



Designation: D5580 – 21

Standard Test Method for Determination of Benzene, Toluene, Ethylbenzene, *p/m*-Xylene, *o*-Xylene, C₉ and Heavier Aromatics, and Total Aromatics in Finished Gasoline by Gas Chromatography¹

This standard is issued under the fixed designation D5580; 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 test method covers the determination of benzene, toluene, ethylbenzene, the xylenes, C₉ and heavier aromatics, and total aromatics in finished motor gasoline by gas chromatography.

1.2 The aromatic hydrocarbons are separated without interferences from other hydrocarbons in finished gasoline. Non-aromatic hydrocarbons having a boiling point greater than *n*-dodecane may cause interferences with the determination of the C₉ and heavier aromatics. For the C₈ aromatics, *p*-xylene and *m*-xylene co-elute while ethylbenzene and *o*-xylene are separated. The C₉ and heavier aromatics are determined as a single group.

1.3 This test method covers the following concentration ranges, in liquid volume %, for the preceding aromatics: benzene, 0.1 % to 5 %; toluene, 1 % to 15 %; individual C₈ aromatics, 0.5 % to 10 %; total C₉ and heavier aromatics, 5 % to 30 %, and total aromatics, 10 % to 80 %.

1.4 Results are reported to the nearest 0.01 % by either mass or by liquid volume.

1.5 This test method includes a relative bias section for U.S. EPA spark-ignition engine fuel regulations reporting for benzene based on Practice D6708 accuracy assessment between Test Method D5580 and Test Method D3606 as a possible Test Method D5580 alternative to Test Method D3606. The Practice D6708 derived correlation equation is only applicable for fuels in the benzene concentration range from 0.0 % to 2.31 % by volume as measured by Test Method D5580. The applicable Test Method D3606 range for benzene is from 0.0 % to 2.38 % by volume as reported by Test Method D3606.

1.6 This test method includes a relative bias section for U.S. EPA spark-ignition engine fuel regulations for total aromatics reporting based on Practice D6708 accuracy assessment be-

¹ This test method is under the jurisdiction of ASTM Committee D02 on Petroleum Products, Liquid Fuels, and Lubricants and is the direct responsibility of Subcommittee D02.04.0L on Gas Chromatography Methods.

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tween Test Method D5580 and Test Method D5769 as a possible Test Method D5580 alternative to Test Method D5769. The Practice D6708 derived correlation equation(s) is only applicable for fuels in the total aromatic concentration range from 5.4 % to 31.6 % by volume as measured by Test Method D5580 and a distillation temperature T₉₅, at which 95 % of the sample has evaporated, as measured by Test Method D86 is in the range of 149.1 °C to 196.6 °C (300.4 °F to 385.9 °F).

1.6.1 The applicable Test Method D5769 range for total aromatics is from 3.7 % to 29.4 % by volume as reported by Test Method D5769 and the distillation temperature T₉₅, at which 95 % of the sample has evaporated, when tested according to Test Method D86 ranged from 149.1 °C to 196.6 °C (300.4 °F to 385.9 °F).

1.7 This test method includes a relative bias section for spark-ignition engine fuels (gasolines) for benzene reporting based on Practice D6708 accuracy assessment between Test Method D5580 and Test Method D5769 as a possible Test Method D5580 alternative to Test Method D5769. The Practice D6708 derived correlation equation for benzene is applicable in the test method inclusive valid reporting concentration ranges, as determined from Practice D6708 data set and precision working limits of Test Method D5580, from 0.08 % to 2.34 % by volume as measured by Test Method D5580.

1.8 Many of the common alcohols and ethers that are added to gasoline to reduce carbon monoxide emissions and increase octane, do not interfere with the analysis. Ethers such as methyl *tert*-butylether (MTBE), ethyl *tert*-butylether (ETBE), *tert*-amylmethylether (TAME), and diisopropylether (DIPE) have been found to elute from the precolumn with the nonaromatic hydrocarbons to vent. Other oxygenates, including methanol and ethanol elute before benzene and the aromatic hydrocarbons. 1-Methylcyclopentene has also been found to elute from the precolumn to vent and does not interfere with benzene.

1.9 The values stated in SI units are to be regarded as standard.

1.9.1 *Exception*—The values given in parentheses are for information only.

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

1.10 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.

1.11 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

- D86** Test Method for Distillation of Petroleum Products and Liquid Fuels at Atmospheric Pressure
- D1298** Test Method for Density, Relative Density, or API Gravity of Crude Petroleum and Liquid Petroleum Products by Hydrometer Method
- D3606** Test Method for Determination of Benzene and Toluene in Spark Ignition Fuels by Gas Chromatography
- D4052** Test Method for Density, Relative Density, and API Gravity of Liquids by Digital Density Meter
- D4057** Practice for Manual Sampling of Petroleum and Petroleum Products
- D4307** Practice for Preparation of Liquid Blends for Use as Analytical Standards
- D5769** Test Method for Determination of Benzene, Toluene, and Total Aromatics in Finished Gasolines by Gas Chromatography/Mass Spectrometry
- D6300** Practice for Determination of Precision and Bias Data for Use in Test Methods for Petroleum Products, Liquid Fuels, and Lubricants
- D6708** Practice for Statistical Assessment and Improvement of Expected Agreement Between Two Test Methods that Purport to Measure the Same Property of a Material
- E355** Practice for Gas Chromatography Terms and Relationships

3. Terminology

3.1 Definitions of Terms Specific to This Standard:

3.1.1 *aromatic, n*—any organic compound containing a benzene ring.

3.1.2 *low-volume connector, n*—a special union for connecting two lengths of narrow bore tubing 1.6 mm (0.06 in.) outside diameter and smaller; sometimes this is referred to as zero dead volume union.

3.1.3 *narrow bore tubing, n*—tubing used to transfer components prior to or after separation; usually 0.5 mm (0.02 in.) inside diameter and smaller.

3.1.4 *split ratio, n*—in capillary gas chromatography, the ratio of the total flow of carrier gas to the sample inlet versus the flow of the carrier gas to the capillary column, expressed by:

$$\text{split ratio} = (S + C)/C \quad (1)$$

where:

S = flow rate at the splitter vent, and

C = flow rate at the column outlet.

3.1.5 *1,2,3-tris-2-cyanoethoxypropane (TCEP), n*—a polar gas chromatographic liquid phase.

3.1.6 *wall-coated open tubular (WCOT), n*—a type of capillary column prepared by coating the inside wall of the capillary with a thin film of stationary phase.

4. Summary of Test Method

4.1 A two-column chromatographic system equipped with a column switching valve and a flame ionization detector is used. A reproducible volume of sample containing an appropriate internal standard such as 2-hexanone is injected onto a precolumn containing a polar liquid phase (TCEP). The C₉ and lighter nonaromatics are vented to the atmosphere as they elute from the precolumn. A thermal conductivity detector may be used to monitor this separation. The TCEP precolumn is backflushed immediately before the elution of benzene, and the remaining portion of the sample is directed onto a second column containing a nonpolar liquid phase (WCOT). Benzene, toluene, and the internal standard elute in the order of their boiling points and are detected by a flame ionization detector. Immediately after the elution of the internal standard, the flow through the nonpolar WCOT column is reversed to backflush the remainder of the sample (C₈ and heavier aromatics plus C₁₀ and heavier nonaromatics) from the column to the flame ionization detector.

4.2 The analysis is repeated a second time allowing the C₁₂ and lighter nonaromatics, benzene and toluene to elute from the polar TCEP precolumn to vent. A thermal conductivity detector may be used to monitor this separation. The TCEP precolumn is backflushed immediately prior to the elution of ethylbenzene and the remaining aromatic portion is directed into the WCOT column. The internal standard and C₈ aromatic components elute in the order of their boiling points and are detected by a flame ionization detector. Immediately after *o*-xylene has eluted, the flow through the nonpolar WCOT column is reversed to backflush the C₉ and heavier aromatics to the flame ionization detector.

4.3 From the first analysis, the peak areas of benzene, toluene, and the internal standard (2-hexanone) are measured and recorded. Peak areas for ethylbenzene, *p/m*-xylene, *o*-xylene, the C₉ and heavier aromatics, and internal standard are measured and recorded from the second analysis. The backflush peak eluting from the WCOT column in the second analysis contains only C₉ and heavier aromatics.

4.4 The flame ionization detector response, proportional to the concentration of each component, is used to calculate the amount of aromatics that are present with reference to the internal standard.

5. Significance and Use

5.1 Regulations limiting the concentration of benzene and the total aromatic content of finished gasoline have been

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.

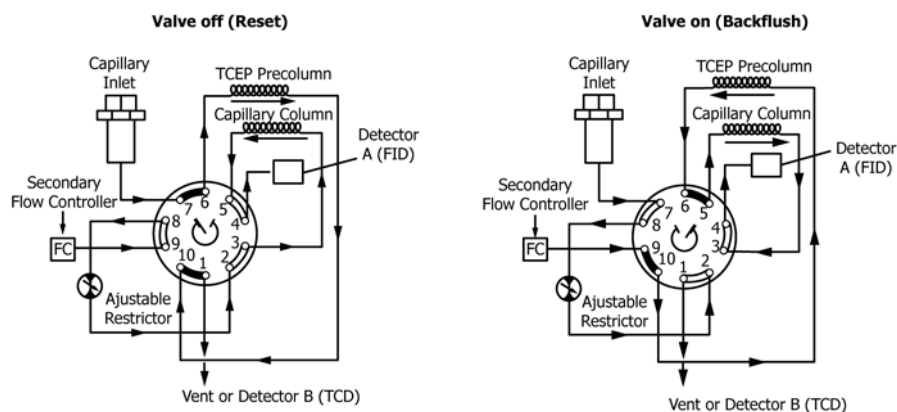


FIG. 1 Valve Diagram, Aromatics in Gasoline

established for 1995 and beyond in order to reduce the ozone reactivity and toxicity of automotive evaporative and exhaust emissions. Test methods to determine benzene and the aromatic content of gasoline are necessary to assess product quality and to meet new fuel regulations.

5.2 This test method can be used for gasolines that contain oxygenates (alcohols and ethers) as additives. It has been determined that the common oxygenates found in finished gasoline do not interfere with the analysis of benzene and other aromatics by this test method.

6. Apparatus

6.1 *Chromatographic System*—See Practice E355 for specific designations and definitions. Refer to Fig. 1 for a diagram of the system.

6.1.1 *Gas Chromatograph (GC)*, capable of operating at the conditions given in Table 1, and having a column switching and backflushing system equivalent to Fig. 1. Carrier gas pressure and flow control devices shall be capable of precise control when column head pressures and flow rates are low.

6.1.2 *Sample Introduction System*, capable of introducing a representative sample into the gas chromatographic inlet. Microlitre syringes and automatic syringe injectors have been used successfully.

6.1.3 *Inlet System, (splitting type)*—Split injection is necessary to maintain the actual chromatographed sample size within the limits required for optimum column efficiency and detector linearity.

6.1.3.1 Some gas chromatographs are equipped with on-column injectors and autosamplers which can inject submicrolitre sample sizes. Such systems can be used provided that column efficiency and detector linearity are comparable to systems with split injection.

6.1.4 *Detector*—A flame ionization detector (Detector A) is employed for quantitation of components eluting from the WCOT column. The flame ionization detector used for Detector A shall have sufficient sensitivity and stability to detect 0.01 % by volume of an aromatic compound.

6.1.4.1 It is strongly recommended that a thermal conductivity detector be placed on the vent of the TCEP precolumn (Detector B). This facilitates the determination of valve

TABLE 1 Typical Chromatographic Operating Parameters 130

Temperatures	
Injection port (split injector)	200 °C
FID (Detector A)	250 °C
TCD (Detector B)	200 °C
Nonpolar WCOT capillary	
Initial	60 °C (6 min)
Program rate	2 °C/min
Final	115 °C (hold until all components elute)
Polar TCEP precolumn (temperature to remain constant before time to BACKFLUSH, T1 or T2. Do not exceed maximum operating temperature.)	60 °C or same as nonpolar WCOT capillary if TCEP/WCOT columns contained in identical heated zone.
Valve	>115 °C or same as nonpolar WCOT capillary if valve and WCOT column contained in identical heated zone.
Flows and Conditions	
Carrier gas	helium
Flow to TCEP precolumn (split injector)	10 mL/min
Flow to WCOT capillary (auxiliary flow)	10 mL/min
Flow from split vent	100 mL/min
Detector gases	as necessary
Split ratio	11:1
Sample size	1 µL

BACKFLUSH and RESET times (10.5) and is useful for monitoring the separation of the polar TCEP precolumn.

6.1.5 *Switching and Backflushing Valve*, to be located within a temperature-controlled heated zone and capable of performing the functions in accordance with Section 10, and illustrated in Fig. 1. The valve shall be of low internal volume design and not contribute significantly to deterioration of chromatographic resolution.

6.1.5.1 A 10-port valve with 1.6 mm (0.06 in.) outside diameter fittings is recommended for this test method. Alternatively, and if using columns of 0.32 mm inside diameter or smaller, a valve with 0.8 mm (0.03 in.) outside diameter fittings should be used.

6.1.5.2 Some gas chromatographs are equipped with an auxiliary oven which can be used to contain the valve. In such a configuration, the valve can be kept at a higher temperature than the polar and nonpolar columns to prevent sample condensation and peak broadening. The columns are then located in the main oven and the temperature can be adjusted for optimum aromatic resolution.