



Designation: ~~D4737-04~~ Designation: **D4737 – 09**

## Standard Test Method for Calculated Cetane Index by Four Variable Equation<sup>1</sup>

This standard is issued under the fixed designation D4737; 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 ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

### 1. Scope\*

1.1 The calculated Cetane Index by Four Variable Equation provides a means for estimating the ASTM cetane number (Test Method D613) of distillate fuels from density and distillation recovery temperature measurements. The value computed from the equation is termed the Calculated Cetane Index by Four Variable Equation.

1.2 The Calculated Cetane Index by Four Variable Equation is not an optional method for expressing ASTM cetane number. It is a supplementary tool for estimating cetane number when a result by Test Method D613 is not available and if cetane improver is not used. As a supplementary tool, the Calculated Cetane Index by Four Variable equation must be used with due regard for its limitations.

1.3 Procedure A is to be used for Specification D975, Grades No. 1-D ~~Low Sulfur~~, S15, No. 1-D S500, No. 1-D S5000, No. 2-D S5000, and No. 4-D. This method for estimating cetane number was developed by Chevron Research Co.<sup>2</sup> Procedure A is based on a data set including a relatively small number of No. 1-D fuels. Test Method D4737 Procedure A may be less applicable to No. 1-D S15, No. 1-D ~~Low Sulfur~~ S500, and No. ~~4-D~~ grades 1-D S5000 than to No. 2-D grade S5000 or to No. 4-D fuels.

1.4 Procedure B is to be used for Specification D975, Grade No. 2-D ~~Low Sulfur~~.

1.5 ~~The test method "Calculated Cetane Index by Four Variable Equation" is particularly applicable to Grade 1-D, Grade No. 1-D Low Sulfur and Grade 2-D diesel fuel oils containing straight-run and cracked stocks, and their blends. It can also be used for heavier fuels with 90% recovery points less than 382°C and for fuels containing derivatives from oil sands and oil shale.~~

~~1.6~~

~~1.7, Grades No. 2-D S15 and No. 2-D S500.~~

1.5 The test method "Calculated Cetane Index by Four Variable Equation" is particularly applicable to Grade 1-D S5000, Grade No. 1-D S500, Grade No. 2-D S5000 and Grade No. 2-D S500 diesel fuel oils containing straight-run and cracked stocks, and their blends. It can also be used for heavier fuels with 90 % recovery points less than 382°C and for fuels containing derivatives from oil sands and oil shale.

NOTE 1—Sxx is the designation for maximum sulfur level specified for the grade. For example, S500 grades are those with a maximum sulfur limit of 500 ppm ( $\mu\text{g/g}$ ).

1.6 Biodiesel blends are excluded from this test method, because they were not part of the datasets use to develop either Procedure A or B.

1.7 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.8 *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 and health practices and determine the applicability of regulatory limitations prior to use.*

### 2. Referenced Documents

2.1 *ASTM Standards:*<sup>3</sup>

D86 Test Method for Distillation of Petroleum Products at Atmospheric Pressure

D613 Test Method for Cetane Number of Diesel Fuel Oil

D975 Specification for Diesel Fuel Oils

<sup>1</sup> This test method is under the jurisdiction of ASTM Committee D02 on Petroleum Products and Lubricants and is the direct responsibility of Subcommittee D02.E0 on ~~Burner, Diesel, Non-Aviation Gas Turbine, and Marine Fuels.~~

Current edition approved Dec. 1, 2004. Published December 2004. Originally approved in 1987. Last previous edition approved in 2003 as D4737-03. DOI: ~~10.1520/D4737-04~~ on Petroleum Products and Lubricants and is the direct responsibility of Subcommittee D02.E0.02 on Diesel Fuel Oils.

Current edition approved Oct. 1, 2009. Published November 2009. Originally approved in 1987. Last previous edition approved in 2004 as D4737-04. DOI: 10.1520/D4737-09.

<sup>2</sup> Ingham, M. C., et al., "Improved Predictive Equations for Cetane Number," SAE Paper No 860250, Society of Automotive Engineers (SAE), 400 Commonwealth Dr., Warrendale, PA 15096-0001.

<sup>3</sup> For referenced ASTM standards, visit the ASTM website, [www.astm.org](http://www.astm.org), or contact ASTM Customer Service at [service@astm.org](mailto: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.



D1298 Test Method for Density, Relative Density (Specific Gravity), or API Gravity of Crude Petroleum and Liquid Petroleum Products by Hydrometer Method

D2887 Test Method for Boiling Range Distribution of Petroleum Fractions by Gas Chromatography

D4052 ~~Test Method for Density and Relative Density of Liquids by Digital Density Meter~~ Test Method for Density and Relative Density of Liquids by Digital Density Meter

D6751 Specification for Biodiesel Fuel Blend Stock (B100) for Middle Distillate Fuels

### 3. Summary of Test Method

3.1 Two correlations in SI units have been established between the ASTM cetane number and the density and 10 %, 50 %, and 90 % distillation recovery temperatures of the fuel. Procedure A has been developed for diesel fuels meeting the requirements of Specification D975 ~~Grades 1-D Low Sulfur, Nos. 1-D, 2-D, and 4-D. The relationship is given by the following equation: Grades No. 1-D S15, No. 1-D S500, No. 1-D S5000, No. 2-D S5000, and No. 4-D. The relationship is given by the following equation:~~

$$(1) \quad CCI = 45.2 + (0.0892)(T_{10N}) + [0.131 + (0.901)(B)][T_{50N}]$$

where:

$CCI$  = Calculated Cetane Index by Four Variable Equation,

$D$  = Density at 15°C, g/mL determined by Test Methods D1298 or D4052,

$DN$  =  $D - 0.85$ ,

$B$  =  $[e^{(-3.5)(DN)}] - 1$ ,

$T_{10}$  = 10 % recovery temperature, °C, determined by Test Method D86 and corrected to standard barometric pressure,

$T_{10N}$  =  $T_{10} - 215$ ,

$T_{50}$  = 50 % recovery temperature, °C, determined by Test Method D86 and corrected to standard barometric pressure,

$T_{50N}$  =  $T_{50} - 260$ ,

$T_{90}$  = 90 % recovery temperature, °C, determined by Test Method D86 and corrected to standard barometric pressure, and

$T_{90N}$  =  $T_{90} - 310$ .

3.2 The empirical equation for Procedure A of the Calculated Cetane Index by Four Variable Equation was derived using a generalized least squares fitting technique which accounted for measurement errors in the independent variables (fuel properties) as well as in the dependent variable (cetane number by Test Method D613). The data base consisted of 1229 fuels including; commercial diesel fuels, refinery blending components and fuels derived from oil sands, shale, and coal. The analysis also accounted for bias amongst the individual sets of data comprising the database.

3.3 Procedure B has been developed for diesel fuels meeting the requirements of Specification D975 ~~Grade 2-D Low Sulfur. The relationship is given by the following equation: Grade 2-D S15 and No. 2-D S500. The relationship is given by the following equation:~~

where:

$CCI$  = Calculated Cetane Index by Four Variable Equation

$D$  = Density at 15°C, g/mL determined by Test Methods D1298 or D4052

$T_{10}$  = 10 % recovery temperature, °C, determined by Test Method D86 and corrected to standard barometric pressure

$T_{50}$  = 50 % recovery temperature, °C, determined by Test Method D86 and corrected to standard barometric pressure

$T_{90}$  = 90 % recovery temperature, °C, determined by Test Method D86 and corrected to standard barometric pressure

3.3.1 The equation for Procedure B when  $T_{10}$ ,  $T_{50}$ , and  $T_{90}$  are in °F is:

where:

$CCI$  = Calculated Cetane Index by Four Variable Equation

$D$  = Density at 15°C, g/mL determined by Test Method D1298 or D4052

$T_{10}$  = 10 % recovery temperature, °F, determined by Test Method D86 and corrected to standard barometric pressure

$T_{50}$  = 50 % recovery temperature, °F, determined by Test Method D86 and corrected to standard barometric pressure

$T_{90}$  = 90 % recovery temperature, °F, determined by Test Method D86 and corrected to standard barometric pressure

3.4 The empirical equation for Procedure B of the Calculated Cetane Index by Four Variable Equation was derived from National Exchange Group data for 87 No. 2 ~~Low Sulfur~~ 2-D S15 and No. 2-D S500 diesel fuels with sulfur level between 16 and 500 ppm using a Partial Least Squares technique. A 2-principal component model was chosen. The model was validated with a set of 980 diesel fuels with sulfur levels in the same range.

### 4. Significance and Use

4.1 The Calculated Cetane Index by Four Variable Equation is useful for estimating ASTM cetane number when a test engine is not available for determining this property directly and when cetane improver is not used. It may be conveniently employed for estimating cetane number when the quantity of sample available is too small for an engine rating. In cases where the ASTM cetane number of a fuel has been previously established, the Calculated Cetane Index by Four Variable Equation is useful as a cetane number check on subsequent batches of that fuel, provided the fuel's source and mode of manufacture remain unchanged.

4.2 Within the range from 32.5 to 56.5 cetane number, the expected error of prediction of Procedure A of the Calculated Cetane Index by Four Variable Equation will be less than  $\pm 2$  cetane numbers for 65 % of the distillate fuels evaluated. Errors may be