



**US Army Corps
of Engineers®**

ENGINEERING AND CONSTRUCTION BULLETIN

No. 2007-21

Issuing Office: CECW-CE

Issued: 16 Nov 2007

Subject: Revision to EM 1110-2-1424 Lubricants and Hydraulic Fluids - Appendix C

Applicability: Guidance

1. Appendix C of the subject manual has been revised to update testing and evaluation of the compatibility of turbine oils used at Corps Hydropower projects. It also provides newly developed guidance for specifying off-line oil filtration systems. A copy of the revised appendix is attached. The subject manual with the revised appendix will be published in the near future.
2. Point of contact for this ECB is Dan Casapulla, 202-761-4227.

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JAMES C. DALTON, P.E.
Chief, Engineering and Construction
Directorate of Civil Works

Appendix C

SPECIFICATION FOR TURBINE OIL

GUIDANCE ON THE USE OF THIS SPECIFICATION

This appendix contains Guidance on the Use of This Specification, Specification for Turbine Oils, and Guidance for Specifying Off-Line Filtration Systems.

The specification below is for zinc and chlorine-free petroleum-based turbine oils for use at hydroelectric power plants in generator and turbine bearings, Kaplan turbine hubs, and governor systems. For additional guidance, reference Chapter 11 Engineer Manual EM 1110-2-1424, Lubricants and Hydraulic Fluids for Civil Works Project

Compatibility between new oil and in-service oils must be evaluated and determined by lab testing. Only oils found to be compatible shall be mixed with in-service oil or used as replacement oil. The compatibility testing is necessary because the new oils currently readily available on the market may have been formulated with different additives, which may not be fully compatible with additives of the in-service oils.

This specification shall be used for the procurement of all turbine oils, whether purchased for initial installation, filling rehabbed hydroelectric units, or for use as additional turbine oil at operating projects.

The method of shipment, type of containers, delivery dates, delivery point, delivery point of contact, and other required information should be included in appropriate sections of the contract specifications.

The turbine oil shall meet or exceed the chemical and physical requirements specified in TABLE 1. Additional characteristics or changes in listed values should not be included in the specifications without prior consultation with the technical proponent of the specification. The Corps' Districts/Projects may perform Quality Assurance (QA) tests on samples taken at the delivery point. The QA tests should include, as a minimum, the viscosity, acid number, elemental spectroscopy, and oxidation stability. Samples shall be taken from each bulk shipment and from not less than 10 percent of the drums taken at random from drum shipments. Such samples shall be not less than 4 L (1 gal), which may be stored in more than one sample container, and a portion of each sample shall be saved for later confirmation tests in the event that the results from the first tests indicate that the oil does not meet the specification requirements.

When soliciting for new contracts or orders using this specification for purchase of turbine oil that will be mixed with the in-service oil or as a replacement oil, the government should require all offerors to provide a 1-gallon sample of the proposed oil, which must meet the requirements of this specification in order to be eligible for award. The solicitation must include this language. The Government may test this oil for compatibility with the in-service oil by sending a portion (1 qt) of new oil in an unmarked container, and a sample of in-service oil to a lab.

EM 1110-2-1424
26 Oct 07
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Prior to awarding the Contract, the compatibility of new oil must be verified by the ASTM D 7155-06 test, Standard Practice for Evaluating Compatibility of Mixtures of Turbine Lubricating Oils. The remaining

quantity of new oil should be retained by the Government for possible further testing. Compatibility testing should be performed at no charge to the bidders.

The personnel from Corps Districts/Project offices can contact Hydroelectric Design Center for assistance and/or request additional information/clarification related to the information contained in the entire document (POC: John Micetic, 503.808.4216 or john.s.micetic@usace.army.mil).

SPECIFICATION FOR TURBINE OIL

TURBINE OIL

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1. GENERAL

This specification covers zinc and chlorine-free rust and oxidation inhibited (R&O) mineral oils for use in hydraulic turbine and generator bearings, Kaplan turbine hubs, hydraulic-turbine governors, and other applications, where high-grade turbine oil having anti-corrosion, anti-oxidation, and anti-foaming properties is required.

2. REFERENCES

The publications listed below form a part of this specification to the extent referenced. The publications are referred to in the text by basic designation only.

AMERICAN SOCIETY FOR TESTING AND MATERIALS (ASTM)

ASTM D 92	(2002b) Flash and Fire Points by Cleveland Open Cup
ASTM D 97	(2004) Pour Point of Petroleum Oils
ASTM D 130	(2004) Corrosiveness to Copper from Petroleum Products by Copper Strip Test
ASTM D 445	(2004e1) Kinematic Viscosity of Transparent and Opaque Liquids (and the Calibration of Dynamic Viscosity)
ASTM D 664	(2004e1) Acid Number of Petroleum Products by Potentiometric Titration

ASTM D 665	(2003) Rust-Preventing Characteristics of Inhibited Mineral Oil in the Presence of Water
ASTM D 892	(2003) Foaming Characteristics of Lubricating Oils
ASTM D 943	(2004a) Oxidation Characteristics of Inhibited Mineral Oils
ASTM D 1401	(2002) Water Separability of Petroleum Oils and Synthetic Fluids
ASTM D 2270	(2004) Calculating Viscosity Index from Kinematic Viscosity at 40 and 100 Degrees C
ASTM D 2272	(2002) Oxidation Stability of Steam Turbine Oils by Rotating Pressure Vessel Oxidation Test
ASTM D 3427	(2003) Air Release Properties of Petroleum Oils
ASTM D 4057	(2000) Manual Sampling of Petroleum and Petroleum Products ASTM D 4177 (2000) Automatic Sampling of Petroleum and Petroleum Products)
ASTM D 6304	(2004ae1) Water in Petroleum Products, Lubricating Oils, and Additives by Coulometric Karl Fisher Titration
ASTM D 7155	(2006) Standard Practice for Evaluating Compatibility of Mixtures of Turbine Lubricating Oils

INTERNATIONAL ORGANIZATION FOR STANDARDIZATION (ISO)

ISO 4406	(1999) Coding the Level of Contamination by Solid Particles
ISO 11171	(1999) Calibration Of Automatic Particle Counters for Liquids

3. SUBMITTALS

Government approval is required for submittals with a "G" designation; submittals not having a "G" designation are for information only. When used, a designation following the "G"

designation identifies the office that will review the submittal for the Government. The following shall be submitted:

3.1 DATA

Data of Chemical and Physical Characteristics of Turbine Oil, G [, _____]

The Contractor shall furnish [_____] copies of certified test data, which show that the oil meets or exceeds characteristics values specified in TABLE 1. The certified test data shall be submitted for approval 30 days before the oil delivery.

3.2 SAMPLES

A gallon of proposed turbine oil, G [, _____]

The prospective bidder shall send one gallon of oil to the Government along with the bid. This oil shall be closely representative to the oil being offered in the bid. The Government plans to send a quart of this oil in an unmarked container to an independent laboratory for compatibility testing with the in-service oil. The compatibility testing will be performed at no charge to the prospective bidder. If the submitted oil sample is found to be incompatible with the in-service oil, this oil will not be further considered in the Contract awarding process.

4. TURBINE OIL CHARACTERISTICS AND REQUIREMENTS

4.1 GENERAL PROPERTIES

The turbine oil shall be a blend of virgin petroleum-based stocks plus additives, free of zinc and chlorine, resulting in high-grade turbine oil having anti-rust, anti-oxidation and anti-foaming properties suitable for use in hydraulic turbines, generator bearings, Kaplan turbine hubs and related applications. Chemical and physical characteristics of oil shall meet or exceed the requirements listed in TABLE 1. Oil characteristics shall be determined by tests conducted in accordance with the tests methods as noted in the table.

4.2 CHEMICAL AND PHYSICAL CHARACTERISTICS

The turbine oil shall conform to the requirements established in TABLE 1 when tested according to the standards indicated there.

4.3 DEGRADATION

The physical and chemical properties of the oil shall not be degraded (changed from the specified values by filtration through two-micron mechanical type filters, by centrifugal purification, or by vacuum type purifier, all of which have been designed for turbine oil.

4.4 HOMOGENEITY

Additive agents shall remain uniformly distributed throughout the oil at all temperatures above the pour point and up to 120 °C (250 °F). When the oil is cooled below the pour point, it shall regain homogeneity while standing at temperatures of 5 °C (10 °F) above the pour point, and retain clear and bright appearance.

5. COMPATIBILITY

Before the oil is being purchased for addition to existing (in-service) oil or as replacement oil, the Government will send samples of new and in-service oil to an independent commercial laboratory for evaluation of compatibility between the two oils. Compatibility evaluation shall be performed in accordance with ASTM D 7155 test, Standard Practice for Evaluating Compatibility of Mixtures of Turbine Lubricating Oils. Potential suppliers shall contact the Contracting Officer to obtain a representative sample of the in-service oil necessary if they wish to conduct the test.

The compatibility test requirements in this paragraph, Paragraphs 3.2 and Paragraph 6 are not applicable for new construction.

TABLE 1

**CHEMICAL AND PHYSICAL CHARACTERISTICS REQUIREMENTS AND TEST
METHODS FOR RUST AND OXIDATION (R&O) INHIBITED ISO 68 & 100 TURBINE
OILS**

Chemical and Physical Characteristics	Requirements		Test Method
	ISO 68 Oil	ISO 100 Oil	
Viscosity at 40 °C, centistokes (cSt)	65-70	95-102	ASTM D 445
Viscosity Index, minimum	98	95	ASTM D 2270
Flash Point, minimum, °C (°F)	204 (400)	210 (410)	ASTM D 92
Pour Point, maximum, °C (°F)	-9 (16)	-9 (16)	ASTM D 97
Acid Number (AN) mg KOH/g, maximum	0.15	0.15	ASTM D 664
Oxidation Stability by Rotating Pressure Vessel Oxidation Test (RPVOT), minutes, minimum	500	500	ASTM D 2272
Oxidation Characteristics, mg KOH/g, max	0.5*	0.5*	ASTM D 943
Rust Preventive Characteristics, Procedures "A" and "B"	Pass	Pass	ASTM D 665
Water Content, parts per million (ppm), max	250	250	ASTM D 6304
Water Separability of Petroleum Oil	40-40-0 (30)	40-40-0 (60)	ASTM D 1401
Corrosion from Oil by Copper Strip Tarnish	Classification 1	Classification 1	ASTM D 130

Test			
Foaming characteristics <u>After 5 minutes blowing period:</u> Sequence 1, foam volume in ml, maximum Sequence 2, foam volume in ml, maximum Sequence 3, foam volume in ml, maximum <u>After 10 minutes settling period:</u> Sequence 1, foam volume in ml, maximum Sequence 2, foam volume in ml, maximum Sequence 3, foam volume in ml, maximum	100 50 100 10 0 10	100 50 100 10 0 10	ASTM D 892 (Option "A" excluded)
Air Release Properties, minutes, maximum	30	60	ASTM D 3427
Cleanliness, ISO Code Particle Count, particle sizes of greater than 4, 6, and 14 μm (c)	17/15/12 (c)	17/15/12 (c)	ISO 4406-99 (ISO 11171 Cal.)
Appearance	Clear & Bright	Clear & Bright	Visual Observation

* At the conclusion of the 1,000 hours test, measured AN should be 0.5 or less. In addition, at that point, the oil and water phases shall be examined for evidence of sludge and catalyst metal corrosion. Permitted maximum level of total sludge in the oil after 1000 hours is 50 mg/kg.

6. PRE-DELIVERY TESTING

The Contractor shall test the oil or a sample blend for all chemical and physical characteristics set forth in TABLE 1, and provide the certified test results as well as one gallon sample of the oil to the Government at least thirty days prior to delivery.

The Contractor may conduct compatibility testing of the oil or sample blend. The Government will provide a sample of in-service oils for such purposes on request.

The Government will conduct compatibility testing of the sample, and notify the contractor of the results prior to purchasing of the oil.

7. DELIVERY

The Contractor shall deliver the oil according to the delivery requirements specified elsewhere in this contract.

8. INSPECTION AND ACCEPTANCE.

At the point of oil delivery, the Government will obtain samples in a manner specified in ASTM D 4057 or ASTM D 4177, and may perform such tests as are deemed necessary to determine whether the oil meets the specifications values listed in TABLE 1. The delivered oil will remain

in a storage tank (if applicable) and will not be used until the test results are received from the laboratory. Should the oil fail any test, the Contractor shall be responsible for disposing of the delivered oil and replacing the oil at its own expense.

GUIDANCE FOR SPECIFYING OFF-LINE FILTRATION SYSTEMS

In FY07, the R&D titled Conditioning of Turbine Oils at Corps Hydropower Facilities was conducted, and completed in Sep 2007. This R&D effort included collating data from a field test of mechanical-type and electrostatic-type filtration systems. The field test was performed at Chief Joseph powerhouse in Bridgeport, WA, where three commercially available mechanical-type filtration systems from different manufacturers were plumbed to three different governor oil sumps. The characteristics of these mechanical systems met a generic specification requirements set by the Corps prior to the test. In addition, an electrostatic-type filtration system, equipped with a cellulose-type moisture scrubber was plumbed to a fourth governor sump.

Monthly testing results of filtered oil were performed and tracked over a three month period. Collated results showed that both types of filtration systems were effective and efficient in removing varnish and other contaminants from turbine oil. Based on this R&D, it was concluded that the following parameters should be used as a generic guideline by the Corps personnel in the process of specifying off-line filtration systems.

- Flow rate of maximum 8.0 GPM
- Filtration system shall not have bypass valve installed
- A thermostatically controlled heater to be attached to the filter, capable of maintaining oil temperature of 40° C (105° F).
- A low-watt-density type oil heater element; not to exceed 12 watt/square inch. The heater designed to automatically turn off if the system shuts down for any reason.
- The pump (screw-type or gear-type) with a pump relief valve to be mounted to the bottom of the filter housing, allowing oil to flow through the cellulose media in an outside-in pattern.
- The system to include a maximum indicating pressure gauge (LENZ or equal), typically set between 32 and 35 psi, and installed on top of the filter housing to alert the operator of the maximum differential pressure reached, and need to change the filter insert. When energized, it must illuminate a red light signal on the control panel.
- The filter system to be equipped with oil valves positioned before and after the filter to enable sampling of unfiltered and filtered oil.
- An automatic low pressure air regulator (vent) to be installed on top of the filter housing, designed to aid separation and discharge of air from the oil.

- The cellulose fiber filter element to be rated at maximum 3-micron absolute and 0.8-micron nominal, at minimum of Beta 3 ≥ 75 .

Notes:

1. The size of the filtration system and its dirt holding capacity varies depending on the quantity of oil in a particular governor sump.
2. The same characteristic for the flow and the heaters apply for electrostatic filter systems. In addition, these systems need to be equipped with a cellulose-type moisture scrubber, because the efficiency of this technology significantly decreases if moisture is present in oil.
3. Heaters are not needed for systems intended to off-line filter oil in the bulk oil storage tanks.