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An American National Standard

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

This standard is issued under the fixed designation D 1660; 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 test method has been adopted for use by government agencies to replace Method 3464 of Federal Test Method Standard No. 791b.

1. Scope

1.1 This test method[2] covers a procedure for rating the tendencies of aviation turbine fuels and similar gas turbine fuel oils to deposit decomposition products in the fuel system components.

1.2 *This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety problems associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* For specific hazard statements, see Notes 1 and 3 and Annex A1.

2. Referenced Documents

2.1 *ASTM Standards:*

D 1655 Specification for Aviation Fuels[3]

D 4306 Practice for Sampling Aviation Fuel for Tests Affected by Trace Contamination[4]

2.2 *ASTM Adjuncts:*

ASTM-CFR Fuel Coker Record Form[5] Color Standard for Tube Deposit Rating (5 Aluminum Strips)[6]

3. Definition

3.1 *thermal stability*—represents the oxidative degradation of jet fuels by application of thermal stresses resulting in a fuel deposit formation which may differ based on temperature(s) applied.

4. Summary of Test Method

4.1 This test method for measuring the high-temperature stability of aviation turbine fuels uses the ASTM-CRC Fuel Coker which subjects the test fuel to temperatures and conditions similar to those occurring in some aviation turbine engines. Fuel is pumped at predetermined rates through a preheater section which simulates the hot fuel line sections of the engine as typified by an engine fuel-oil cooler. It then passes through a heated filter section which represents the nozzle area or small fuel passages in the hot section of the engine where fuel degradation products may become trapped. A precision sintered stainless steel filter in the heated filter section traps fuel degradation products formed during the test. The extent of the build-up is noted as an increased pressure drop across the test filter, and, in combination with the deposit condition of the preheater, is used as an assessment of the thermal stability of the fuel.

5. Significance and Use

5.1 This test method is indicative of fuel performance during gas turbine operation and is used to assess fuel thermal stability at specific temperatures.

6. Apparatus

6.1 *ASTM-CRC Fuel Coker*—Either of the two specified models of the ASTM-CRC Fuel Coker, Manual Unit (Model 01FC) or Semi-Automatic Unit (Model 02FC), as described in detail in Annex A2, may be used.[7]

6.2 *Accessories and Materials*—The flushing solvents, metal polish, and cleaning equipment specified in Section 7 for use in cleaning and flushing operations shall conform to the specifications listed in Annex A3 on Accessories and Materials. Other optional tools and accessories are also described in Annex A3. These include certain essential accessories which are not furnished with the Fuel Coker.

7. Preparations for Test

7.1 *Fuel Pre-Filtering*—The nature of the thermal stability test requires that all fuel be essentially clean and free of moisture as determined visually. Accordingly, the test fuel and solvent flushing fluids shall be filtered (**Warning**—See Note 1) by a single pass through a close-textured filter before loading the fuel reservoir.[8]

NOTE 1: **Warning**—A potential hazard involving static electricity can exist if all parts of the filter system are not grounded. It is therefore strongly recommended that a stainless steel funnel be used, and that it be adequately grounded.

7.2 *Test Fuel Reservoir*—The fuel reservoir must be cleaned before it is filled with filtered fuel.

NOTE 2—Test method results are known to be sensitive to trace contamination from sampling containers. For recommended containers refer to Practice D 4306.

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[1] This test method is under the jurisdiction of ASTM Committee D-2 on Petroleum Products and Lubricants and is the direct responsibility of Subcommittee D02.J on Aviation Fuels.

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[2] This test method was developed on the basis of cooperative work carried out by the Coordinating Research Council from 1955 to 1958, and published in CRC Report "Investigation of Thermal Stability of Aviation Turbine Fuels with CFR Fuel Coker," (CRC Project CFA-2-54), July, 1957 and "Fuel Thermal Stability Exchange Program," (CRC Project CA-2-58), September, 1958.

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

[4] *Annual Book of ASTM Standards*, Vol 05.03.

[5] Available from ASTM Headquarters; order Adjunct No. 12-416600-01.

[6] Available from ASTM Headquarters; order Adjunct No. 12-416600-00

[7] The automatic unit (Model 03FC) may also be used and is described in Part 17 of the *1969 Annual Book of ASTM Standards* (*Second Edition*). Its description herein has been deleted to simplify the test method. Models 03FC and 01FC are no longer manufactured.

[8] A single sheet of No. 12 Whatman filter paper is specified for this purpose.

7.3 *Air Saturation*—The amount of air dissolved in the test fuel may affect test results. All test fuel shall, therefore, have comparable dissolved air content. To accomplish this, air-saturate the filtered test fuel by blowing air[9] through a fritted glass[10] dispersion tube into the test fuel at room temperature for 3 min (**Warning**—See Note 3). Adjust the air flow rate (approximately 1 to 2 L/min) to give only a slight cuff on the fuel. Perform this operation immediately before starting the test.

NOTE 3—If the fuel has been stored under an inert gas blanket, the aeration time should be extended to 20 min. (**Warning**—Aeration must be accomplished in a ventilated area or under a hood to prevent accumulation of potentially hazardous vapors.)

7.4 *Flushing Operation*—Install a preheater assembly containing a temporary inner tube and a small needle valve in place of the filter furnace.[11] Open the small needle valve and add 3.8 L of filtered tri-solvent to the reservoir. Pump through the system at a minimum rate of 3.6 kg/h. After flushing for 5 min, purge the manometer lines by carefully closing and opening the temporary needle valve so that the mercury pressure cycles between 0 to 635 mm. Repeat the manometer purging procedure three times or more until the fuel in the manometer is clear. Continue flushing until the tri-solvent is consumed (Note 4). Repeat this procedure with 3.8 L of Stoddard solvent. After draining all Stoddard solvent, the system is considered clean and ready for installation of the clean preheater and filter assembly (Note 5).

NOTE 4—If the system has been contaminated with an unstable fuel, additional tri-solvent flushing is recommended.

NOTE 5—The flushing operation is considered most effective when carried out at the finish of a previous test. The equipment is still considered ready for the following test even though an elapsed time of several days may occur between flushing and testing.

7.5 *Cleaning of Test Section Components*—Dismantle the preheater and filter body components and soak in tri-solvent. Complete disassembly of the preheater section is not required after each test. The fitting which receives the thermocouple is not to be removed since this may affect the location of the thermocouple. Manually clean all accessible interior recesses using nylon or copper-free wire brushes dipped in tri-solvent. Rinse these parts consecutively in tri-solvent, Stoddard solvent, and pentane and inspect for cleanliness before reassembling.

7.6 *Preparation of Preheater Tube:*

7.6.1 Check the inner preheater tube to be used in the test for straightness by rolling the tube on a machinist's flat or a suitably mounted piece of plate glass. Place the tube on the flat so that the short portion beyond the recessed ring overhangs. Discard any tube having a bow greater than 0.13 mm when checked using a feeler gage on the flat surface. Also discard any tubes that have been scratched, nicked, or otherwise damaged during handling. New tubes must be checked for straightness and damage.

7.6.2 Shake the can of Silvo polish vigorously. Dampen a clean dry cloth with the Silvo polish. Keep the cloth wet but not saturated with polish during this operation. Polish the entire surface of the inner preheater tube to a mirror finish. New tubes should be polished in the same manner as used tubes. Go immediately to 7.6.3 before the polish dries on the tube.

7.6.3 Saturate a clean dry cloth with filtered tri-solvent. Carefully wipe all traces of the polish off the tube with this cloth. Discard the cloth when finished.

7.6.4 Dry the tube thoroughly with a clean dry cloth.

7.6.5 Repeat 7.6.3 and 7.6.4 two more times.

7.6.6 Rinse the tube with filtered Stoddard solvent without wiping.

7.6.7. Repeat the rinsing without wiping using filtered pentane. Place the tube on a clean dry cloth and allow to air dry. After dry, lightly wipe the surface of the tube with lens cleaning tissue that has not been silicone treated.

7.6.8 View the tube in the tuberator and if the surface appears hazy or if a film has been left in spots, repeat 7.6.6 and 7.6.7. If the second rinse does not produce a clean mirror surface when viewed in a tuberator, repeat 7.6.2 through 7.6.8. If this does not work, discard the tube and prepare a new tube for the test.

7.7 *Assembly of Test Section:*

7.7.1 Insert the clean, polished preheater tube in the preheater assembly. The tube should be installed so that it projects 41.3 mm past the preheater outlet end body. Tighten first the tubing connector nut at the hot end. Then tighten the seal plug which secures the Teflon packing at the cold end. Use of the preheater assembly jig is recommended for this operation. Sparingly apply anti-seize compound to all high-temperature male threads. Position the cartridge heater inside the preheater inner tube. Make sure the heater butts against the end stop in the tube.

7.7.2 Install a new unused test filter in the filter body so that the side with the retaining aluminum washer is exposed to the incoming fuel (Fig. A2.2).

7.7.3 Install the clean preheater and filter furnace assembly.

7.8 *Semi-Automatic Temperature Controllers*—In addition to the normal preparations, the following steps are required for the semi-automatic unit:

7.8.1 Set the preheater temperature by depressing and positioning the pointer of the temperature controller to the desired temperature.

7.8.2 Set the filter temperature by depressing and positioning the pointer of the temperature controller to the desired temperature.

8. Test Sequence

8.1 Make sure the rig has been cleaned, flushed, and the test section components assembled in accordance with Section 7.

8.2 Be sure that the test section door and rig back cover are closed. Determine the empty weight of the discharge reservoir. Connect the test fuel reservoir containing filtered test fuel. Turn the power and pump switches to ON.

8.3 Set the desired fuel flow rate by means of the hand needle valve located on the front panel immediately below the rotameter which indicates fuel flow rate. The rotameter

[9] Clean air essentially free of oil and moisture is required.

[10] Pyrex, glass such as Corning Glass No. 39533 Extra Coarse Disk, or equivalent, has been found satisfactory for this purpose.

[11] A jumper line can be used in place of the preheater assembly; provisions must be made for connection to the manometer high pressure tap.

TABLE 1 Warm-up Instructions for ASTM-CRC Fuel Coker (For 2.7 kg/h Fuel Flow Only)

NOTE 1—Combinations of preheater and filter temperatures are listed in columns 1 and 2. The corresponding initial preheater and filter watt requirements are listed in columns 3 and 4. In order to avoid overshooting the desired final temperatures it is necessary to reduce the wattage input when the temperatures indicated in columns 5 and 6 are reached. The approximate final wattages required are indicated in columns 7 and 8.

Example.—For desired test conditions of 149°C preheater temperatures, 204.5°C filter temperature and 2.7 kg/h fuel flow the detailed procedure would be as follows:

1. When heaters are turned on, set preheater power at 296 W and filter heater power at 223 W.
2. When the preheater temperature reaches 141°C (7.5°C early), reset the preheater power to approximately 260 W.
3. When the filter temperature reaches 196°C (8.5°C early), reset the filter power to approximately 105 W.
4. Continue to monitor these temperatures throughout the test and adjust powers as necessary to maintain desired temperatures within ±3°C.
5. On the semi-automatic unit it is necessary only to make the initial power settings. Thereafter the automatic temperature controls will regulate the power input.

NOTE 2—The wattage values indicated are approximate only. The final power settings may vary for different fuels and should be adjusted to give the desired test temperatures.

SUMMARY TABLE

Test Conditions, °C		Initial Watts		Cutback Temperature, °C		Approximate Final Watts	
Preheater *1*	Filter *2*	Preheater *3*	Filter *4*	Preheater *5*	Filter *6*	Preheater *7*	Filter *8*
93	204	165	263	88	196	140	150
107	204	196	253	102	196	170	138
121	204	230	243	114	196	200	127
135	204	262	233	128	196	230	117
149	204	296	223	141	196	260	105
163	204	329	211	154	196	290	92
177	204	362	200	173	196	320	80
149	260	295	368	141	252	260	180
163	260	329	357	154	252	290	167
177	260	362	342	173	252	320	153
191	260	395	327	181	252	350	138
204	260	428	310	194	252	380	123
218	260	462	295	208	252	410	106
232	260	495	278	221	252	440	90

must be recalibrated for each new fuel. This can be done by any of several procedures. One method involves weighing the discharge reservoir, collecting fuel in it for 10 min, reweighing, and multiplying the difference in kilograms by six to obtain a rate in terms of kilograms per hour. Based on this figure, estimate a new indicated fuel rotameter setting and again check the flow for 10 min. Repeat this process until fuel is collected at the desired rate. Normally the desired fuel flow rate is 2.7 ± 0.05 kg/h.

NOTE 6: **Caution**—The specified fuel rate is to be maintained throughout the test and an average value during 5 h of operation is not acceptable. To ensure that the fuel is kept within test limits, fuel flow calibration checks must be done at hourly intervals throughout the test period. The weight of fuel obtained during these checks must be taken into account when calculating the final fuel flow. Continuous weighing with frequent calculations of flow rate is a satisfactory procedure. Use of a constant rotameter setting is not an adequate means of obtaining a constant flow rate throughout the test. The temperature of the fuel in the test reservoir changes due to change in ambient temperature or to introduction of fuel through the pump bypass system.

8.4 Turn the cooling water on. Turn the heater switch on and adjust the two variable autotransformers to deliver the watts specified in columns 3 and 4 of Table 1 for the conditions specified in columns 1 and 2. When the preheater temperature reaches the prescribed cutback temperature on the manual unit as shown in column 5, reduce the power to the value indicated in column 7. When the filter temperature reaches the prescribed cut-back temperature (column 6) on the manual unit, reduce the power to the value indicated in column 8. On the semi-automatic unit, it is only necessary to make the initial power setting.

8.6 Start the timer when the heat is first turned on. When the timer is turned to ON, connect a weighed discharge receiver to the fuel outlet line. When the desired test conditions have been reached, adjust the scale on the manometer to zero, or record (Note 7) the actual reading for a reference. If other than zero, subtract this reference from all subsequent readings.

NOTE 7—Some data sheets require the recording of elapsed test time and the manometer reading at the point when desired test temperatures have been reached.

8.6 Adjust the variable autotransformers on manual units as necessary during the test to maintain the required preheater fuel and filter body temperatures. The tolerances are as follows:

Preheater fuel temperature	±3°C
Filter temperature	±5.5°C

8.7 Record the data in accordance with data sheet requirements. A suggested data sheet form is shown in Fig. 1.[5]

8.8 When the manometer reading reaches 660 mm Hg, or when the test is completed, turn both heaters to OFF and switch the fuel discharge line from the preweighed discharge reservoir to the scrap fuel reservoir.

9. Shutdown Sequence

9.1 Continue the fuel flow until the apparatus has cooled sufficiently (65.6°C filter temperature). During this period, reduce the flow of the fuel as necessary to prevent excessive filter pressure drop.

9.2 Shut off the fuel pump. Leave the main power switch at ON to operate the ventilating blower until the test components and all excess fuel have been removed from the cabinet.

9.3 Drain the pressure regulator. Disassemble the preheater and filter assemblies and remove the test filter and preheater inner tube using the appropriate jigs. Record the description of the deposit on the surface of the preheater tube as described in Section 10.

9.4 At the end of the test, weigh the reservoir containing the spent test fuel. Determine the total weight of fuel flow for

LABORATORY ____________________

DATE OF TEST__________ LAB TEST NO. __________

OPERATOR ____________________

FUEL ____________________

INSTRUMENT SERIAL NUMBER ____________________

TEST CONDITIONS:

TEST FILTER AIR FLOW _____ CFM (CORRESPONDING FLOW RATE DATA SUPPLIED FOR EACH TEST FILTER MUST BE 3.00 ± 0.15 CFM)

PREHEATER TEMPERATURE ____________________

FILTER TEMPERATURE ____________________

NOMINAL FUEL FLOW RATE ____________________

FUEL CONTAINER WEIGHT: BEFORE __________ AFTER __________

EXACT AVERAGE FUEL FLOW RATE ____________________

TEST DATA	MANOMETER READING	MINUTES
CONDITIONS SET		
8 mm Hg Δ P ABOVE CONDITIONS SET		
25 mm Hg Δ P		
76 mm Hg Δ P		
250 mm Hg Δ P		
635 mm Hg Δ P		
END OF TEST		

PREHEATER TUBE DEPOSITS

DEPOSIT CODE:

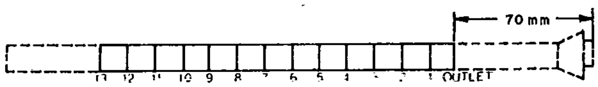
0 – NO VISIBLE DEPOSITS

1 – HAZE OF DULLING, NO COLOR

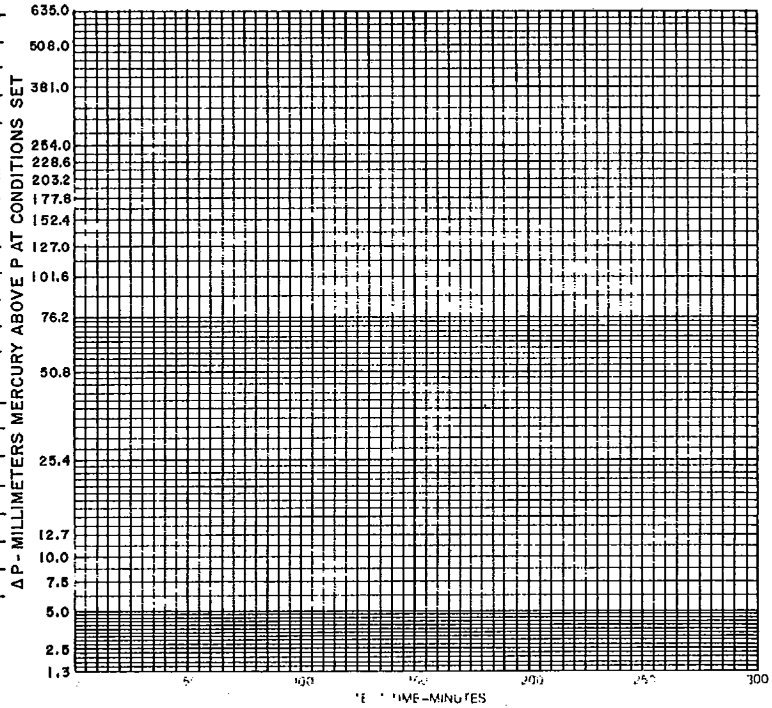
2 – BARELY VISIBLE DISCOLORATION

3 – LIGHT TAN

4 – HEAVIER THAN CODE 3



(EACH SPACE = 25.4 mm)



COMMENTS: ____________________

FIG. 1 Suggested Data Sheet Form[5]

the test. Divide this weight by the length of the test in hours and record the results on the data sheet as "Exact Average Fuel Flow Rate." This rate must be within ±0.05 kg/h of the required fuel flow rate for a valid test.

9.5 Shut off the water supply and make sure that the main power switch is OFF.

10. Rating Preheater Deposits

10.1 Rate the preheater deposits using the tube deposit rating code on the ASTM Color Standard[6] according to the following procedure:

10.1.1 Dry the tube with a stream of pentane or by gently dipping in a nonagitated bath for a few seconds and hanging vertically in still air. Perform this operation immediately after shutdown and removal of the preheater and filter assemblies and carry out the tube rating within 30 min of tube removal.

10.1.2 Visually examine the dry preheater tube under a diffused light source in a Tuberator. Each inch of tube length should be separately rated in the sequence noted in Fig. 1. When a section of the tube corresponds visually to a Color Standard, that number should be recorded. If the section being rated is in the obvious transition state between any two adjacent Tuberator Color Standards, it should be rated as less than the darker (that is, higher number) standard. No attempt should be made to rate the deposits on the basis of apparent density or thickness.

NOTE 8—It is important to ensure that all light bulbs in the Tuberator are functioning because a change in light intensity can shift the rating standard significantly.

NOTE 9—The Color Standards are known to fade on exposure to strong light and must be stored in the dark. The lifetime of the standards is not established when continuously or intermittently exposed to light. It is advisable to maintain a separate standard for periodic comparison

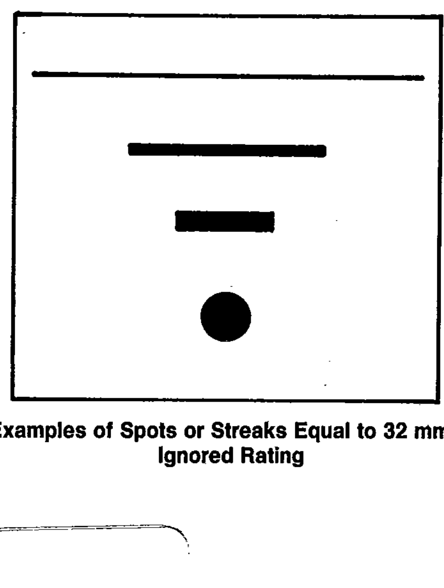


FIG. 2 Examples of Spots or Streaks Equal to 32 mm[2] and to be Ignored Rating

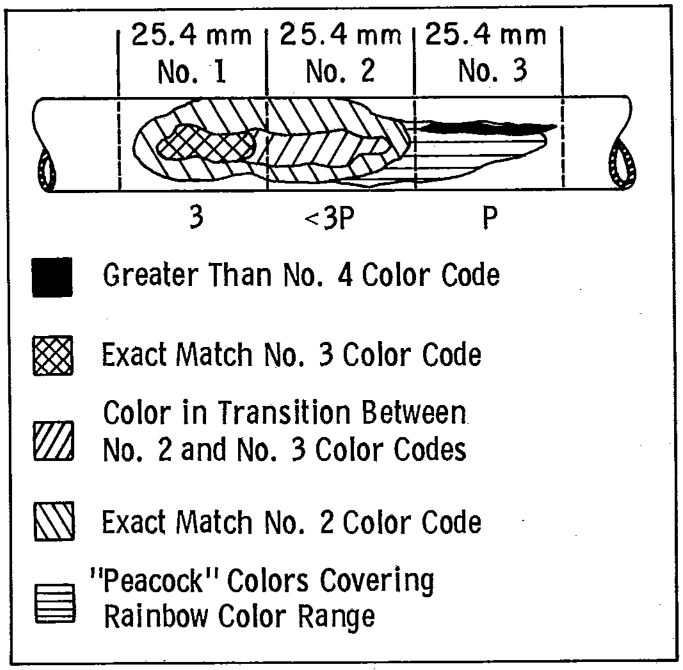


FIG. 3 Example of Tube Deposit

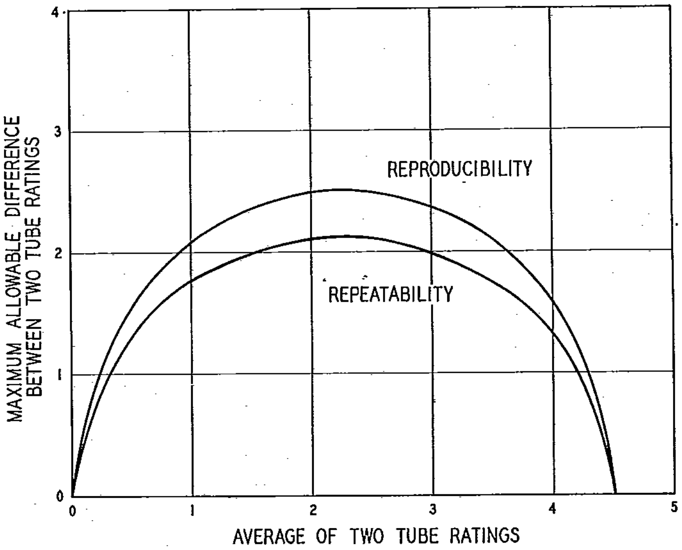


FIG. 4 Variation of Repeatability and Reproducibility with Tube Rating Level

under light conditions as used in the Tuberator. See Annex A3.18.

10.1.3 In rating the preheater tube, the darkest deposits govern and the code number reported should be representative of the darkest section rather than average deposits. Small individual spots, streaks, or bands of the dark deposit should be ignored provided the area of each such spot or streak is less than 32 mm^2 (which corresponds to a circle about 6.4 mm in diameter; see Fig. 2 for examples). If there are more than three such areas on the entire tube, a fresh fuel sample shall be retested if it passes in all other respects. If a streak covering two or more adjacent sections of the tube causes a fail result, the test should be repeated on a fresh fuel sample since such a streak suggests misalignment of the heater element within the preheater tube. If a continuous spot, streak, or band falls on the boundary of sections being rated but covers a total area of 32 mm^2 or more, it should be rated.

10.1.4 Deposits that do not conform to established Color Standards but are of the type identified as peacock should *not be rated* but shall be reported for the appropriate tube interval using the letter "P."

NOTE 10—Peacock or color streaks do not match the Color Standard strips. They are near a Code 2 deposit in depth and thickness.

10.1.5 An example of how the rating procedure is to be used is given below and by reference to Fig. 3.

10.1.5.1 In Inch 1, the *darkest* deposit matches Color Standard and the rating reported is "3."

10.1.5.2 In Inch 2, the *darkest* color is the transition range between Color Standards 2 and 3. It is rated as "<3," that is, less than the darker Color Standard. Also present is some "peacock" deposit so the letter "P" is reported to indicate the presence of colored deposits. Thus, the deposit for this section is "<3P."

10.1.5.3 In Inch 3, there is a streak of deposit darker than No. 4 Color Standard, but smaller than 32 mm^2. It is *not* rated. The only other deposit observable is "peacock" deposit, and it is recorded as "P."

10.1.5.4 When summarizing the overall tube rating, the *maximum observed Color Code* shall be reported. In this example, the rating would be "3."

11. Report

11.1 Report on a suitable data sheet,[5] as shown in Fig. 1, the following:

11.1.1 Preheater temperature,

11.1.2 Filter temperature,

11.1.3 Nominal fuel flow rate,

11.1.4 Fuel container weight before and after test,

11.1.5 Exact average fuel flow rate, and

11.1.6 Fuel deposit code rating, and

11.1.7 Pressure drop across the filter at the end of the test or the time required to reach a pressure differential of 635 mm of mercury.

12. Precision[12] and Bias

12.1 The following criteria should be used for judging the acceptability of results obtained in using this test method.

12.1.1 *Repeatability*—The difference between successive test results obtained by the same apparatus under constant operating conditions on identical test materials, would in the long run, in the normal and correct operation of this test method, exceed those shown in Figs. 4 and 5 in only one case in twenty.

12.1.2 *Reproducibility*—The difference between two single, independent test results, obtained by different operators working in different laboratories on identical test materials, would in the long run in the normal and correct operation of this test method exceed those shown in Figs. 4 and 5 only in one case in twenty.

[12] Supporting data are filed and may be obtained from ASTM Headquarters. Request RR:D02-1179.

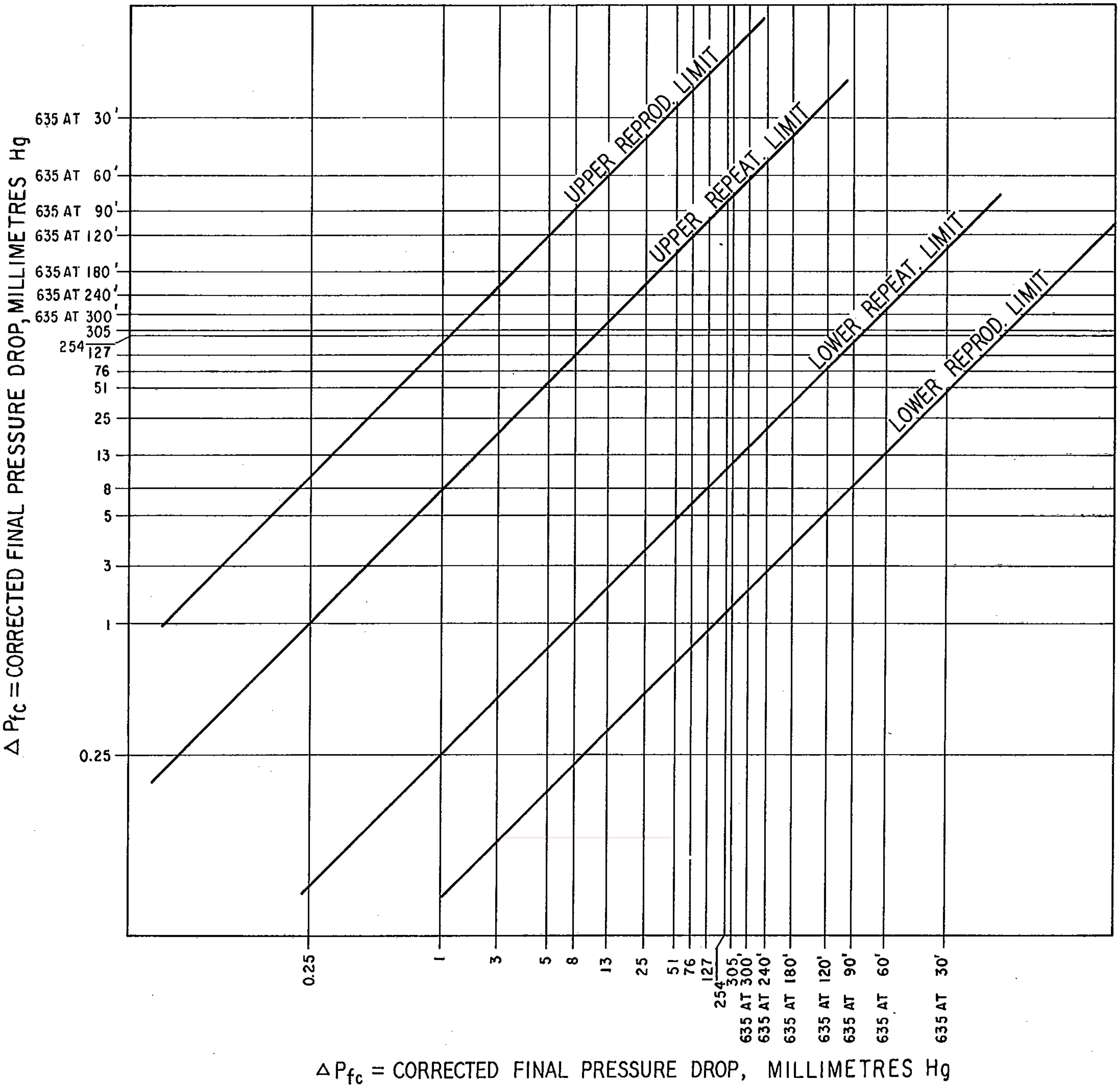


FIG. 5 Repeatability and Reproducibility for Filter Pressure Drop

12.2 *Bias*—The procedure in this test method has no bias because the values obtained can be defined only in terms of the test method.

12.3 *Test Procedure and Explanation*

12.3.1 The precision of this method for aviation turbine fuels only has been determined by cooperative tests carried out by Section D02.J.08, Subcommittee D02.J of ASTM Committee D-2 on Petroleum Products and Lubricants. Thirteen laboratories participated, running three aviation turbine fuels and covering preheater temperature/filter temperature/flow rate operating range of 135/190.5/2.7 to 246/301.5/2.7. The data were tested for bias using the Youden Rank Score Test, and results are shown for consensus laboratories only.

12.3.2 Figure 4 indicates precision criteria for maximum tube code. Precision is seen to be a function of rating level. In computing averages, "less than" ratings are considered to be halfway between the higher and lower values.

12.3.3 For precision criteria on filter pressure drop, refer to Fig. 5. The two pressure drop readings to be compared are to determine a point of intersection on the plot. The appropriate limits for satisfactory data are indicated; intersections falling outside these limits must be considered