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Standard Test Method for Thermal Stability of Organic Heat Transfer Fluids¹

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1. Scope*

1.1 This test method covers the determination of the thermal stability of unused organic heat transfer fluids. The procedure is applicable to fluids used for the transfer of heat at temperatures both above and below their boiling point (refers to normal boiling point throughout the text unless otherwise stated). It is applicable to fluids with maximum bulk operating temperature between 260 °C (500 °F) and 454 °C (850 °F). The procedure shall not be used to test a fluid above its critical temperature. In this test method, the volatile decomposition products are in continuous contact with the fluid during the test. This test method will not measure the thermal stability threshold (the temperature at which volatile oil fragments begin to form), but instead will indicate bulk fragmentation occurring for a specified temperature and testing period. Because potential decomposition and generation of high pressure gas may occur at temperatures above 260 °C (500 °F), do not use this test method for aqueous fluids or other fluids which generate high-pressure gas at these temperatures.

1.2 DIN Norm 51528 and GB/T 23800 cover other test methods that are similar to this test method.

1.3 The applicability of this test method to siloxane-based heat transfer fluids has not been determined.

1.4 The values stated in SI units are to be regarded as standard. The values given in parentheses are for information only.

1.5 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.* For specific warning statements, see 7.2, 8.8, 8.9, and 8.10.

1.6 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recom-*

mendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.

2. Referenced Documents

- 2.1 *ASTM Standards:*²
D2887 Test Method for Boiling Range Distribution of Petroleum Fractions by Gas Chromatography
D4175 Terminology Relating to Petroleum Products, Liquid Fuels, and Lubricants
E691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method

- 2.2 *DIN Norms:*³
51528 Determination of the Thermal Stability of Unused Heat Transfer Fluids

- 2.3 *China National Standard:*⁴
GB/T 23800 Heat transfer fluids – Determination of thermal stability

3. Terminology

3.1 Definitions:

3.1.1 *thermal stability, n*—the resistance to permanent changes in properties caused solely by heat. **D4175**

3.2 Definitions of Terms Specific to This Standard:

3.2.1 *decomposition products that cannot be vaporized, n*—materials from the thermally stressed heat transfer fluid, from which those fractions that can be vaporized are removed by distillation procedures, that are quantitatively determined as residues in a bulb tube distillation apparatus.

3.2.2 *fluid within the unstressed fluid boiling range, n*—any fluid components with boiling point between the initial boiling point and final boiling point of the unstressed fluid.

3.2.3 *gaseous decomposition products, n*—materials with boiling points below room temperature, at normal pressure, such as hydrogen and methane, that escape upon opening the

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² For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

³ Available from Deutsches Institut für Normung e.V.(DIN), Burggrafenstrasse 6, 10787 Berlin, Germany, http://www.din.de.

⁴ Available from China National Standards (GB), 106# Zhongmao Building, Sungang, Beizhan Rd., Luohu, Shenzhen, China, http://gbstandards.org.

*A Summary of Changes section appears at the end of this standard

test cell and that can be determined by measuring the mass immediately thereafter.

3.2.4 *high boiling components, n*—materials from the thermally stressed heat transfer fluid, with boiling points above the final boiling point of the unstressed heat transfer fluid, but which can still be separated by distillation from the heat transfer fluid by means of classical separation procedures.

3.2.5 *low boiling components, n*—materials from the thermally stressed heat transfer fluid, with boiling points below the initial boiling point of the unstressed heat transfer fluid.

3.2.6 *mass percentage of high boiling components, n*—the percentage of thermally stressed heat transfer fluid with a boiling point above the final boiling point of the unstressed fluid.

3.2.7 *mass percentage of low boiling components, n*—the percentage of thermally stressed heat transfer fluid with a boiling point below the initial boiling point of the unstressed fluid.

3.2.8 *test cell, n*—an ampoule constructed from stainless steel tubing and sealed with compression fittings at each end.

3.2.9 *thermally stressed, adj*—subjected to heating, as described in this test method.

4. Summary of Test Method

4.1 Charge the test fluid in a thermal stability test cell purged with nitrogen and tightly seal the test cell to remove and preclude introduction of oxygen and water from the atmosphere. Heat the fluid in an oven at a given temperature and for a given period of time. Determine the boiling range of the heated fluid by gas chromatography (GC) analysis and compare it to the boiling range of pure, unused fluid.

5. Significance and Use

5.1 Heat transfer fluids degrade when exposed to sufficiently high temperatures. The amount of degradation increases as the temperature increases or the length of exposure increases, or both. Due to reactions and rearrangement, degradation products can be formed. Degradation products include high and low boiling components, gaseous decomposition products, and products that cannot be evaporated. The type and content of degradation products produced will change the performance characteristics of a heat transfer fluid. In order to evaluate thermal stability, it is necessary to quantitatively determine the mass percentages of high and low boiling components, as well as gaseous decomposition products and those that cannot be vaporized, in the thermally stressed heat transfer fluid.

5.2 This test method differentiates the relative stability of organic heat transfer fluids at elevated temperatures in the absence of oxygen and water under the conditions of the test.

5.3 The user shall determine to his own satisfaction whether the results of this test method correlate to field performance. Heat transfer fluids in industrial plants are exposed to a variety of additional influencing variables. Interaction with the plant's materials, impurities, heat build-up during impaired flow conditions, the temperature distribution in the heat transfer

fluid circuit, and other factors can also lead to changes in the heat transfer fluid. The test method provides an indication of the relative thermal stability of a heat transfer fluid, and can be considered as one factor in the decision-making process for selection of a fluid.

5.4 The accuracy of the results depends very strongly on how closely the test conditions are followed.

5.5 This test method does not possess the capability to quantify or otherwise assess the formation and nature of thermal decomposition products within the unstressed fluid boiling range. Decomposition products within the unstressed fluid boiling range may represent a significant portion of the total thermal degradation.

6. Apparatus

6.1 *Test Cell*—The test cell shall be a new, clean ampoule made from ASTM A-269 grade 316L stainless steel tubing, 25 mm (1 in.) outside diameter, 2 mm (0.083 in.) wall thickness. The test cell shall be 0.152 m \pm 0.003 m (6 in. \pm 0.125 in.) in length and sealed with compression fittings at each end.

NOTE 1—Where tubing with SI dimensions is not readily available, the use of tubing with inch-pound dimensions is acceptable.

NOTE 2—Use of a torque multiplier can facilitate tightening of the compression fittings. A gap inspection gauge can be used to confirm that the compression fittings are completely tight.

6.2 *Heating Oven*—The oven shall be capable of being controlled within ± 1 °C (± 1.8 °F) at test temperature. The test temperature selected will typically be between 260 °C (500 °F) and 427 °C (800 °F), depending on the fluid being tested.

6.3 *Bulb Tube Distillation Apparatus*—This apparatus shall be capable of heating to at least 250 °C (482 °F) and pressure down to at least 0.1 mm Hg.

6.4 *Dewar Flask*—The flask is used to hold the test cells during cooling after removal from the heating oven.

6.5 *Balance*—The balance shall be capable of measuring mass to the nearest 0.01 g.

7. Preparation of Apparatus

7.1 *Test Cell*—The test cell used shall always be a clean, new ampoule. Reuse of ampoules is not permitted.

7.2 *Cleaning of Test Cell*—A new test cell shall be cleaned by washing with a suitable volatile solvent such as acetone and dried. (**Warning**—Use adequate safety precautions with all solvents and cleaners.)

8. Procedure

8.1 Determine the initial boiling point (IBP) and final boiling point (FBP) of the unstressed heat transfer fluid by GC, in accordance with Test Method **D2887** with the following requirements: the column shall be wall-coated open tubular type of 7.5 m to 10 m length with a 100 % polydimethylsiloxane film thickness of 0.88 μ m, the detector shall be flame ionization type, the initial oven temperature shall be set to 35 °C (95 °F) eliminating cryogenic cooling, the calibration mixture shall cover the boiling range from *n*-C₅ to *n*-C₆₀. The

following GC parameters are recommended: oven temperature rate 10 °C (18 °F) per minute, oven final temperature 375 °C (707 °F), time at oven final temperature 3 min, injector initial temperature 100 °C (212 °F), injector temperature rate 10 °C (18 °F) per minute, injector final temperature 375 °C (707 °F), detector temperature 375 °C (707 °F).

8.2 Measure the mass of a clean, dry test cell including compression fittings to the nearest 0.01 g. Pour the unstressed heat transfer fluid into the clean, dry test cell in a vertical position. The quantity of heat transfer fluid transferred to the test cell shall be 27 g ± 0.2 g. Invert the test cell in a vertical position and allow it to drain until all free-flowing material has been removed. More viscous fluids may require as long as 15 min to drain completely. At the end of the draining period, tap the test cell to remove a drop clinging to the open end of the test cell—do not wipe away any fluid. Measure the mass of the test cell and its remaining contents including compression fittings to the nearest 0.01 g.

NOTE 3—The intent is to perform this step only once for each heat transfer fluid being tested at this time.

8.3 Measure the mass of a clean, dry test cell including compression fittings to the nearest 0.01 g. Introduce high purity nitrogen using tubing at the bottom of the clean, dry test cell for 2 min at 60 mL/min to 70 mL/min.

NOTE 4—To ensure accurate results, at least three test cells containing samples of the same heat transfer fluid should be heated simultaneously.

8.4 Pour the thermally unstressed heat transfer fluid into the clean, dry test cell. The quantity of heat transfer fluid transferred to the test cell shall be 27 g ± 0.2 g.

8.5 Completely displace the air remaining in the gas space in the test cell by introducing high purity nitrogen using tubing just above the liquid surface of fluid inside the test cell at 30 mL/min to 35 mL/min for 12 min at ambient temperature.

8.6 Carefully seal the test cell and measure its mass to the nearest 0.01 g.

8.7 Insert the test cell vertically in the oven. Adjust the heating oven to the proper test temperature. The time to achieve proper test temperature should be approximately 3 h. The test temperature shall be maintained throughout the entire test duration and controlled in such a way that the temperature of the test liquid does not deviate by more than ±1 °C (±1.8 °F) at any location, including the heated wall. Temperature shall be measured and recorded throughout the test at least once per day. If test cells containing different fluids are tested at the same time, the test cells shall be distributed symmetrically inside the oven to minimize the effect of oven temperature variation on the results. The test duration shall be the time from attaining the test temperature to the time the heat supply is cut off. The test duration at the specified test temperature shall be a minimum of 500 h. The preferred test duration is 500 h ± 1 h, however, a longer test duration may be used. Thermal degradation cannot be assumed to be linear with time. Therefore, the stability of two fluids can only be compared at the same test temperature and test duration.

8.8 Protect the oven from heat transfer fluid that may spill in case of damage by placing a collecting pan under the test cell.

(**Warning**—If fluid leaks out due to improper sealing of the test cell, there may be the potential of flammable vapors inside the oven. The oven design and installation should consider this possibility.)

8.9 At the conclusion of the heating period, shut off the oven. Do not immediately remove the test cell. Leave the oven closed and allow the oven and the test cell to cool to ambient temperature to reduce the internal pressure. (**Warning**—Pressure inside the test cell may reach several thousand kPa during the test.)

8.10 Remove the test cell from the oven. (**Warning**—Use adequate safety precautions when removing the test cells from the oven in case some portion of the equipment is still hot.)

8.11 Carefully measure the mass of the test cell to the nearest 0.01 g. If the evaporation loss of gaseous decomposition products is calculated at greater than 0.5 % by mass, the test should be repeated since this would indicate tube leakage.

8.12 Place the test cell in a Dewar flask containing a cooling mixture of acetone or isopropanol and dry ice. Allow the test cell to cool to at least -78 °C (-108.4 °F). The duration of cooling is approximately 5 min to 10 min. Stand the test cell in a vertical position and allow it to reach ambient temperature, then exercise care to remove any condensed water on the exterior of the test cell. Stand the test cell in a vertical position and open the top of the test cell. (**Warning**—Exercise caution when removing the compression fitting from the test cell. Gaseous decomposition products may remain pressurized within the test cell. Use of the torque multiplier to remove the compression fitting is recommended because it can hold the compression fitting more securely.) Then measure the mass of the test cell including compression fittings and its contents to the nearest 0.01 g. Put a portion of the fluid into sample bottles for analytical evaluation and store the remainder for additional measurement in a glass bottle that is hermetically sealed. Invert the test cell and allow it to drain until all free-flowing material has been removed. More viscous fluids may require as long as 15 min to drain completely. At the end of the draining period, tap the test cell to remove a drop clinging to the open end of the test cell—do not wipe away any fluid. Measure the mass of the test cell and its remaining contents including compression fittings to the nearest 0.01 g.

8.13 Visually observe the appearance of the fluid sample for any insolubles, or other changes in the fluid. Examples include high pressure upon opening the test cell, appearance of fouling in the head space of the test cell and evidence of a leak from the test cell. Observations shall be noted in the report.

8.14 Determine the mass percentage of low and high boiling components in the thermally stressed sample, in accordance with Test Method D2887 using the same equipment and requirements as specified in 8.1.

8.15 The decomposition products that cannot be vaporized are determined separately in a bulb tube distillation apparatus. Measure approximately 4 g of the thermally stressed heat transfer fluid into the distillation flask. Record the mass to the nearest 0.01 g. Apply vacuum slowly by means of a vacuum pump. Pressure shall be 0.1 mm Hg ± 0.01 mm Hg at the end