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Standard Guide for Evaluation of Hydrocarbon Heat Transfer Fluids[1]

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1. Scope [2]

1.1 This guide provides information, without specific limits, for selecting standard test methods for testing heat transfer fluids for quality and aging. These test methods are considered particularly useful in characterizing hydrocarbon heat transfer fluids in closed systems.

2. Referenced Documents

2.1 *ASTM Standards:*

D 86 Test Method for Distillation of Petroleum Products[3]

D 91 Test Method for Precipitation Number of Lubricating Oils[3]

D 92 Test Method for Flash and Fire Points by Cleveland Open Cup[3]

D 93 Test Methods for Flash Point by Pensky-Martens Closed Tester[3]

D 95 Test Method for Water in Petroleum Products and Bituminous Materials by Distillation[3]

D 97 Test Methods for Pour Point of Petroleum Oils[3]

D 189 Test Method for Conradson Carbon Residue of Petroleum Products[3]

D 445 Test Method for Kinematic Viscosity of Transparent and Opaque Liquids (and the Calculation of Dynamic Viscosity)[3]

D 471 Test Method for Rubber Property—Effect of Liquids[4]

D 524 Test Method for Ramsbottom Carbon Residue of Petroleum Products[3]

D 664 Test Method for Acid Number of Petroleum Products by Potentiometric Titration[3]

D 893 Test Method for Insolubles in Used Lubricating Oils[3]

D 1160 Test Method for Distillation of Petroleum Products at Reduced Pressure[3]

D 1298 Test Method for Density, Relative Density (Specific Gravity), or API Gravity of Crude Petroleum and Liquid Petroleum Products by Hydrometer Method[3]

D 1500 Test Method for ASTM Color of Petroleum Products (ASTM Color Scale)[3]

D 2160 Test Method for Thermal Stability of Hydraulic Fluids[3]

D 2270 Practice for Calculating Viscosity Index from Kinematic Viscosity at 40 and 100°C[3]

D 2717 Test Method for Thermal Conductivity of Liquids[5]

D 2766 Test Method for Specific Heat of Liquids and Solids[5]

D 2887 Test Method for Boiling Range Distribution of Petroleum Fractions by Gas Chromatography[5]

D 3241 Test Method for Thermal Oxidation Stability of Aviation Turbine Fuels (JFTOT Procedure)[5]

D 4530 Test Method for Micro Carbon Residue of Petroleum Products[5]

E 659 Test Method for Autoignition Temperature of Liquid Chemicals[6]

G 4 Method for Conducting Corrosion Coupon Tests in Plant Equipment[7]

3. Terminology

3.1 *Description of Term Specific to This Standard:*

3.1.1 *heat transfer fluid—in this guide*, a petroleum oil or related hydrocarbon material which remains essentially a liquid while transferring heat to or from an apparatus or process. Small percentages of nonhydrocarbon components such as antioxidants and dispersants can be present.

4. Significance and Use

4.1 The significance of each test method will depend upon the system in use and the purpose of the test method as listed under Section 5. Use the most recent editions of ASTM test methods.

5. Recommended Test Procedures

5.1 *Pumpability of the Fluid*:

5.1.1 *Flash Point*, closed cup (Test Method D 93)—This test method will detect low flash ends which are one cause of cavitation during pumping. In closed systems, especially when fluids are exposed to temperatures of 225°C (approximately 400°F) or higher, the formation of volatile hydrocarbons by breakdown of the oil may require venting through a pressure relief system to prevent dangerous pressure build-up.

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[1] This guide is under the jurisdiction of ASTM Committee D-2 on Petroleum Products and Lubricants and is the direct responsibility of Subcommittee D02.L0.06 on Nonlubricating Process Fluids.

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[2] The background for this standard was developed by a questionnaire circulated by ASTM-ASLE technical division L-VI-2 and reported in *Lubrication Engineering*, Vol 32, No. 8, August 1976, pp. 411–416.

[3] *Annual Book of ASTM Standards*, Vol 05.01.

[4] *Annual Book of ASTM Standards*, Vol 09.01.

[5] *Annual Book of ASTM Standards*, Vol 05.02.

[6] *Annual Book of ASTM Standards*, Vol 14.02.

[7] *Annual Book of ASTM Standards*, Vol 03.02.

5.1.2 *Pour Point* (Test Method D 97)—The pour point can be used as an approximate guide to the minimum temperature for normal pumping and as a general indication of fluid type and low temperature properties. Should a heat transfer system be likely to be subjected to low temperatures when not in use, the system should be trace heated to warm the fluid above minimum pumping temperature before start-up.

5.1.3 *Viscosity* (Test Method D 445)—Fluid viscosity is of importance in the determination of Reynolds and Prandtl numbers for heat transfer systems, to estimate fluid turbulence, heat transfer coefficient, and heat flow. Generally, a fluid that is above approximately 200 centistokes is difficult to pump. The pump and system design will determine the viscosity limit required for pumping. The construction of a viscosity/temperature curve using determined viscosities can be used to estimate minimum pumping temperature.

5.1.4 *Specific Gravity* (Test Method D 1298)—Hydraulic shock during pumping has been predicted via the use of a combination of density and compressibility data.[8]

5.1.5 *Water Content* (Test Method D 95)—The water content of a fresh heat transfer fluid can be used to indicate how long the heat transfer system must be dried out during commissioning, while raising the bulk oil temperature through the 100°C plus region, with venting, before the system can be safely used at higher temperatures. The expansion tank should be full during the operations to ensure that moisture is safely vented in the lowest pressure part of the systems. Positive nitrogen pressure on the heat exchange systems will minimize entry of air or moisture. Heat transfer systems operating at temperatures of 120° or greater must, for reasons of safety, be dry, because destructive high pressures are generated when water enters the high temperature sections of the system. Heating the oil before it is placed in service also removes most of the dissolved air in the oil. If not removed, the air can cause pump cavitation. The air can also accumulate in stagnant parts of the system at high pressure and could cause an explosion.

5.2 *Safety in Use*:

5.2.1 *Autoignition Temperature* (Test Method E 659)—The above test relates to the autoignition temperature of a bulk fluid. Hydrocarbon fluids absorbed on porous inert surfaces can ignite at temperatures more than 50°C (approximately 100°F) lower than indicated by Test Method E 659. An open flame will ignite leaking hydrocarbon fluids exposed on a porous surface at any temperature.

NOTE 1—A "Soaked Cube Fire Test," now under development by ASTM Committee D.02.0N.06, may prove more relevant in assessing fire hazards from heat transfer fluid leaks.

5.2.2 *Flash Point* (Test Methods D 92 and and D 93)—Some heat transfer fluids are volatile and present a fire hazard at slightly elevated temperatures, or even below 25°C (77°F).

5.3 *Effect on Equipment*:

5.3.1 *Effect on Rubber or Elastomeric Seals* (Test Method D 471)— Most seals in heat exchange equipment are made of steel or other metal. If rubber seals are present, it is desirable to maintain rubber swelling in the range of 1 to 5 % to prevent leakage because of poor seal contact. Seals may degrade in some fluids. As an oil deteriorates in service, additional tests may be required to assure that seals remain compatible with the altered oil. The temperature ranges of the tests should correspond to temperatures to which seals will be exposed in service.

5.3.2 *Corrosion* (Guide G 4)—The above tests concern selection of materials of construction with fluids usable for heat transfer systems. Guide G 4 uses test metal specimens fixed within the stream of test fluid under use. The specimens and conditions for test must be specified for each system.

5.4 *Efficiency*:

5.4.1 *Thermal Conductivity* (Test Method D 2717) and *Specific Heat* (Test Method D 2766)—These thermal conductivity and specific heat tests are difficult to carry out, facilities for performing them are few, and the precision data is yet to be established. Values can be estimated for design use from the general chemical composition. Differences contribute to efficiency to a lesser degree than values such as viscosity, moisture contamination, and other measurable values in 5.1 and 5.5 of this guide. The values for thermal conductivity and specific heat may be available from the fluid supplier.[9]

5.5 *Service Life*:

5.5.1 *Thermal Stability, Laboratory Tests*[10]—Thermal stability is here defined as the resistance of a hydrocarbon liquid to permanent changes in properties that make it a less efficient heat transfer fluid. These changes may be related to alterations in the liquid's properties, such as viscosity, or to the tendency to foul heat exchanger surfaces with insulating deposits. Normally, testing should be done in the absence of air and moisture to stimulate "tight" systems. The test may be useful for assessing the remaining service life of a used fluid, or it may be used to compare the expected service life of a competitive new heat transfer fluids.

5.5.2 The following test methods can be used to determine the change in values between new and used fluids, or between a fluid before and after subjection to a laboratory thermal stability test. These test methods have been found especially useful for determining the end of a fluid's service life when an identical fluid has been monitored with the same tests throughout its service life. These test methods can also detect leakage of foreign material into the heat transfer fluid.

5.5.2.1 *Precipitation Number* (Test Method D 91) *and Insolubles* (Test Method D 893)—These test methods determine the extent to which insolubles that may contribute to fouling of metal surfaces are increasing.

5.5.2.2 *Flash Point* (Test Methods D 92 and D 93)—A lowering of flash point is indicative of thermal cracking to produce lower molecular weight hydrocarbons. A rapid increase may indicate that fluid is being exposed to excessive temperatures.

[8] Abbey, J., "Hydraulic Surge," Bulletin No. 768, Aeroquip Corporation, Vol 14, No. 1, February 1963.

[9] Useful estimates may be obtained from sources such as the "Technical Data Book, Petroleum Refining," American Petroleum Institute, 1220 L St., N.W, Washington, DC 200005–4070.

[10] At present, no suitable method has been approved for thermal stability of heat transfer fluids. Test Method D 2160 is of limited value due to the limitations in testing small noncirculating samples in glass containers. A modified version of Test Method D 3241 has been used, but the precision bias has not been assessed by ASTM.

5.5.2.3 *Carbon Residue* (Test Methods D 189, D 524, and D 4530)—An increase of carbon residue during service provides an indication of the fluid's tendency to form carbonaceous deposits. These deposits, which may impair heat transfer, are caused by precipitation of high molecular weight materials produced by thermal cracking of the fluid.

5.5.2.4 *Viscosity* (Test Method D 445)—An increase in viscosity may reduce the fluid's ability to transfer heat (see 5.1.3). Cracking of hydrocarbons in high temperature service in closed systems often causes a decrease in viscosity. Thus a change in viscosity taken by itself is insufficient to judge the performance of a fluid in service.

5.5.2.5 *Distillation* (Test Methods D 86, D 1160, and D 2887)—Distillation can show directly the percentage of a fluid that has cracked into lower boiling products or has been converted into higher boiling products. Distillation data can serve as the sole criterion for changing a heat transfer fluid.

5.5.2.6 *Neutralization Number* (Test Method D 664)—A marked increase in neutralization number is a warning of oxidation in the system, which may be the result of leaks. In high-temperature service (200°C, approximately 400°F), organic acids may decompose, and the use of infrared analyses may serve as a more reliable method for detection of oxidation.

5.5.2.7 *Color* (Test Method D 1500)—In itself, color is not important, but may be the initial indication of chemical changes in the heat transfer system.

5.5.2.8 *Viscosity Index* (Test Method D 2270)—The viscosity index of a fluid may change during service. Generally, the viscosity of a heat transfer fluid is not measured at the operating temperature (see 5.5.2.4). If the viscosity index of new and used fluids are known, the viscosities at operating temperature can be estimated and compared.

5.5.2.9 *Water Content* (Test Method D 95)—Small amounts of water present in heat transfer systems may cause corrosion, high pressures, or pump cavitation.

6. Keywords

6.1 characterization; heat transfer fluid; heat transfer oil; heat transfer system