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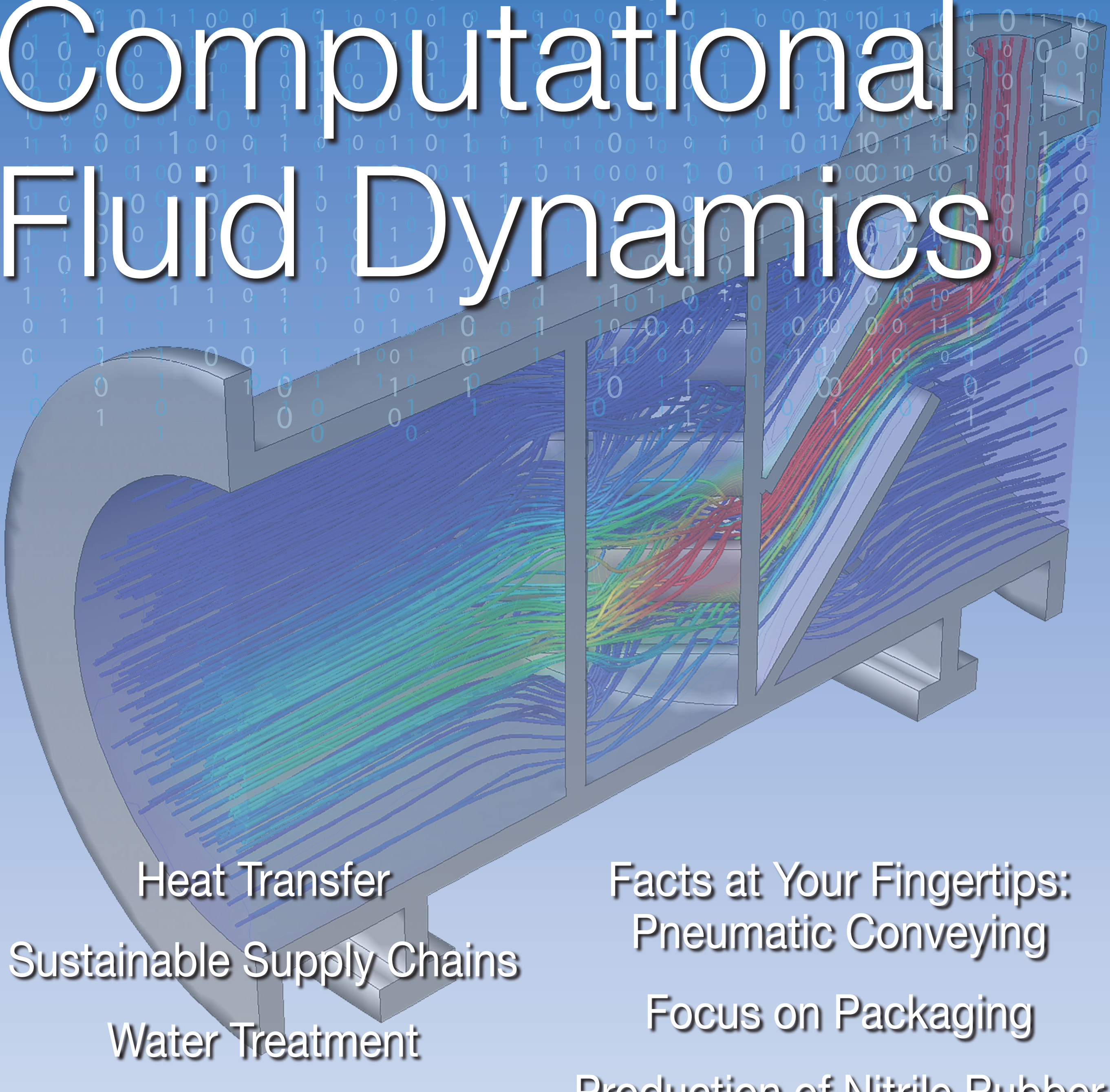

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ASTM Standards For Heat Transfer Fluids

This practical overview of ASTM standards can serve as a roadmap when selecting and evaluating heat transfer fluids

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Heat-transfer-fluid systems are often used for process heating to 500°F or higher. To accomplish heating above 500°F, steam pressure must be above 600 psig. For many plants, distributing steam above 600 psig is impractical due to high cost and more stringent water-purity requirements. High-temperature heat-transfer fluids have a much lower vapor pressure than water at high temperature, so the design pressure of a heat-transfer-fluid system can be lower.

Most systems operate with the heat transfer fluid in the liquid phase. A few heat transfer fluids have a narrow boiling range and can be used in a vapor-phase system, but the design of the system is much different and the process heating temperature must match the boiling range of the fluid.

High-temperature heat-transfer fluids are generally classified as inorganic eutectic salts, synthetic organics (Figure 1), aromatic oils, paraffinic oils and silicone-based fluids. The chemistry of each heat-transfer fluid is different, so each fluid has different properties. Considerable background and technical information about heat transfer fluids is provided in chapter 21 of the ASTM Fuels and Lubricants Handbook. A new version of this handbook is expected to be published this month.

ASTM International (formerly known as the American Society for Testing and Materials; West Conshohocken, Pa.; www.astm.org) has developed several standards for heat transfer fluids other than inorganic eutectic salts. This article provides an overview of these standards. ASTM standards are listed using their ASTM designations, for example D5372. "D" indicates that the standard is administered by one of the D committees. "5372" is the number of the standard. These designations are used throughout this article.

FIGURE 1. One type of synthetic organic heat transfer fluid is shown here

ASTM D5372 standard guide

ASTM D5372, "Standard Guide for Evaluation of Hydrocarbon Heat Transfer Fluids," covers the factors that should be considered to characterize a heat transfer fluid. These factors are also relevant to selection of a new heat-transfer fluid, so it can be used as a reference when choosing a new fluid. These factors are grouped into five categories: pumpability of the fluid, safety in use, effect on equipment, efficiency (heat-transfer capability) and service life.

Pumpability. Several properties are relevant to the pumpability of a heat transfer fluid. Pumpability is briefly discussed in this standard, but it is discussed more extensively in D8046. Decreased flash point (measured by D92 or D93) is indicative of the presence of low-boiling compounds produced by thermal degradation of the fluid. Viscosity (measured by D445 or D7042) is a measurement of the fluid's resistance to flow. The presence of thermal degradation products can affect the viscosity of the fluid. As fluid temperature is decreased, at some point the fluid viscosity becomes too high to pump. There is some correlation between hydraulic shock during pumping with the fluid's specific gravity (measured by D1298 or D4052) and compressibility properties. Water in a heat-transfer-fluid system will vaporize and expand as system temperature is increased, building pressure. It is therefore important to keep water out of the system as much as possible. Water content can be measured using D95.

Safety. Factors related to safety in use include autoignition temperature and flashpoint. Autoignition temperature can be measured using E659. The user should keep in mind that a hydrocarbon fluid absorbed on a porous inert surface (such as insulation) can ignite at temperatures more than 50°C lower than the value determined by E659. Flashpoint (measured by D92 Cleveland open cup tester or D93 Pensky-Martens closed cup tester) indicates the temperature at which flammable vapors given off by a liquid form a mixture with air that can be ignited by contact with a hot surface, spark, or flame.

Effect on equipment. Two ASTM standards can provide information about the effect of the heat transfer fluid on equipment. D471 provides data about the effect of the fluid on rubber or elastomeric seals. G4 is a guide for conducting corrosion tests in field applications.

Efficiency. Several properties — thermal conductivity, specific heat, density and viscosity — are relevant to the heat transfer capability of the fluid. These are the properties used to calculate Reynolds number, Prandtl number and Nusselt number, which determine the heat transfer coefficient. D2717 measures thermal conductivity, D1298 or D4052 measures specific gravity, and D445 or D7042 measures viscosity. D2766, the test method listed for specific heat, has recently been withdrawn but E1269 and E2716 are other methods that could be considered.

Service life. Heat transfer fluids degrade when exposed to sufficiently high temperature. The amount of degradation increases as temperature increases or exposure time increases. Thermal stability is measured using D6743.

Several tests are used to determine the condition of the fluid and its remaining service life. These tests include precipitation number (measured by D91), insoluble content (measured by D893), flash point (measured by D92 or D93), carbon residue (measured by D189, D524 or D4530), distillation (D86, D1160 and D2887 are listed but D2887 is more commonly used), neutralization number (measured by D664), color (measured by D1500), viscosity, viscosity index (measured by D2270) and water content (measured by D95). Typically, a sample of used heat-transfer fluid should be taken from each system at least once per year so that these tests can be conducted to evaluate fluid condition. To ensure that the sample is representative, it should be taken from the main circulating loop rather than from a dead leg. Some heat transfer fluid suppliers offer free evaluation of used fluid using these tests.

ASTM D7665 standard guide

ASTM D7665, "Standard Guide for Evaluation of Biodegradable Heat Transfer Fluids," addresses biodegradable heat transfer fluids. It covers the same factors mentioned in D5372 but also includes a few others. Vapor pressure (measured by D2879) is included as a factor that influences pumpability of the fluid. Biodegradation (measured by D5864) is included as a factor to consider for safety in use. D6384, which covers terminology related to biodegradability and ecotoxicity of lubricants, is listed as a reference document. D7044, which is a specification for biodegradable fire-resistant hydraulic fluids, is also listed as a reference.

ASTM D6743 standard test method

ASTM D6743, "Standard Test Method for Thermal Stability of Organic Heat Transfer Fluids," is a test method that measures thermal stability of a heat transfer fluid. Thermal stability is the resistance to permanent change in fluid properties caused solely by heat. All heat-transfer fluids degrade with exposure to high temperature over time. Typically, the user wants their heat transfer fluid to last for many years. It's important to select a fluid that is thermally stable enough to last for many years at the expected system operating temperature.

The thermal degradation products for most heat transfer fluids include high- and low-boiling components, very low-boiling gases, and residue that cannot be evaporated. The presence of degradation products in the fluid affects its properties.

D6743 quantifies the high-boiling components, low-boiling components, very low-boiling gases, and residue that cannot be evaporated for a heat transfer fluid that is exposed to specified temperature for a specified time period. The test procedure consists of weighing heat transfer fluid into a stainless-steel ampoule, purging with nitrogen, sealing the ampoule, and heating it in an oven. After the ampoule is removed from the oven and cooled, the fluid is analyzed to quantify the amount of thermal degradation products produced. Measurement of thermal degradation products is done by gas chromatography (GC), distillation and weighing.

Before D6743 was developed, each heat-transfer-fluid manufacturer had its own method for determining thermal stability. There were differences in the methods, as well as differences in the equipment used to conduct them. These differences sometimes led to conflicting test results. One supplier's test data might indicate that fluid A was more thermally stable than fluid B, while another supplier's test data might show the opposite.

D6743 provides a standard test method for developing data that a user can evaluate to compare heat transfer fluids. Using D6743, thermal stability of two or more different heat-transfer-fluid chemistries can be directly compared by heating them at the same time in the same oven, and then analyzing them using the same equipment. D6743 is very specific about the type of equipment that can be used. For example, it specifies the type and length of the GC column, film type and thickness, type of detector, calibrant range, material and dimensions of the ampoule, temperature control capability of the oven, and accuracy of the balance for weighing. Statistical analysis of test data from one laboratory showed very good repeatability of test results (see the precision and bias statement in the method).

DIN (Deutsches Institute für Normung e.V.; Berlin, Germany; www.din.de) also has a test method for thermal stability, but it is less specific about the test equipment that can be used. Differences in test equipment used can cause significant differences in test results.

ASTM D7863 standard guide

ASTM D7863, "Standard Guide for Evaluation of Convective Heat Transfer Coefficient of Liquids," provides information about the calculation of convective heat-transfer coefficient. The factors that affect calculation of convective heat-transfer coefficient are described. Results from previous studies have been presented in different ways, so direct comparison of

LIST OF ASTM STANDARDS REFERENCED IN THIS ARTICLE

D5372	Standard Guide for Evaluation of Hydrocarbon Heat Transfer Fluids
D93	Standard Test Methods for Flash Point by Pensky-Martens Closed Cup Tester
D445	Standard Test Method for Kinematic Viscosity of Transparent and Opaque Liquids (and Calculation of Dynamic Viscosity)
D7042	Standard Test Method for Dynamic Viscosity and Density of Liquids by Stabinger Viscometer (and the Calculation of Kinematic Viscosity)
D1298	Standard Test Method for Density, Relative Density, or API Gravity of Crude Petroleum and Liquid Petroleum Products by Hydrometer Method
D4052	Standard Test Method for Density, Relative Density, and API Gravity of Liquids by Digital Density Meter
D95	Standard Test Method for Water in Petroleum Products and Bituminous Materials by Distillation
E659	Standard Test Method for Autoignition Temperature of Chemicals
D92	Standard Test Method for Flash and Fire Points by Cleveland Open Cup Tester
D471	Standard Test Method for Rubber Property—Effect of Liquids
G4	Standard Guide for Conducting Corrosion Tests in Field Applications
D2717	Standard Test Method for Thermal Conductivity of Liquids
D6743	Standard Test Method for Thermal Stability of Organic Heat Transfer Fluids
D91	Standard Test Method for Precipitation Number of Lubricating Oils
D893	Standard Test Method for Insolubles in Used Lubricating Oils
D189	Standard Test Method for Conradson Carbon Residue of Petroleum Products
D524	Standard Test Method for Ramsbottom Carbon Residue of Petroleum Products
D4530	Standard Test Method for Determination of Carbon Residue (Micro Method)
D86	Standard Test Method for Distillation of Petroleum Products and Liquid Fuels at Atmospheric Pressure
D1160	Standard Test Method for Distillation of Petroleum Products at Reduced Pressure
D2887	Standard Test Method for Boiling Range Distribution of Petroleum Fractions by Gas Chromatography
D664	Standard Test Method for Acid Number of Petroleum Products by Potentiometric Titration
D1500	Standard Test Method for ASTM Color of Petroleum Products (ASTM Color Scale)
D2270	Standard Practice for Calculating Viscosity Index from Kinematic Viscosity at 40 °C and 100 °C
D7665	Standard Guide for Evaluation of Biodegradable Heat Transfer Fluids
D2879	Standard Test Method for Vapor Pressure-Temperature Relationship and Initial Decomposition Temperature of Liquids by Isoteniscope
D5864	Standard Test Method for Determining Aerobic Aquatic Biodegradation of Lubricants or Their Components
D6384	Standard Terminology Relating to Biodegradability and Ecotoxicity of Lubricants
D7044	Standard Specification for Biodegradable Fire Resistant Hydraulic Fluids
D7863	Standard Guide for Evaluation of Convective Heat Transfer Coefficient of Liquids
D8046	Standard Guide for Pumpability of Heat Transfer Fluids
E794	Standard Test Method for Melting And Crystallization Temperatures By Thermal Analysis
D2983	Standard Test Method for Low-Temperature Viscosity of Automatic Transmission Fluids, Hydraulic Fluids, and Lubricants using a Rotational Viscometer
D891	Standard Test Methods for Specific Gravity, Apparent, of Liquid Industrial Chemicals
D6304	Standard Test Method for Determination of Water in Petroleum Products, Lubricating Oils, and Additives by Coulometric Karl Fischer Titration

convective heat-transfer-coefficient data from these studies can be challenging. Therefore, this guide focuses on describing a standard approach for obtaining data, interpreting data, and presenting results.

This guide describes a test equipment arrangement with turbulent fluid flow inside an electrically heated tube that has a wall temperature higher than the bulk fluid temperature. Features of this test-equipment arrangement are discussed and the required measurements are defined. The ASTM test methods recommended for making each of the required measurements are listed. Considerations for calibration of the test equipment are discussed. Formulas used to calculate the heat-transfer coefficient are summarized. Appropriate ways to interpret, present and report the test results are explained.

ASTM D8046 standard guide

ASTM D8046, "Standard Guide for Pumpability of Heat Transfer Fluids," discusses the fluid properties and system configuration issues that affect the ability to pump a heat transfer fluid. These properties include flashpoint (measured by D92 or D93), crystallization temperature (measured by E794), viscosity (measured by D445, D2983 or D7042), relative density (measured by D891 or D4052), water content (measured by D6304), vapor pressure (measured by D2879), and boiling range distribution (measured by D2887). System configuration issues include the type of pump used, mechanical seals, the pump suction piping arrangement, net positive-suction head required by the pump, and electric motor sizing. The need to consider how fluid viscosity will change as the fluid degrades and how that affects pump and motor selection is also discussed. This guide addresses several considerations about pumping that are a useful reference when selecting a new heat-transfer fluid. ■

Edited by Gerald Ondrey

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