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Designation 323/21

Standard Test Method for Thermal Oxidation Stability of Aviation Turbine Fuels[1,2]

This standard is issued under the fixed designation D3241; 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.

This standard has been approved for use by agencies of the U.S. Department of Defense.

1. Scope*

1.1 This test method covers the procedure for rating the tendencies of gas turbine fuels to deposit decomposition products within the fuel system.

1.2 The differential pressure values in mm Hg are defined only in terms of this test method.

1.3 The deposition values stated in SI units shall be regarded as the referee value.

1.4 The pressure values stated in SI units are to be regarded as standard. The psi comparison is included for operational safety with certain older instruments that cannot report pressure in SI units.

1.5 No other units of measurement are included in this standard.

1.6 *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 6.1.1, 7.1, 7.3, 12.1.1, and Annex A6.

1.7 *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:*[3]

D1655 Specification for Aviation Turbine Fuels
D4057 Practice for Manual Sampling of Petroleum and Petroleum Products
D4306 Practice for Aviation Fuel Sample Containers for Tests Affected by Trace Contamination
E177 Practice for Use of the Terms Precision and Bias in ASTM Test Methods

[1] This test method is under the jurisdiction of ASTM International Committee D02 on Petroleum Products, Liquid Fuels, and Lubricants and is the direct responsibility of Subcommittee D02.J0.03 on Combustion and Thermal Properties. The technically equivalent standard as referenced is under the jurisdiction of the Energy Institute Subcommittee SC-B-8.

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[2] This test method has been developed through the cooperative effort between ASTM and the Energy Institute, London. ASTM and IP standards were approved by ASTM and EI technical committees as being technically equivalent but that does not imply both standards are identical.

[3] 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**

E691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method

2.2 *ISO Standards:*[4]

ISO 3274 Geometrical Product Specifications (GPS)—Surface texture: Profile method—Nominal characteristics of contact (stylus) instruments

ISO 4288 Geometrical Product Specifications (GPS)—Surface texture: Profile method—Rules and procedures for the assessment of surface texture

2.3 *ASTM Adjuncts:*[5]

Color Standard for Heater Tube Deposit Rating

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *deposits, n*—oxidative products laid down on the test area of the heater tube or caught in the test filter, or both.

3.1.1.1 *Discussion*—

Fuel deposits will tend to predominate at the hottest portion of the heater tube, which is between the 30 mm and 50 mm position.

3.1.2 *heater tube, n*—an aluminum coupon controlled at elevated temperature, over which the test fuel is pumped.

3.1.2.1 *Discussion*—

The heater tube is resistively heated and controlled in temperature by a thermocouple positioned inside. The critical test area is the thinner portion, 60 mm in length, between the shoulders of the heater tube. Fuel inlet to the heater tube is at the 0 mm position, and fuel exit is at 60 mm.

3.2 *Abbreviations:*

3.2.1 *ΔP*—differential pressure.

4. Summary of Test Method

4.1 This test method for measuring the high temperature stability of gas turbine fuels uses an instrument that subjects the test fuel to conditions that can be related to those occurring in gas turbine engine fuel systems. The fuel is pumped at a fixed volumetric flow rate through a heater, after which it enters a precision stainless steel filter where fuel degradation products may become trapped.

4.1.1 The apparatus uses 450 mL of test fuel ideally during a 2.5 h test. The essential data derived are the amount of deposits on a heater tube, and the rate of plugging of a 17 µm nominal porosity precision filter located just downstream of the heater tube.

5. Significance and Use

5.1 The test results are indicative of fuel performance during gas turbine operation and can be used to assess the level of deposits that form when liquid fuel contacts a heated surface that is at a specified temperature.

TABLE 1 Instrument Models

Instrument Model	Pressurize With	Principle	Differential Pressure by
230[A]	hydraulic	syringe	Transducer + Printout
240[A]	hydraulic	syringe	Transducer + Printout
230 Mk III[B]	hydraulic	dual piston (HPLC Type)	Transducer + Printout
F400[C]	hydraulic	dual piston (HPLC Type)	Transducer + Printout
~~230 Mk IV[D]~~	~~hydraulic~~	~~single piston (HPLC Type)~~	~~Transducer + Printout~~
230 Mk IV[D, E]	hydraulic	single piston (HPLC Type)	Transducer + Printout

[A] See RR:D02-1309.
[B] See RR:D02-1631.
[C] See RR:D02-1728.
[D] See RR:D02-1757.
[E] There are two versions of the 230 Mk IV instrument; one with an inline internal non-consumable filter located upstream of the 0.45 µm pre-filter and one without. Only the 230 Mk IV instruments without the inline internal non-consumable filter were included in RR:D02-1757 and have been determined by ASTM Committee D02 to be equivalent to the other apparatus listed above in Table 1. There are no external markings on the instruments to indicate which apparatus contains the inline internal non-consumable filter. Contact the manufacturer for further information on removal of the inline internal non-consumable filter.

[4] Available from International Organization for Standardization (ISO), 1, ch. de la Voie-Creuse, CP 56, CH-1211 Geneva 20, Switzerland, http://www.iso.org.

[5] Available from ASTM International Headquarters. Order Adjunct No. ADJD3241. Original adjunct produced in 1986.

6. Apparatus

6.1 *Aviation Fuel Thermal Oxidation Stability Tester*[6]—Five models of suitable equipment may be used as indicated in Table 1.

6.1.1 Portions of this test may be automated. Refer to the appropriate user manual for the instrument model to be used for a description of detailed procedure. A manual is provided with each test rig. (**Warning—**No attempt should be made to operate the instrument without first becoming acquainted with all components and the function of each.)

6.1.2 Certain operational parameters used with the instrument are critically important to achieve consistent and correct results. These are listed in Table 2.

6.2 *Heater Tube Deposit Rating Apparatus:*

6.2.1 *Visual Heater Tube Rater (VTR),* the tuberator described in Annex A1.

6.2.2 *Standardization of Metrology Requirements:*

6.2.2.1 *Number of Measured Points*—1200 in the ratable area of the heater tube (between 5 mm and 55 mm above the bottom shoulder of the heater tube).

(1) Circumferential Resolution—(number of points measured on the heater tube circumference), 24 points equally spaced.

(2) Longitudinal Resolution—(number of points measured on the 50 mm ratable length of the heater tube), 50 points equally spaced.

6.2.2.2 *Standard Spot*—Thickest average deposit area described by either a 2×3 or 3×2 (longitudinal × circumferential) arrangement of adjoining thickness measurement points, amongst the 1200 measured by the metrology techniques.

6.2.3 *Interferometric (Heater) Tube Rater (ITR)*—the tuberator described in Annex A2.

6.2.4 *Ellipsometric (Heater) Tube Rater (ETR)*—the tuberator described in Annex A3.

6.2.5 *Multi-Wavelength Ellipsometric (Heater) Tube Rater (MWETR)*—the tuberator described in Annex A4.

6.3 Because jet fuel thermal oxidation stability is defined only in terms of this test method, which depends upon, and is inseparable from, the specific equipment used, the test method shall be conducted with the equipment used to develop the test method or equivalent equipment.

7. Reagents and Materials

7.1 Use methyl pentane, 2,2,4-trimethylpentane, or n-heptane as a general cleaning solvent. General cleaning solvent shall be 95 mol % purity, minimum. This solvent will effectively clean internal metal surfaces of apparatus before a test, especially those surfaces (before the heater tube test section) that contact fresh sample. (**Warning—**Extremely flammable. Harmful if inhaled (see Annex A6).)

7.2 Use a nylon bristle brush and trisolvent to clean internal (working) surface of heater tube test section only. Trisolvent is an equal mix of acetone (*1*), toluene (*2*), and isopropanol (*3*). All three components of trisolvent shall be 95 mol % purity, minimum. (**Warning—**(*1*) Extremely flammable, vapors may cause flash fire; (*2*) and (*3*) Flammable. Vapors of all three harmful. Irritating to skin, eyes, and mucous membranes.) Use a nylon bristle brush that makes stiff contact with the inner walls of the heater tube test section.

7.3 Use dry calcium sulfate + cobalt chloride granules (97 + 3 mix) or other self-indicating drying agent in the aeration dryer. This granular material changes gradually from blue to pink color indicating absorption of water. (**Warning—**Do not inhale dust or ingest. May cause stomach disorder.)

[6] The following equipment, as described in Table 1 and RR:D02-1309, was used to develop this test method. The following equipment, as described in Table 1 and determined as equivalent in testing as detailed in RR:D02-1631, is provided by PAC, 8824 Fallbrook Drive, Houston, TX 77064. The following equipment, as described in Table 1 and determined as equivalent in testing as detailed in RR:D02-1728, is provided by Falex Corporation, 1020 Airpark Dr., Sugar Grove, IL, 60554-9585. This is not an endorsement or certification by ASTM International.

TABLE 2 Critical Operating Characteristics of D3241

Item	Definition	
Test apparatus	Tube-in-shell heat exchanger as illustrated in Fig. 1 and dimensions in Fig. A5.1.	
Heater Tube:		
Heater tube [A, B, C, D, E]	Specially fabricated heater tube that produces controlled heated test surface; new one for each test.	
Heater Tube identification[E]	Each heater tube shall be physically identified with a unique serial number, identifying the manufacturer and providing traceability to the original material batch.	
Heater Tube metallurgy	6061-T6 Aluminum, plus the following criteria a) The Mg:Si ratio shall not exceed 1.9:1 b) The Mg_2Si percentage shall not exceed 1.85 %	
Heater Tube surface polish over circumference of center section	Rotational cut buffing technique with polishing compound to achieve mechanical surface finish.	
Heater Tube dimensions:	Dimension	Tolerance
Heater Tube length,[F] mm	161.925	±0.254
Center section length, mm	60.325	±0.051
Outside diameters, mm		
Shoulders	4.724	±0.025
Center section	3.175	±0.051
Inside diameter, mm	1.651	±0.051
Total indicator runout, mm, max	0.013	
Mechanical surface finish, nm, over circumference in center section in accordance with ISO 3274 and ISO 4288 using the mean of four 1.25–measurements	50 ± 20	
Test filter [6]	nominal 17 µm stainless steel mesh filter element to trap deposits; new one for each test	
Stainless Steel Mesh	Twilled Dutch Weave, 304 Stainless Steel, 165 × 1400 Mesh (tolerance; 4 % on 1400 and 2 % on 165) with Warp Diameter = 0.0028 in. and Shute Diameter = 0.0016 in.	
Instrument parameters:		
Sample volume	600 mL of sample is aerated, then 450 mL ± 45 mL of this aerated fuel shall be pumped during the heating phase for a valid test	
Aeration rate	1.5 L ⁄min dry air through sparger	
Flow during test	3.0 mL ⁄min ± 10 % (2.7 mL/min minimum to 3.3 mL/min maximum)	
Pump mechanism	positive displacement or piston syringe	
Cooling	bus bars fluid cooled to maintain consistent tube temperature profile	
Thermocouple (TC)	Type J, Inconel sheathed, or Type K, Inconel sheathed	
Operating pressure:		
System	3.45 MPa ± 10 % on sample by hydraulically transmitted force against control valve outlet restriction	
At test filter	differential pressure (ΔP) measured across test filter by electronic transducer in mm Hg	
Operating temperature:		
For test	as stated in specification for fuel	
Uniformity of run	maximum deviation of ±2 °C from specified temperature	
~~Calibration~~	~~Models 230 and 240T – Three point calibration including pure tin at 232 °C, pure lead at 327 °C for high point and ice + water for low point reference~~ ~~All other models – Two point calibration using pure lead at 327 °C for high point and ice + water for low point reference~~	
Calibration	Models 230 and 240 – Three point calibration including tin (see 7.5) at 232 °C, lead (see 7.4) at 327 °C for high point and ice + water for low point reference All other models – Two point calibration using pure lead at 327 °C for high point and ice + water for low point reference	

[A] D3241/IP 323 Thermal Stability is a critical aviation fuel test, the results of which are used to assess the suitability of jet fuel for aviation operational safety and regulatory compliance. The integrity of D3241/IP 323 testing requires that heater tubes meet the regulations of D3241 Table 2 and give equivalent D3241 results to the heater tubes supplied by the original equipment manufacturer (OEM).
[B] The following equipment, heater tubes, manufactured by PAC, 8824 Fallbrook Drive, Houston, TX 77064, was used in the development of this test method. This is not an endorsement or certification by ASTM International.
[C] A test protocol to establish equivalence of heater tubes is on file at ASTM International Headquarters and may be obtained by requesting Research Report RR:D02-1550.
[D] The following equipment, heater tube and filter kits, manufactured by Falex Corporation, 1020 Airpark Dr., Sugar Grove, IL, 60554-9585, was run through the test protocol in RR:D02-1550 and determined as equivalent to the equipment used to develop the test method. This test is detailed in RR:D02-1714. This is not an endorsement or certification by ASTM International.
[E] An electronic recording device, such as a radio-frequency identification device (RFID), may be embedded into the heater tube rivet located at the bottom of the heater tube. Tube identification data may be stored on an electronic recording device, such as a RFID, embedded into the heater tube.
[F] Tube length measurements are only applicable to the aluminum portion of the heater tube. Additions, such as an RFID, do not contribute to the length measurement of the heater tube.

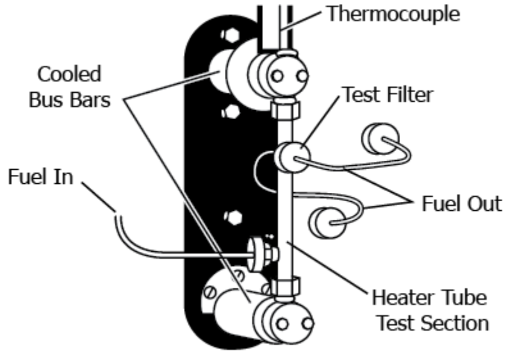

FIG. 1 Standard Heater Tube Test Section, Essential to All D3241 Test Instruments

7.4 *Lead,* 99.9 % minimum purity.

7.5 *Tin,* 99.0 % minimum purity.

8. Sampling

8.1 *General Requirements*—The choice of construction materials is an important factor, particularly in the case of aviation turbine fuel, where thermal stability can be degraded by the presence of very low concentration of copper. The use of copper or copper alloys shall be eliminated wherever possible by the use of alternative materials such as stainless steel or aluminum. Zinc and cadmium are two other metals that adversely affect product quality. Copper, copper alloys (such as brass), zinc-rich (galvanized) coatings, cadmium alloys, and cadmium plating shall not be used in sampling aviation fuels for evaluation under this test method.

8.1.1 *Sampling Containers*—Sampling containers shall be in accordance with the requirements for thermal stability testing described in Practice D4306.

8.1.2 *Sampling Equipment*—Sampling equipment fabricated from copper or its alloys shall not be used for sampling in accordance with this test method. Sampling equipment shall be in accordance with the requirements for aviation fuel described in Practice D4057.

9. Standard Operating Conditions

9.1 Standard conditions of the test method are as follows:

9.1.1 *Fuel Quantity,* 450 mL minimum for test plus about 50 mL for system.

9.1.2 *Fuel Pre-Treatment*—Filter the fuel through a single layer of "qualitative" quality, medium-flow, cellulose filter paper. Filter should be a pleated (folded) circular shape and fitted into a conical funnel to filter fuel. Filter paper grades 2V, MN514, or better, are recommended. After filtration, aerate the fuel for 6 min at 1.5 L ⁄min air flow rate for a maximum of 1000 mL sample using a coarse 12 mm borosilicate glass gas dispersion tube.

9.1.3 *Fuel System Pressure,* 3.45 MPa (500 psi) ±10 % gauge.

9.1.4 *Thermocouple Position,* at 39 mm.

9.1.5 *Fuel System Prefilter Element,* filter paper of 0.45 µm pore size.

9.1.6 *Heater Tube Control Temperature,* preset as specified in applicable specification.

9.1.7 *Fuel Flow Rate,* 3.0 mL ⁄min ± 10 %.

9.1.8 *Minimum Fuel Pumped During Test,* 405 mL.

9.1.9 *Test Duration,* 150 min ± 2 min.

9.1.10 *Cooling Fluid Flow,* approximately 39 L/h, or center of green range on cooling fluid meter.

9.1.11 *Power Setting,* internally set for computer models.

10. Preparation of Apparatus

10.1 *Cleaning and Assembly of Heater Tube Test Section:*

10.1.1 Clean the inside surface of the heater tube test section using a nylon brush saturated with trisolvent to remove all deposits. Replace the nylon brush when it shows signs of wear (such as missing bristles) and no longer makes stiff contact with inner walls of heater tube test section.

10.1.2 Check the heater tube to be used in the test for surface defects and straightness by referring to the procedure in A1.10. Be careful, also, to avoid scratching the heater tube shoulder during the examination, since the heater tube shoulder must be smooth to ensure a seal under the flow conditions of the test.

10.1.3 Assemble the heater tube test section using new items: (*1*) visually checked heater tube, (*2*) test filter, and (*3*) three O-rings. Inspect insulators to be sure they are undamaged.

NOTE 1—Heater tubes must not be reused. Tests indicate that magnesium migrates to the heater tube surface under normal test conditions. Surface magnesium may reduce adhesion of deposits to reused heater tube.

10.1.4 During assembly of the heater tube test section, handle the heater tube carefully so as not to touch center part of heater tube. IF THE CENTER OF HEATER TUBE IS TOUCHED, REJECT THE HEATER TUBE SINCE THE CONTAMINATED SURFACE MAY AFFECT THE DEPOSIT-FORMING CHARACTERISTICS OF THE HEATER TUBE.

10.2 *Cleaning and Assembly of Remainder of Test Components:*

10.2.1 Perform the following steps in the order shown prior to running a subsequent test.

NOTE 2—It is assumed that the apparatus has been disassembled from previous test (see Annex A5 or appropriate user manual for assembly/disassembly details).

10.2.2 Inspect and clean components that contact test sample and replace any seals that are faulty or suspect.

10.2.3 Install the prepared heater tube test section (as described in 10.1.1 – 10.1.4).

10.2.4 Assemble pre-filter with new element and install.

10.2.5 Check thermocouple for correct reference position, then lower into standard operating position.

10.2.6 On Models 230 and 240, make sure the water beaker is empty.

11. Calibration and Standardization Procedure

11.1 Perform checks of key components at the frequency indicated in the following (see Annexes or user manual for details).

11.1.1 *Thermocouple*—Calibrate a thermocouple when first installed and then at least every 6 months (see A5.2.8).

11.1.2 *Differential Pressure Cell*—Standardize once a year or when installing a new cell (see A5.2.6).

11.1.3 *Aeration Dryer*—Check at least monthly and change if color indicates significant absorption of water (see 7.3).

11.1.4 *Metering Pump*—Perform two checks of flow rate for each test as described in Section 12.

12. Procedure

12.1 *Preparation of Fuel Test Sample:*

12.1.1 Filter and aerate sample using standard operating conditions (see A5.2.9). (**Warning—**All jet fuels must be considered flammable except JP5 and JP7. Vapors are harmful (see A6.3, A6.6, and A6.7).)

NOTE 3—Before operating, see **Warning** in 6.1.1.

NOTE 4—Test method results are known to be sensitive to trace contamination from sampling containers. For recommended containers, refer to Practice D4306.

12.1.2 Maintain temperature of sample between 15 °C and 32 °C during aeration.

12.1.3 Allow no more than 1 h to elapse between the end of aeration and the start of the heating of the sample.

12.2 *Final Assembly:*

12.2.1 Check all lines to ensure tightness.

12.2.2 Recheck thermocouple position at 39 mm.

12.2.3 Make sure drip receiver is empty.

12.3 *Power Up and Pressurization:*

12.3.1 Turn POWER to ON.

12.3.2 Inspect the system for leaks. Depressurize the system as necessary to tighten any leaking fittings.

12.3.3 Set controls to the standard operating conditions.

12.3.4 Use a heater tube control temperature as specified for the fuel being tested. Apply any thermocouple correction from the most recent calibration (see A5.2.8).

NOTE 5—The test can be run to a maximum tube temperature of about 350 °C. The temperature at which the test should be run and the criteria for judging results are normally embodied in fuel specifications.

12.4 *Start Up:*

12.4.1 Use procedure for each model as described in the appropriate User Manual.

12.4.2 Some instrument models may do the following steps automatically, but verify that:

12.4.2.1 No more than 1 h maximum elapses from aeration to start of heating.

12.4.2.2 The test filter bypass valve is closed as soon as the heater tube temperature reaches the test level, so fuel flows through the test filter (see A5.2.6).

12.4.2.3 DP transducer is set to zero once DP stabilizes (see A5.2.6).

12.4.3 Check fuel flow rate against Standard Operating Conditions by timing flow or counting the drip rate during first 15 min of test. (See X1.5.)

NOTE 6—When counting drop rate, the first drop is counted as drop 0, and time is started. As drop 20 falls, total time is noted.

12.5 *Test:*

12.5.1 Record filter pressure drop every 30 min minimum during the test period.

12.5.2 If the filter pressure drop begins to rise sharply and it is desired to run a full 150 min test, a bypass valve common to all models must be opened in order to finish the test. See appropriate User Manual for details on operation of the bypass system (see A5.2.2).

12.5.3 Make another flow check within final 15 min before shutdown (see 12.4.3 and accompanying note). (See X1.5.)

12.6 *Heater Tube Profile*—If a heater tube temperature profile is desired, obtain as described in X1.4.

12.7 *Shutdown:*

12.7.1 Shut down the instrument; some models may do this automatically.

12.7.1.1 For applicable models after shutdown, turn FLOW SELECTOR VALVE to VENT to relieve pressure.

12.7.1.2 For Models 230 and 240, the piston actuator will retreat automatically.

12.7.1.3 Measure the amount of spent fluid pumped during the test.
(1) For the Models 230 and 240, measure effluent water in drip receiver, then empty.
(2) For other models, measure the fuel in the receipt container.

12.7.1.4 If the amount of water or fuel measured is less than 405 mL, the test shall be rejected.

12.8 *Disassembly:*

12.8.1 Disconnect fuel inlet line to the heater tube test section.

12.8.2 Disconnect the heater tube test section.

12.8.2.1 Remove the heater tube from the heater tube test section carefully so as to avoid touching the center part of heater tube, and discard the test filter.

12.8.2.2 Flush the heater tube with recommended general cleaning solvent (see 7.1) from top down. If the heater tube is grasped from the top, do not wash solvent over gloves or bare fingers. Allow to dry, return the heater tube to original container, mark with identification and hold for evaluation.

12.8.3 Disconnect and remove any containers.

12.8.3.1 Discard water and fuel to waste disposal.

12.8.4 Disconnect gas dispersion tube (i.e., sparger).

12.8.4.1 Flush gas dispersion tube (i.e., sparger) with recommended general cleaning solvent (see 7.1). Allow solvent to fully dry before using the gas dispersion tube (i.e., sparger) for another test.

13. Heater Tube Evaluation

13.1 Rate the deposits on heater tube in accordance with Annex A1, Annex A2, Annex A3, or Annex A4 as directed by the specification referencing this method and record data.

13.1.1 When a specification allows multiple rating techniques, the method providing deposit measurements in SI units is preferred.

13.1.2 When the rating techniques do not agree, the method providing measurements in SI units shall be regarded as the referee.

13.2 Return the heater tube to original container and retain as appropriate.

14. Report

14.1 Report the following information:

14.1.1 The heater tube control temperature. This is the test temperature of the fuel.

14.1.2 Heater tube deposit rating(s).

14.1.3 Maximum pressure drop across the filter during the test or the time required to reach a pressure differential of 25 mm Hg.

14.1.4 If the normal 150 min test time was not completed, for example, if the test is terminated because of pressure drop failure, also report the test time that corresponds to this heater tube deposit rating.

NOTE 7—Either the heater tube rating or the ΔP criteria, or both, are used to determine whether a fuel sample passes or fails the test at a specified test temperature.

14.1.5 Spent fuel at the end of a normal test (see 12.7.1.3).

14.1.6 Heater tube serial number may be reported.

15. Precision and Bias

15.1 An interlaboratory study of oxidative stability testing was conducted in accordance with Practice E691 by eleven laboratories, using thirteen instruments including two models with five fuels at two temperatures for a total of ten materials. Each laboratory obtained two results from each material.[7]

15.1.1 The terms repeatability and reproducibility in this section are used as specified in Practice E177.

15.2 *Precision*—It is not possible to specify the precision of this test method because it has been determined that test method results cannot be analyzed by standard statistical methodology.

15.3 *Bias*—This test method has no bias because jet fuel thermal oxidative stability is defined only in terms of this test method.

16. Keywords

16.1 differential pressure; fuel decomposition; oxidative deposits; heater tube deposits; thermal stability; turbine fuel

ANNEXES

(Mandatory Information)

A1. TEST METHOD FOR VISUAL RATING OF HEATER TUBES

A1.1. Scope

A1.1.1 This method covers a procedure for visually rating the heater tube produced by Test Method D3241.

[7] Supporting data have been filed at ASTM International Headquarters and may be obtained by requesting Research Report RR:D02-1309. Contact ASTM Customer Service at service@astm.org.

A1.1.2 The final result from this test method is a heater tube color rating based on an arbitrary scale established for this test method plus two additional yes/no criteria that indicate the presence of an apparent large excess of deposit or an unusual deposit, or both.

A1.1.3 *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.*

A1.2. Referenced Documents

A1.2.1 *Adjunct:*[5]
Color Standard for Heater Tube Deposit Rating

A1.3. Terminology

A1.3.1 *abnormal*—a heater tube deposit color that is neither peacock nor like those of the Color Standard.

A1.3.1.1 *Discussion*—This refers to deposit colors such as blues and grays that do not match the Color Standard.

A1.3.2 *peacock*—A multicolor, rainbow-like heater tube deposit.

A1.3.2.1 *Discussion*—This type of deposit is caused by interference phenomena where deposit thickness exceeds the quarter wave length of visible light.

A1.3.3 *Heater Tube Rating*—A ten-step discrete scale from 0 to >4 with intermediate levels for each number starting with 1 described as less than the subsequent number.

A1.3.3.1 *Discussion*—The scale is taken from the five colors—0, 1, 2, 3, 4—on the ASTM Color Standard. The complete scale is: 0, <1, 1, <2, 2, <3, 3,< 4, 4, >4. Each step is not necessarily of the same absolute magnitude. The higher the number, the darker the deposit rating.

A1.4. Summary of Test Method

A1.4.1 This test method uses a specially constructed light box to view the heater tube. The heater tube is positioned in the box using a special heater tube holder. Uniformity of the new heater tube surface is judged under the optimum light conditions of the box. Color of the heater tube is judged under light and magnification by comparing to the Color Standard plate slid into optimum position immediately behind the heater tube.

A1.5. Significance and Use

A1.5.1 The final heater tube rating is assumed to be an estimate of condition of the degraded fuel deposit on the heater tube. This rating is one basis for judging the thermal oxidative stability of the fuel sample.

A1.6. Apparatus

A1.6.1 *Heater Tube Deposit Rating Apparatus*—The colors of deposits on the heater tube are rated by using a tuberator and the ASTM Color Standard.

A1.7. Test Samples (Heater Tube)

A1.7.1 Handle the heater tube carefully so as not to touch the center portion at any time.

NOTE A1.1—Touching the center of the heater tube will likely contaminate or disturb the surface of the heater tube, deposit, or both, which must be evaluated in pristine condition.

A1.8 Standard Operating Conditions

A1.8.1 *Inside of Light Box,* opaque black.

A1.8.2 *Light Source,* three 30 W incandescent bulbs, clear, reflective type; all shall be working for optimum viewing.

A1.8.3 *Bulb Positions,* one above, two below, each directed toward heater tube holder and color standard.

A1.8.4 *Magnification,* 2×, covering viewing window.

A1.8.5 *Evaluators*—Use persons who can judge colors, that is, they should not be color blind.

A1.9. Calibration and Standardization

A1.9.1 No standardization is required for this test apparatus, but since the Color Standard is known to fade, store it in a dark place.

NOTE A1.2—The lifetime of the Color Standard is not established when continuously or intermittently exposed to light. It is good practice to keep a separate Standard in dark (no light) storage for periodic comparison with the Standard in regular use. When comparing, the optimum under the light conditions are those of the heater tube rating box.

A1.9.2 *Standardization of Rating Technique:*

A1.9.2.1 In rating a heater tube, the darkest deposits are most important. Estimate grades for the darkest uniform deposit, not for the overall average color of the deposit area.

A1.9.2.2 When grading, consider only the darkest continuous color that covers an area equal or larger than a circle of size one-half the diameter of the heater tube.

A1.9.2.3 Ignore an axial (that is, longitudinal) deposit streak that is less in width than one-quarter the diameter of the heater tube regardless of the length of the streak.

A1.9.2.4 Ignore spots, axial (that is, longitudinal) streaks, or scratches on a heater tube that are considered heater tube defects. These will normally not be present, since the heater tube is examined before use to eliminate defective heater tubes.

A1.10 Pretest Rating of Heater Tubes

A1.10.1 Examine the heater tube without magnification in laboratory light. If a defect is visible, discard the heater tube. Then examine the center (thinner area) of the heater tube between 5 mm and 55 mm above the bottom shoulder using the Tuberator. If a defect is seen, establish its size. If it is larger than 2.5 mm^2, discard the heater tube. Fig. A1.1 provides an illustration of defect areas equivalent to 2.5 mm^2.

A1.10.2 Examine the heater tube for straightness by rolling the heater tube on a flat surface and noting the gap between the flat surface and the center section. Reject any bent heater tube.

A1.11. Procedure

A1.11.1 *Set Up:*

A1.11.1.1 Snap the upper end of the heater tube into the clamp of the holder for the heater tube.

A1.11.1.2 Push the heater tube against the stop of the holder for the heater tube.

A1.11.1.3 Slide the holder with the heater tube over the guide rod into the tuberator.

A1.11.1.4 Rotate the holder and position the heater tube such that the side with the darkest deposit is visible.

A1.11.1.5 Insert the ASTM Color Standard into the tuberator.

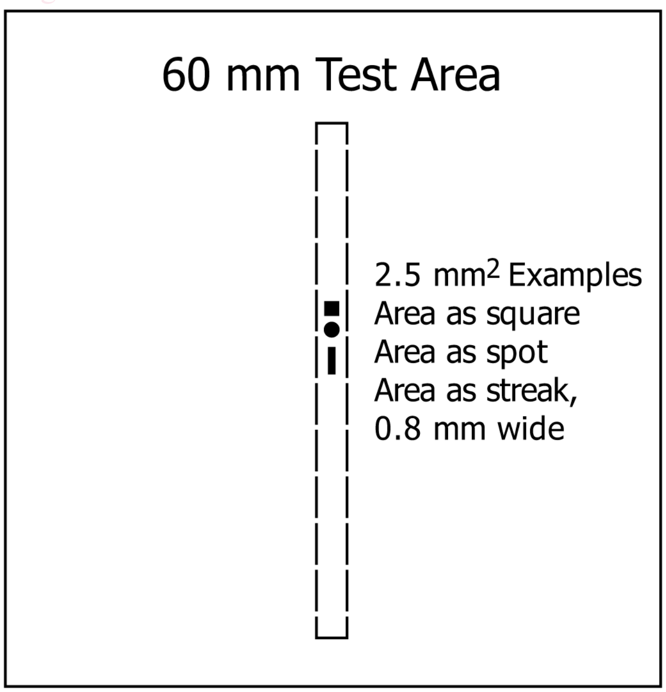

FIG. A1.1 Defect Areas