenance, including regular inspection of hoses, seals, and fittings

USACE has determined that these measures alone are not sufficient to minimize any adverse impacts of operations on the environment and that additional measures are necessary. To comply with the USACE Environmental Operating Principles listed below (<http://www.usace.army.mil/Missions/Environmental/EnvironmentalOperatingPrinciples.aspx>), the use of environmentally acceptable hydraulic fluids must be maximized in floating plant operations.

- Foster sustainability as a way of life throughout the organization
- Proactively consider environmental consequences of all Corps activities and act accordingly
- Create mutually supporting economic and environmentally sustainable solutions
- Continue to meet corporate responsibility and accountability under the law for activities undertaken by the Corps, which may impact human and natural environments
- Consider the environment in employing a risk management and systems approach throughout the life cycles of projects and programs

- Leverage scientific, economic, and social knowledge to understand the environmental context and effects of Corps actions in a collaborative manner
- Employ an open, transparent process that respects views of individuals and groups interested in Corps activities

Floating plant operations are subjected to laws, regulations, and operating principles from multiple agencies and government levels with respect to discharges, water quality, pollution, etc. The U.S. Clean Water Act (CWA), the United States Coast Guard (USCG), the United States Environmental Protection Agency (EPA), and the International Maritime Organization (IMO) provide specific regulations regarding water pollution. Local, state, and tribal organizations also impose their own laws and regulations regarding water pollution, vessel discharges, etc. In addition, the USACE Environmental Operating Principles (EOP) reinforce Executive Orders 13423 (2007) and 13514 (2009) and the necessity to use environmentally acceptable hydraulic fluids.

It is anticipated that the current laws and regulations will only become more restrictive and stringent in the future. This document is intended to assist floating plant operators in selecting an environmentally acceptable hydraulic fluid that satisfies the criteria outlined below and is suitable for their operations. The environmental criteria were selected based on the upper tiers of current standards.

**PURPOSE:** The objective of this technical note is to educate USACE end users (boat operators, plant managers, lock and dam operators, project managers, supervisors, etc.) about the use of environmentally acceptable hydraulic fluids. The USACE definition and classification criteria for an environmentally acceptable hydraulic fluid are presented in this document, along with considerations for selecting an environmentally acceptable hydraulic fluid. This technical note is intended to provide basic knowledge and understanding for end users considering the use of environmentally acceptable hydraulic fluid.

**ENVIRONMENTALLY ACCEPTABLE HYDRAULIC FLUID CLASSIFICATION:** Fluids that are designated as “environmental” are described in many ways; e.g., “environmentally friendly,” “environmentally safe,” “environmentally acceptable,” etc. The term “environmentally acceptable,” or EA, will be used throughout this document to describe a fluid that satisfies biodegradability, toxicity, and fluid chemistry criteria established to meet USACE EOP.

“Environmentally acceptable” fluids are classified by the International Standards Organization (ISO) Standard 6743-4:1999 (ISO 1999). Specifications for four of the groups classified by ISO 6743-4:1999 are contained in ISO 15380:2011 (ISO 2011). These four categories of EA hydraulic fluids include the following:

- Synthetic esters (SE) – ISO Classification HEES
- Polyglycols (particularly Polyalkylene Glycols (PAG)) – ISO Classification HEPG
- Triglycerides (vegetable oils) - ISO Classification HETG
- Polyalphaolefins (PAO) and related hydrocarbon products – ISO Classification HEPR

Note: ISO fluid class prefix “HE” is defined as hydraulic oil environmental.

The four classes of EA hydraulic fluids listed in ISO 15380:2011 are defined as follows (Rudnick 2009):

- Synthetic Esters (SE) – made from synthetic alcohols and fatty acids
- Polyalkylene Glycols (PAG) – water-soluble (polyethylene glycols) or oil-soluble (polypropylene glycols) synthesized from petrochemical starting materials
- Triglycerides (Vegetable Oils) – plant-based oils, such as rapeseed, canola, etc.
- Polyalphaolefins (PAO) and related hydrocarbon products – produced from petrochemicals

Environmentally acceptable fluids are composed of two basic items: (1) base fluid, and (2) additives. The resulting mixture of both components of the fluid must meet the environmental criteria in order for the fluid to be rated as EA.

**FLUID PERFORMANCE FACTORS AND ENVIRONMENTAL CRITERIA:** The factors that must be considered for use of EA fluids fall into two categories: (1) performance-based, and (2) environment-based. Minimum technical performance should be based on ISO 15380:2011 guidance. Some typical performance-based criteria for EA fluids (Rudnick 2009, USACE 1999) include the following:

- Viscosity/viscosity index
- Lubricity
- Pour point (point of oil solidification)
- Wear protection (pump wear test, gear loading)
- Foam
- Air release
- R&O (rust and oxidation inhibitors)
- Corrosion and oxidation resistance
- Water retention (demulsability / water separation)
- Water solubility
- Hydrolytic stability
- Operating temperature range/thermal stability
- Low temperature performance
- Seal and hose material compatibility
- Fluid compatibility with other hydraulic fluids per ASTM 7752
- Fluid miscibility (mixing) with mineral oil
- Additive solubility
- Fluid life and disposability
- Paint compatibility
- Fire resistance / Flash point

As related to USACE, environmentally-based factors will include the following:

- Biodegradability
- Toxicity (specifically, ecotoxicity)
- Fluid chemistry
- Sheen generation

Although the sheen-generating characteristics of a hydraulic fluid are not being considered with respect to the EA designation by USACE, discussion and classification criteria for a “no sheen” hydraulic fluid are provided in this technical note.

The focus of this technical note will be on the environmental criteria for fluids to obtain an EA rating, along with a general description of the physical performance factors. Specific hydraulic system manufacturers and hydraulic fluid providers should be consulted to determine the physical performance factors required for the system and associated equipment.

**FLUID CHARACTERISTICS:** Select relative performance and environmental characteristics of the four classes of EA hydraulic fluids are shown in Table 1 below:

<b>Table 1. Comparisons of Various Types of Environmentally Acceptable Fluids (Rudnick 2009, USACE 1999)</b>				
<b>Parameter</b>	<b>Hydraulic Fluid Type</b>			
	<b>Vegetable Oil (HETG)</b>	<b>Synthetic Ester (HEES)</b>	<b>Polyglycol (HEPG)</b>	<b>PAO &amp; Related Hydrocarbon Fluids (HEPR)</b>
Viscosity Index ASTM D 2270	100-250	120-200	100-200	140-160 <sup>1</sup>
Water solubility	Low solubility	Low solubility	Soluble <sup>2</sup>	Low solubility
Miscibility (mixing) with Mineral Oil	Good	Good	Not Miscible <sup>2</sup>	Good <sup>3</sup>
Low-temperature performance	Weak	Good	Good	Good
Oxidation resistance	Weak	Good	Good	Good
Hydrolytic stability	Low	Medium	Good	Good
Seal material compatibility	Limited/Good	Limited	Limited	Good
Paint compatibility	Good	Limited/Good	Limited	Good
Additive solubility	Good	Good	Moderate	Limited/Good
Lubricity of base fluid	Good	Good	Limited/Good	Limited/Good
Corrosion resistance	Poor	Limited/Good	Limited	Good
Renewability content	High	Variable	None	Variable
Biodegradability	Good	Good	Moderate/Good	Poor/Moderate/Good
Toxicity, LC50, (Rainbow) Trout, EPA 560/6-82-002	633 - > 5000	>5000	80 - > 5000	100 - >5000

<sup>1</sup> Bosch Rexroth AG Publication No. RE90221/05.10, “Environmentally Acceptable Hydraulic Fluids,” p. 9.

<sup>2</sup> Solubility and miscibility ratings shown are for polyethylene glycol type PAGs. Polypropylene glycol type PAG fluids are not addressed in the table.

<sup>3</sup> Mortier et al. 2010.

Parameters in Table 1 that require a more uniform definition, due to various definitions used throughout the EA hydraulic fluid industry, are as follows:

- Water solubility – ability of the fluid to be dissolved in water

- Miscibility – ability of new fluid to mix with existing residual mineral oil-based hydraulic fluid, without separation, to form a homogenous fluid. Please note that favorable environmental characteristics of an EA fluid may diminish if the fluid is mixed with a non-EA fluid
- Renewability content – fluid content made from renewable resources

**CRITERIA FOR ENVIRONMENTALLY ACCEPTABLE FLUIDS:** The environmental factors for EA fluids are defined by the American Society for Testing and Materials (ASTM) Standard ASTM D 6046 – 02 (2006) (USACE 2014) as follows:

- Biodegradability – The process of chemical breakdown or transformation of a material caused by organisms or their enzymes
- Ecotoxicity – The propensity of a test material to produce adverse behavioral, biochemical, or physiological effects in non-human organisms or populations
- Fluid chemistry – see page nine of this paper

Fluid testing for these criteria is to be conducted in accordance with the following standards:

- Biodegradability – test performed in accordance with Table 4 of the referenced ASTM Standard (USACE 2014)
- Ecotoxicity – acute toxicity test, performed in accordance with Table 5 of the referenced ASTM Standard (USACE 2014)

USACE has determined that for a hydraulic fluid to obtain an EA rating, the fluid must meet or exceed the following minimum criteria:

- **Biodegradability** – **Readily biodegradable**: Environmental persistence classification **Pw1**, as stated in ASTM D6046-02(2006) (USACE 2014)
- **Ecotoxicity** –test results for acute ecotoxicity in water (or aquatic toxicity), must meet or exceed the minimum requirements of the EPA or the referenced ASTM Standard (USACE 2014), as follows:
  - EC50 or LC50 concentration levels defined for “**Practically Nontoxic**” rating as defined by EPA (and the United States Fish and Wildlife Service (USFWS)), or IC50 concentration level as defined by USFWS (2010), or;
  - EL50, LL50, or IL50 loading rates for class **Tw2** fluids as defined by the referenced ASTM Standard (ASTM 2006).
- **Fluid Chemistry** – fluid does not contain any heavy metals (lead, mercury, etc.)

Details of these requirements are provided in the following sections.

**Biodegradability.** Biodegradability of EA fluids is evaluated at rates defined by organizations such as the Coordinating European Council (CEC), Organization for Economic Cooperation and Development (OECD), and the United States Environmental Protection Agency (EPA). The rates are determined through tests measuring the primary and ultimate biodegradability of the fluid. The following definitions are contained in EPA Office of Prevention, Pesticides, and Toxic Substances (OPPTS 835.3110, Ready Biodegradable) (USEPA 1998):



- Primary biodegradation is the alteration in the chemical structure of a substance, brought about by biological action, resulting in the loss of a specific property of that substance
- Ultimate biodegradation (aerobic) is the level of degradation achieved when the test compound is totally utilized by microorganisms resulting in the production of carbon dioxide, water, mineral salts, and new microbial cellular constituents (biomass)

Ultimate biodegradation is directly related to complete biodegradation, while primary biodegradation is related to the partial biodegradation of a fluid. The results of tests measuring the primary and/or ultimate biodegradation are often used to label a fluid with classifications as either readily or inherently biodegradable.

Readily biodegradable is an arbitrary classification of chemicals that have passed certain specified screening tests for ultimate biodegradability; these tests are so stringent that it is assumed that such compounds will rapidly and completely biodegrade in aquatic environments under aerobic conditions (ASTM 2006).

Inherently biodegradable is a classification of chemicals for which there is unequivocal evidence of biodegradation (primary or ultimate) in any test of biodegradability (ASTM 2006).

ASTM Standard D 6046–02 (2006) uses classifications such as Pw1, Pw2, etc., to define a fluid's properties with respect to biodegradability.

USACE has determined that in order to meet its own EOPs, which address minimizing adverse impact on the environment, an EA hydraulic fluid shall be classified as readily biodegradable. With respect to ASTM, fluids are classified as readily biodegradable when they meet or exceed the minimum biodegradability performance requirements as stated in Table 4 of ASTM D6046-02 (2006) for fluid environmental persistence classification **Pw1**. The biodegradability testing class and performance requirements for this class of EA fluids are defined by the referenced ASTM Standard as the following:

- **Pw1** - Test results for ultimate biodegradation must meet the requirements that the theoretical percent of CO<sub>2</sub> and O<sub>2</sub> remaining after 28 days shall be greater than or equal to 60% and 67%, respectively, for hydraulic fluids containing less than 10 wt % O<sub>2</sub>. For hydraulic fluids that contain greater than 10 wt % O<sub>2</sub>, the biodegradability test result requirement is that the theoretical percent of O<sub>2</sub> or CO<sub>2</sub> remaining after 28 days shall be greater than or equal to 60%. These requirements are the most stringent standards for ultimate biodegradation

Note: Other international standards with respect to biodegradability testing and classifications (such as OECD), will be considered by USACE on a case-by-case basis.

Fluids that are not readily biodegradable, and only inherently biodegradable, will not be considered by USACE to be environmentally acceptable.

**Ecotoxicity.** Ecotoxicity ratings for EA fluids are measured in concentrations of the fluid that may cause toxicity to the environment, which includes toxicity effects on the aquatic

environment, soil contamination, avian species, and mammals. Ecotoxicity ratings are defined as follows (USEPA 2012):

- Effect concentration (ECXX): The concentration at which some environmental effect, such as growth or deformity, will occur in XX% of the test organisms
- Lethal concentration (LCXX): The concentration that will cause the death of XX% of the test organisms
- Inhibitive concentration (ICXX): The concentration at which some inhibitory effect will occur in XX% of the test organisms

Other ecotoxicity criteria are defined by the referenced ASTM Standard (ASTM 2006) in terms of loading rates, as follows:

- Effect load (ELXX): A statistically or graphically estimated loading rate of test material that is expected to cause one or more specified effects in XX% of a group of organisms under specified conditions for a specified time
- Lethal load (LLXX): A statistically or graphically estimated loading rate of test material that is expected to be lethal to XX% of a group of organisms under specified conditions for a specified time
- Inhibitive load (ILXX): A statistically or graphically estimated loading rate of test material that is expected to cause XX% inhibition of a biological process (such as growth or reproduction), which has an analog as opposed to a digital measure

The USFWS Research Information Bulletin No. 84-78 defines ecotoxicity for the aquatic environment (acute toxicity) in terms of concentration levels measured for an effect concentration, EC50, and for a lethal concentration, LC50. The USFWS definitions for these acute toxicity concentrations for the aquatic environment are as follows:

- LC50: A 96-hr LC50 value is the concentration of chemical that would be lethal to 50% of a population of the test organisms (invertebrates, fishes, and amphibians) within 96 hr
- EC50: Toxicity to some invertebrates (daphnids and midge larvae), expressed as 48-hr EC50, is the estimated concentration of chemical that would produce an effect (immobilization, loss of equilibrium, etc.) within 48 hr

The USFWS also defines an ecotoxicity rating based upon an inhibition concentration, IC50, which is defined as follows (Totten 2000):

- IC50: The concentration at which 50% reduction occurs as compared to the controls after a short-term exposure (i.e., growth, enzyme activities, etc.)

ASTM D 6046–02 (2006) defines acute ecotoxicity load limits in weight parts per million (wppm), in terms of EL50, IL50, and LL50. However, this ASTM standard adds that the ELXX, LLXX, and ILXX classifications should be used in lieu of ECXX, LCXX, and ICXX, “...when the hydraulic fluid is not completely soluble under test conditions.”

Given the above information, USACE has determined that in order for a fluid to be rated as EA, the fluid must be tested to meet acute ecotoxicity ratings in water (or aquatic toxicity) , based

upon the test methods defined by EPA Regulations (USEPA 1998, 2012) or the ASTM Standard (2006), depending upon complete solubility of the fluid during test conditions. This means that acute toxicity testing measurements must be made at concentration levels measured for EC50, IC50, and LC50, or at loading rates measured at EL50, IL50, and LL50.

It is recommended that ecotoxicity tests be performed on a vertebrate, invertebrate, and plant (algal) species that is naturally found in the area of operation for the piece of floating plant. For example, an ecotoxicity test on a salt water species is not applicable for a floating plant that is operating on an inland river system. The EC50 tests are commonly performed with daphnia species due to their increased sensitivity to chemical concentrations.

Ecotoxicity ratings for aquatic environments subjected to chemicals are shown in acute toxicity scales developed by various organizations (see Tables 2 and 3 below).

<b>Table 2. USFWS and EPA acute toxicity rating scales for aquatic organisms.</b>		
<b>Relative Toxicity</b>	<b>USFWS</b>	<b>EPA</b>
	<b>EC50 or LC50 (mg/L or ppm)</b>	<b>LC50 (ppm)</b>
Super Toxic	< 0.01	Not Defined
Extremely Toxic	0.01-0.1	< 0.1
Highly Toxic	0.1-1.0	0.1-1
Moderately Toxic	1.0-10.0	>1-10
Slightly Toxic	10-100	>10-100
Practically Nontoxic	100-1000	>100
Relatively Harmless	>1000	Not Defined

Source: U. S. Environmental Protection Agency (2012).

<b>Table 3. ASTM aquatic toxicity rating scale.</b>	
<b>Ecotoxicity in Water Designation</b>	<b>Loading Rate, wppm, EL50, LL50 or IL50</b>
Tw1	>1000
Tw2	1000-100
Tw3	100-10
Tw4	<10

Source: ASTM Standard ASTM D 6046 – 02 (2006).

Given the information in Tables 2 and 3 above, USACE has determined that for a fluid to be rated as EA, the test results for acute ecotoxicity in water (or aquatic toxicity) must meet or exceed the minimum requirements of EPA (USEPA 2012) or the referenced ASTM Standard (2006), as follows:

- EC50 or LC50 concentration levels defined for the ***“Practically Nontoxic”*** rating as defined by EPA (and USFWS), or IC50 concentration level defined by USFWS (2010), or;
- EL50, LL50, or IL50 loading rates for class ***Tw2*** fluids as defined by the ASTM Standard (2006)

**Fluid chemistry.** In addition to the critical environmental properties detailed above, USACE has determined that in order for a fluid to be rated as “environmentally acceptable,” the chemistry of the fluid must not contain any toxic heavy metals. Examples of toxic heavy metals include, but are not limited to: lead, mercury, arsenic, etc.

**Sheen Generation:** The sheen-generating properties of hydraulic fluid and how sheen relates to the environment are often-debated topics. Some argue that oil sheens on the surface of the water allow for faster detection of a spill/leak/problem and aid in determining the source and severity of the oil spill. Additionally, the oil sheen has the potential to be contained with booms and recovered, whereas non-sheening, water-soluble oils may enter the water column directly and cannot be recovered. On the other side of the argument, a non-sheen oil is less likely to remain on the surface of the water where it has the potential to coat the feathers of fowl or mammals coming to the surface for air, which can hinder their ability to breathe and survive. Additionally, there are applications where the oil-to-sea interface will only seep small/limited amounts of oil, due to the nature of the service (i.e., stern tube, submerged bearing, etc.). In these instances, a non-sheening, environmentally acceptable fluid may be desirable.

Regardless of the arguments for or against sheen generation, the end user must be aware of the Federal regulations relating to oil discharge. The CWA and the Oil Pollution Act of 1990 (OPA 90) prohibit the discharge of oil into the waters of the United States in quantities that may be harmful. The Code of Federal Regulations (40 CFR Part 110.3(b) defines “quantities that may be harmful” as those causing a film or sheen upon or discoloration of the surface of the water or adjoining shorelines or cause a sludge or emulsion to be deposited beneath the surface of the water or upon adjoining shorelines. The current EPA Vessel General Permit (VGP) allows for discharges of lubricants from normal operations in amounts that are not harmful (per 40 CFR Part 110). In addition to the Federal statutes, the discharge of oil must also be in accordance with appropriate state, local, and/or tribal governments.

As the regulations read above, any oil discharge or spill that results in a sheen must be reported to the appropriate authorities. If the discharge or spill does not create a sheen, it still is reportable if it created sludge or emulsion below the water. Operators and supervisors must be aware of the regulations and the requirements to report any discharge of oil in quantities that may be harmful.

Although employing a “non-sheening” EA hydraulic fluid may be desirable over a sheening type EA hydraulic fluid, USACE has determined that sheen-generating, or non-generating, properties of a hydraulic fluid will not be considered in the determination of the fluid’s EA classification. It is the responsibility of the floating plant and facility operators to evaluate their operations and determine the desirable sheen characteristics. Considerations may include the location of the equipment, open or closed systems, expected operational seepage, spill potential, the level of monitoring on the system, the operating area, and other environmental factors.

If a non-sheen EA hydraulic fluid is required by the operators, it shall meet sheen requirements as defined by the “Static Sheen Test.” Sheen test requirements are defined in 40 CFR 435, Subpart A, Appendix 1, Part 1, Scope and Application, which states:

*This method is to be used as a compliance test for the “no discharge of free oil” requirement for discharges of drilling fluids, drill cuttings, produced sand, and well*

*treatment, completion, and workover fluids. “Free oil” refers to any oil contained in a waste stream that when discharged will cause a film or sheen upon a discoloration of the surface of the receiving water.*

Appendix 1, Part 8.6, of the referenced CFR (40 CFR 435) provides requirements regarding sheen detection and growth. These requirements are as follows:

- Detection of “free oil”

*Detection of a “silvery” or “metallic” sheen or gloss, increased reflectivity, visual color, iridescence, or an oil slick on the water surface of the test container surface shall constitute a demonstration of “free oil”...*

- Sheen growth

*If an oil sheen or slick occurs on less than one-half of the surface area after the sample is introduced to the test container, observations will continue for up to 1 hour. If the sheen or slick increases in size and covers greater than one-half of the surface area of the test container during the observation period, the discharge of the material shall cease. If the sheen or slick does not increase in size to cover greater than one-half of the test container surface area after one hour of observation, discharge may continue and additional sampling is not required.*

*If a sheen or slick occurs on greater than one-half of the surface area of the test container after the test material is introduced, discharge of the tested material shall cease. The permittee may retest the material causing the sheen or slick. If subsequent tests do not result in a sheen or slick covering greater than one-half of the surface area of the test container, discharge may continue.*

**COST:** The cost of EA fluids can currently range from 1.5-4 times that of a regular-grade, petroleum-based hydraulic fluid. Costs can vary, depending on the fluid manufacturer and volume required. Despite the higher initial costs for EA hydraulic fluids compared to petroleum-based fluids, there can be significant savings in cleanup costs, when compared to cleanup costs for petroleum-based hydraulic fluids. In some instances, if an accidental discharge occurs, the fines may be reduced or eliminated if the issuing agency is aware (or is made aware) that the fluid is EA and the impact on the environment is minimal.

In addition, some EA hydraulic fluids have a longer life expectancy than a traditional mineral oil; therefore, the life cycle costs over time may be reduced.

**REPLACEMENT OF EXISTING HYDRAULIC FLUIDS:** Hydraulic fluids in existing machinery must be flushed/removed as much as possible to minimize the contamination to the new/replacement EA hydraulic fluid. Thorough flushing of an existing system ensures that the new fluid will retain the desired environmental properties and maximize the performance in the hydraulic system. The recommended process is flushing the entire system with the new EA hydraulic fluid until the residual level of the previous oil is not more than 5% of the total fluid volume, or as recommended by the fluid and system manufacturers. The hydraulic system

manufacturer should also be consulted on the correct flushing procedure to prevent damage to the equipment.

All removed oil and oil used during flushing, should be disposed of in accordance with federal, state, local, and tribal regulations.

Maintenance of machinery systems containing EA hydraulic fluids must strictly follow the hydraulic fluid manufacturer's recommendations. Following these maintenance procedures is especially critical during the initial change from mineral oil-based to EA hydraulic fluid. Maintenance shall include hydraulic fluid analysis and regular fluid and filter changes.

Some fluid providers may analyze the hydraulic fluid on a regular scheduled basis as part of the purchase price of the hydraulic fluid. USACE highly recommends that the operators maintain the analysis schedule, as this is a critical step in ensuring that the fluid is not becoming contaminated and maintaining its physical and environmental properties. In addition, properly maintaining the fluid can extend the time interval between fluid changes, thus reducing the overall operating cost of the EA hydraulic fluid. It is also possible for particular types of EA hydraulic fluids to be restored/reconditioned to the "as-new" condition, prolonging the life of the fluid indefinitely.

Annex A of ISO Standard 15380:2011 (ISO 2011) contains useful information and guidance for changing fluids from mineral-based oils to EA fluids.

**SELECTING AN ENVIRONMENTALLY ACCEPTABLE HYDRAULIC FLUID:** Selecting an EA hydraulic fluid to replace a fluid, or to commission a new system, is not a task that should be taken lightly. There is a wealth of information and misinformation available on EA fluids. The EA fluid industry is growing, and as such, there are many choices when it comes to selecting EA fluids. Some of the products available are truly "environmentally acceptable," while other products only make those claims. Below is a summary of important considerations when evaluating an EA fluid:

- System Requirements and Compatibility
  - Consult with the hydraulic system manufacturer to determine all of the physical characteristics/parameters the fluid for that system requires and if the proposed fluid is acceptable
  - Consult with the hydraulic system manufacturer and fluid provider to ensure that the operating environment is suitable for the fluid
  - Consult with the hydraulic system manufacturer to determine if ALL of the seals in the system are compatible with the proposed fluid
  - Ensure that the new fluid will not void the remaining warranty if the hydraulic system is still under warranty
  - Examine the tank/reservoir coating system and determine if the fluid is compatible
  - Obtain written approval from the hydraulic system manufacturer indicating that the proposed fluid is compatible with the system, reservoir, and seals, and that the physical and performance properties are within the requirements system

- Coordinate with the hydraulic system manufacturer and the fluid provider on the proper flushing procedures
- If commissioning a new system, require the hydraulic system manufacturer to factory/bench test the system with the proposed EA fluid
- Environmental Properties
  - All testing regarding environmental properties should be performed by independent labs/testing companies. Documentation should be provided for all required tests, as follows:
    - Biodegradability – ASTM Pw1 Classification or equivalent
    - Ecotoxicity
      - Tests performed on a vertebrate, invertebrate, and/or plant (algal) species that is naturally found in the area of operation
        - ASTM Tw2 Classification, or;
        - USFWS/EPA “Practically Nontoxic” Classification, or;
        - an approved equivalent classification
    - Sheen Generation – pass the EPA Static Sheen Test as described in 40 CFR 435, Subpart A, Appendix 1
  - Provide a list of the chemical compounds in the fluid and ensure that no heavy metals are present
- Costs and Fluid Maintenance
  - Obtain a quote(s) from the suppliers
  - Determine if additional fluid is necessary for proper system flushing and ensure that fluid cost is included
  - Consult with the suppliers on the life expectancy of the fluid and recommended intervals between fluid changes, filter changes, dryer/breather changes, etc.
  - Develop a life-cycle cost analysis to compare the fluid(s) to the conventional fluid over a fix period of time
  - Include periodically scheduled fluid analysis as part of the maintenance program

It is important for the end users to apply due diligence when considering an EA fluid. This includes the following actions:

- Understand the federal, state, local, and tribal laws and regulations
- Understand the basics behind EA fluids, standards, and classifications
- Ask questions of the system manufacturer and the fluid suppliers
- Talk to suppliers of the different types of fluids (SE, PAG, PAO, vegetable oils) to determine if a particular fluid is right for the intended application (more than one type of fluid may work)

- Require the fluid supplier to provide documentation from independent labs/testing companies
- Consider the overall and life-cycle costs (including potential savings from fines)
- Ensure that the fluid supplier is a reputable company
- Most importantly, obtain the approval from the hydraulic system manufacturer for the use of the EA hydraulic fluid

**FUTURE CONSIDERATIONS FOR ENVIRONMENTALLY ACCEPTABLE HYDRAULIC FLUIDS:** The requirements for the EA-rated hydraulic fluids above have been developed based on current guidelines, standards, and technology. Additional future considerations to bolster the USACE EA rating for hydraulic fluids include the following:

- Development of more stringent fluid aquatic ecotoxicity requirements, such as implementation of ASTM Acute Ecotoxicity Classification Tw1
- Development of test standards/requirements by ASTM for bioaccumulation (current standards are defined by EPA and OECD)

It is recommended that this document be reviewed for relevancy at least once every five years. As laws, regulations, and technology change, this document will be revised to ensure that the criteria for EA hydraulic fluid remain up-to-date, and at the upper tiers with the current standards.

**CONCLUSIONS:** The development and use of EA hydraulic fluids are expanding every day. The definition or classification of EA hydraulic fluids varies among agencies, suppliers, and end users. The information provided by vendors and suppliers can be overwhelming and easily misunderstood.

The biodegradability and the ecotoxicity of a hydraulic fluid are the significant characteristics used to gauge the environmental impact and determine if the fluid is environmentally acceptable. An EA hydraulic fluid shall be rated as “*Readily Biodegradable*” and the ecotoxicity as “*Practically Nontoxic*.” Additionally, the chemical formula for the fluid shall not include heavy metals.

It is imperative for users considering an EA hydraulic fluid to understand the types of fluids and weigh a variety of factors. The fluid selected should be compatible with the system and components, be classified as an EA fluid according to this document, and have the desirable sheen characteristics. The total cost of ownership, not just the initial fill costs, should also be included in the fluid selection. This technical note has provided basic knowledge and understanding for end users considering the use of EA hydraulic fluid, but due diligence must be employed throughout the process to ensure a successful conversion (or system start-up) and operation.

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Marine Design Center; and Timothy L. Welp, Research Hydraulic Engineer, U.S. Army Engineer Research and Development Center. The research and development of the classification standard and selection guidance were conducted as an activity of the DOER and DOTS Programs. For information on DOER, please consult <http://el.erd.c.usace.army.mil/dots/doer/> or contact the Program Manager, Dr. Todd S. Bridges, at [Todd.S.Bridges@usace.army.mil](mailto:Todd.S.Bridges@usace.army.mil) and for information on DOTS, consult <http://el.erd.c.usace.army.mil/dots/> or contact the Program Manager, Cynthia Banks, at [Cynthia.J.Banks@usace.army.mil](mailto:Cynthia.J.Banks@usace.army.mil). This technical note should be cited as follows:

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