Designation: D4418 – 22

Standard Practice for Receipt, Storage, and Handling of Fuels for Gas Turbines[1]

This standard is issued under the fixed designation D4418; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 This practice covers the receipt, storage, and handling of fuels for gas turbines, except for gas turbines used in aircraft. It is intended to provide guidance for the control of substances in a fuel that could cause deterioration of either the fuel system, or the gas turbine, or both.

1.2 This practice provides no guidance for either the selection of a grade of fuel, a topic covered by Specification D2880, or for the safety aspects of the fuel and fuel systems. For example, this practice does not address the spacings of storage tanks, loading and unloading facilities, etc., and procedures for dealing with the flammability and toxic properties of the fuels.

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

1.4 *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.*

1.5 *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 Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D1500 Test Method for ASTM Color of Petroleum Products (ASTM Color Scale)

D1796 Test Method for Water and Sediment in Fuel Oils by the Centrifuge Method (Laboratory Procedure)

D2274 Test Method for Oxidation Stability of Distillate Fuel Oil (Accelerated Method)

D2276 Test Method for Particulate Contaminant in Aviation Fuel by Line Sampling

D2880 Specification for Gas Turbine Fuel Oils

D4057 Practice for Manual Sampling of Petroleum and Petroleum Products

D6469 Guide for Microbial Contamination in Fuels and Fuel Systems

3. Terminology

3.1 *Definitions:*

3.1.1 *dissolved water, n*—water that is homogeneously distributed on a molecular scale in a different liquid, called the solvent.

3.1.1.1 *Discussion*—Dissolved water does not settle out of solution, nor does it form a separate layer or haze in the container. The amount of water dissolved in the solution depends on the temperature of the solution. For most solvents the amount of dissolved water will increase as the temperature of the solution increases.

3.1.1.2 *Discussion*—Tall tanks may stratify on a macroscopic scale. That is, the concentration of the water at different locations in the tank may vary due to the influence of macroscopic factors such as gravity, temperature of the addition of a different fuel blend to the tank.

3.1.2 *free water, n*—water in excess of that soluble in the liquid sample (fuel) at the temperature of the test and usually appearing in the liquid sample (fuel) as a haze (cloudiness), droplets or water layer.

3.1.2.1 *Discussion*—If free water is present at high enough concentration, it will frequently settle out of the liquid sample to form a haze or separate layer in the container. If free water is present as very small droplets or in a biofilm it may not be visible to the naked human eye but may still have an effect on the liquid product.

3.1.3 *fuel contaminant, n*—material not intended to be present in a fuel, whether introduced during manufacture, handling, distribution, or storage, that makes the fuel less suitable for the intended use.

3.1.3.1 *Discussion*—Contaminants, which can be soluble in the fuel or insoluble (suspended liquid droplets or solid or semi-solid particles), can be the result of improper processing

[1] This practice is under the jurisdiction of ASTM Committee D02 on Petroleum Products, Liquid Fuels, and Lubricants and is the direct responsibility of Subcommittee D02.E0 on Burner, Diesel and Non-Aviation Gas Turbine Fuels.

Current edition approved Nov. 1, 2022. Published November 2022. Originally approved in 1984. Last previous edition approved in 2017 as D4418 – 17. DOI: 10.1520/D4418-22.

[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.

*A Summary of Changes section appears at the end of this standard or contamination by a wide range of materials including water, rust, airblown dust, deterioration of internal protective coatings on pipes or vessels, and products of fuel degradation and microbial growth.

3.1.3.2 *Discussion*—Solid or semisolid contaminants can be referred to as silt or sediment.

3.1.4 *fuel entering the combustor(s), n*—this term is used to designate the fuel that is actually burned in the gas turbine. Fuel may actually be sampled at a point upstream from the point of entry into the combustor(s), provided the sample is representative of the fuel actually entering the combustor(s).

3.1.5 *metallic compounds, n*—metals may be present as metallic compounds in the fuel as a natural result of the composition of the crude oil and of the refining process. However, unless special precautions are taken, additional metallic compounds can be acquired during distribution and storage. A commercial product pipeline may contain residues of lead-containing gasoline that would then be dissolved by the gas turbine fuel. Tank trucks, railroad tankcars, barges, and tankers may be inadequately cleaned and contain residues of past cargos. Acidic components in saline water salts in the fuel may react with distribution and storage equipment.

3.1.6 *microbial slimes, n*—may result when conditions are conducive to the growth of microorganisms that are always present. The presence of free water is essential to the growth of many of these microorganisms that grow in tank water bottoms and feed on nutrients in the water or on the hydrocarbons.

3.1.7 *particulate solids, n*—may enter a fuel from the air (suspended dirt and aerosols) or from the distribution and storage systems (rust, corrosion products, gasket debris, and so forth).

4. Summary of Practice

4.1 The body of this practice defines the contaminants frequently found in turbine fuel oils and discusses the sources and significance of such contaminants.

4.2 Annex A1 is a guide for the receipt, storage, and handling of distillate gas turbine fuels, Grades 1-GT and 2-GT, in accordance with Specification D2880.

4.3 Annex A2 is a guide for the receipt, storage, and handling of gas turbine fuels, Grades 3-GT and 4-GT, that contain residual components.

4.4 Annex A3 is a guide for the selection and storage of fuels intended for long-term storage, when such fuels are distillate fuels.

4.5 Annex A4 is a guide for gas turbine users who are considering the use of fuels from alternative non-petroleum sources.

5. Significance and Use

5.1 This practice provides the user of gas turbine fuel oils and the designer of gas turbine fuel systems with an appreciation of the effects of fuel contaminants and general methods of controlling such contaminants in gas turbine fuel systems.

5.2 This practice is general in nature and should not be considered a substitute for any requirement imposed by warranty of the gas turbine manufacturer, or by federal, state, or local government regulations.

5.3 Although it cannot replace a knowledge of local conditions or the use of good engineering and scientific judgment, this practice does provide guidance in development of individual fuel management systems for the gas turbine user.

6. Significance of Contaminants

6.1 Contamination levels in the fuel entering the combustor(s) must be low for improved turbine life. Low contamination levels in the fuel in the turbine's in-plant fuel system are required to minimize corrosion and operating problems. Providing fuel of adequate cleanliness to the gas turbine combustor(s) may require special actions by the user. These actions might include special transportation arrangements with the fuel supplier, particular care in on-site fuel storage and quality control procedures, and establishment of on-site cleanup procedures. Each of the four classes of contaminants defined in 3.1.3 has its own significance to system operation.

6.1.1 Water will cause corrosion of tanks, piping, flow dividers, and pumps. Corrosion or corrosion products in close-tolerance devices, such as flow dividers, may cause plugging and may stop flow to the turbines. Free water is potentially corrosive in sulfur-containing fuels, it may be particularly corrosive. Free water may contain dissolved salts that may be corrosive, and may encourage microbiological growth.

6.1.2 Particulate solids may shorten the life of fuel system components. Life of fuel pumps and of various close-tolerance devices is a function of particulate levels and size distributions in the fuel. High levels of particulates can lead to short cycle times in the operation of filters, filter/separators, centrifuges, and electrostatic purifiers. Since such separation devices do not remove all the particulates, certain quantities will be present in the down-stream fuel.

6.1.3 Trace metals refer both to those metals present as metallic compounds in solution and to metals present in particulates like rust. They are dissolved or suspended either in the fuel hydrocarbons or in free water present in the fuel. The significance of several individual trace metals with respect to hot corrosion is discussed in 6.1.4 through 6.1.5. Although lower levels of trace metals in a fuel will promote longer turbine service from a corrosion standpoint, the specification of excessively low levels may limit the availability of the fuel or materially increase its cost. Table 1 suggests levels of trace metals that would probably yield satisfactory service.

TABLE 1 Trace Metal Limits of Fuel Entering Turbine Combustor(s)

Designation	Trace Metal Limits by Weight, max, ppm			
	Vanadium	Sodium plus Potassium	Calcium	Lead
No. 0-GT	0.5	0.5	0.5	0.5
No. 1-GT	0.5	0.5	0.5	0.5
No. 2-GT	0.5	0.5	0.5	0.5
No. 3-GT	0.5	0.5	0.5	0.5
No. 4-GT	(Consult turbine manufacturers)			

6.1.4 Ash is the noncombustible material in an oil. Ash forming materials may be present in fuel oil in two forms: (*1*) solid particles, and (*2*) oil- or water-soluble metallic compounds. The solid particles are for the most part the same material that is designated as sediment in the water and sediment test. Depending on their size, these particles can contribute to wear in the fuel system and to plugging of the fuel filter and the fuel nozzle. The soluble metallic compounds have little or no effect on wear or plugging, but they can contain elements that produce turbine corrosion and deposits as described in 6.1.5.

6.1.5 *Vanadium and Lead*—Fuel contaminants might include soluble compounds such as vanadium porphyrins, metallic soaps, or tetraethyl lead that cannot be removed from the fuel at the gas-turbine site.

6.1.5.1 Vanadium can form low melting compounds such as vanadium pentoxide which melts at 691 °C (1275 °F), and causes severe corrosive attack on all of the high-temperature alloys used for gas-turbine blades. If there is sufficient magnesium in the fuel, it will combine with the vanadium to form compounds with higher melting points and thus reduce the corrosion rate to an acceptable level. The resulting ash will form deposits in the turbine and will require appropriate cleaning procedures.

6.1.5.2 When vanadium is present in more than trace amounts either in excess of 0.5 ppm or a level recommended by the turbine manufacturer, it is necessary to maintain a weight ratio of magnesium to vanadium in the fuel of not less than 3.0 in order to control corrosion.

6.1.5.3 An upper limit of 3.5 is suggested since larger ratios will lead to unnecessarily high rates of ash deposition. In most cases, the required magnesium-to-vanadium ratio will be obtained by additions of magnesium-containing compounds to the fuel oil. The special requirements covering the addition and type of magnesium-containing additive, or equivalent, shall be specified by mutual agreement between the various interested parties. The additive will vary depending on the application, but it is always essential that there is a fine and uniform dispersion of the additive in the fuel at the point of combustion.

6.1.5.4 For gas turbines operating at turbine-inlet gas temperatures below 650 °C (1200 °F), the corrosion of the high-temperature alloys is of minor importance, and the use of a silicon-base additive will further reduce the corrosion rate by absorption and dilution of the vanadium compounds.

6.1.5.5 Lead can cause corrosion, and in addition it can spoil the beneficial inhibiting effect of magnesium additives on vanadium corrosion. Since lead is only rarely found in significant quantities in crude oils, its appearance in the fuel oil is primarily the result of contamination during processing or transportation.

6.1.6 *Sodium, Potassium, and Calcium*—Fuel contaminants might also include fuel-insoluble materials such as water, salt, or dirt, potential sources of sodium, potassium, and calcium. These are normally removed at the gas-turbine site, unless such contaminants are extremely finely divided.

6.1.6.1 *Sodium and Potassium* can combine with vanadium to form eutectics that melt at temperatures as low as 566 °C (1050 °F) and can combine with sulfur in the fuel to yield sulfates with melting points in the operating range of the gas turbine. These compounds produce severe corrosion, and for turbines operating at gas inlet temperatures above 650 °C (1200 °F), additives are not yet in general use that control such corrosion.

6.1.6.2 Accordingly, the sodium-plus-potassium level must be limited, but each element is measured separately. Some gas turbine installations incorporate systems for washing oil with water to reduce the sodium-plus-potassium level. In installations where the fuel is moved by sea transport, the sodium-plus-potassium level should be checked prior to use to ensure that the oil has not become contaminated with sea salt. For gas turbines operating at turbine inlet gas temperatures below 650 °C (1200 °F), the corrosion due to sodium compounds is of minor importance and can be further reduced by silicon-base additives. A high sodium content is even beneficial in these turbines because it increases the water-solubility of the deposits and thereby increases the ease with which gas turbines can be water-washed to obtain recovery of the operating performance.

6.1.6.3 *Calcium*—Calcium is not harmful from a corrosion standpoint: in fact, it serves to inhibit the corrosive action of vanadium. However, calcium can lead to hard-bonded deposits that are not self-spalling when the gas turbine is shut down, and are not readily removed by water washing of the turbine. The fuel-washing systems, used at some gas turbine installations to reduce the sodium and potassium level, will also significantly lower the calcium content of fuel oil.

6.1.7 *Microbial Slimes*—Microbial slimes caused by micro-organisms can plug filters and other close-tolerance openings. Some organisms can cause corrosion as well as produce slimes. Under anaerobic conditions, hydrogen sulfide, which may cause corrosion, can be generated by biological action. Biocides are available for controlling the growth of microorganisms, but their effect on trace metal levels and other fuel properties should be considered. Since water is required for the growth of the microorganisms, one way of controlling their growth is to eliminate the presence of water through tank-stripping operations or other separation techniques. Refer to Guide D6469 for a more complete discussion.

7. Keywords

7.1 contaminants; fuel handling; fuel storage; gas turbine fuels