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(54) **Title:** PENTAMETHYLHEPTANE AS A PRIMARY REFERENCE STANDARD FOR CETANE NUMBER
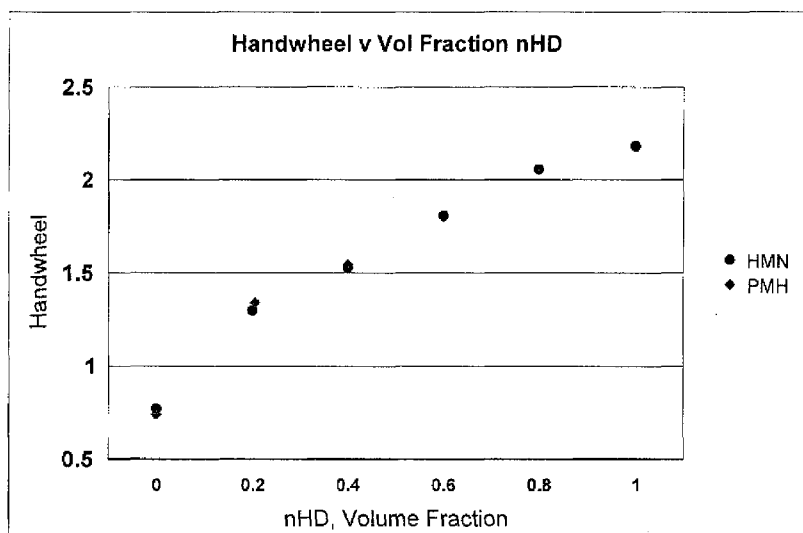

FIGURE 1

(57) **Abstract:** A composition useful as a Reference Standard for measurement of Cetane Number or for use as a standard for determining a Derived Cetane Number consists essentially of a blend of n-hexadecane and 2,2,4,6,6-pentamethylheptane. The disclosed Reference Standards can be used directly as substitutes for blends of n-hexadecane and 2,2,4,4,6,8, 8-heptamethylnonane in ASTM D613-10a for determining Cetane Number, or in ASTM D6890, ASTM D7170 or ASTM D7668 to determine a Derived Cetane Number.

PENTAMETHYLHEPTANE AS A PRIMARY REFERENCE STANDARD FOR CETANE NUMBER

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001]   Not applicable.

FIELD OF THE DISCLOSURE

[0002]   Disclosed herein is a primary reference standard for determining Cetane Number of a fuel and processes for determining Cetane Number and Derived Cetane Number using the primary reference standard.

BACKGROUND OF THE DISCLOSURE

[0003]   Cetane Number is a measure of the ignition performance of a diesel fuel compared to the ignition performance of reference fuels in a standardized engine test. Within the context of evaluating the Cetane Number of a fuel in accordance with ASTM D613-10a ("Standard Test Method for Cetane Number of Diesel Fuel Oil"), ignition performance refers to the ignition delay of the fuel as determined in a standard test engine under controlled conditions of fuel flow rate, injection timing and compression ratio. The Cetane Number is currently defined with respect to two primary reference fuels n-cetane and heptamethylnonane. N-cetane is assigned a Cetane Number of 100, and heptamethylnonane is assigned a Cetane Number of 15. Volumetrically proportioned mixtures are assigned a Cetane Number equal to the volume percent of n-cetane added to the volume percent of heptamethylnonane multiplied by 0.15.

[0004]   The Cetane Number of a test sample is determined by comparing its combustion characteristics in a test engine with those for blends of reference fuels of known Cetane Number under standard operating conditions using a bracketing hand-wheel procedure which varies the compression ratio (hand-wheel reading) for the test sample and each of two bracketing reference fuels to obtain a specific ignition delay by interpolation of Cetane Number in terms of hand-wheel reading.

[0005]   A complete description of the test apparatus, reagents, reference materials, sampling, engine and instrument settings, standard operating conditions, calibration and engine qualification, and test procedure is provided in ASTM D613-10a.

[0006]   The performance of a diesel engine is greatly impacted by the combustibility of the diesel fuel (light distillates oil) used. Similar to the octane number rating that is applied to gasoline to rate its ignition stability, Cetane Number is the rating assigned to diesel fuel to rate its combustion

quality. For gasoline octane number signifies its ability to resist auto-ignition (also referred to as pre-ignition, knocking, pinging, or detonation). For diesel Cetane Number is a measure of the fuel's delay of ignition time (the amount of time between the injection of fuel into the combustion chamber and the actual start of combustion of the fuel charge).

[0007]   Since diesels rely on compression ignition (no spark), the fuel must be able to auto-ignite—and generally, the quicker the better. A higher Cetane Number means a shorter ignition delay time and more complete combustion of the fuel charge in the combustion chamber. This, of course, translates into a smoother running, better performing engine with more power and fewer harmful emissions.

[0008]   A fuel with a low Cetane Number can cause a diesel engine to operate rough and generate higher emissions as the fuel is not burned as efficiently as it might with a higher Cetane Number fuel. Low Cetane Number fuels also make it more difficult to start the engine, while a diesel fuel with a high Cetane Number will ignite more readily, burn more completely, and deliver more power than fuels with lower numbers. In other words, Cetane Number (CN) is a measure of a fuel's ignition delay which is the time period between the start of injection and the first identifiable pressure increase due to combustion of the fuel.

[0009]   Historically, accurate measurements of the Cetane Number have been difficult. It requires burning the fuel in a rare diesel engine called a Cooperative Fuel Research (CFR) engine, under standard test conditions (ASTM D613 method). The operator of the CFR engine, which was first developed in 1932, uses a hand-wheel to increase the compression ratio (and therefore the peak pressure within the cylinder) of the engine until the time between fuel injection and ignition is 2.407ms. The resulting Cetane Number is then calculated by determining which mixture of known Cetane Number Primary Standard fuel will result in the same ignition delay.

[0010]   Two Primary Reference Fuels (hydrocarbons) define the Cetane Number scale and all diesel fuel and diesel fuel components are indexed to the Primary Reference Fuels. Initially, n-hexadecane (also called n-cetane or n-$C_{16}H_{34}$), which has very good ignition quality, was assigned the Cetane Number of 100, and 1-methylnaphthalene, which has a poor ignition quality, was assigned a Cetane Number of zero.

[0011]   The industry had problems in producing *1-methylnaphthalene* with consistent high quality and in 1962, this low Cetane Number Reference Fuel standard was replaced with 2,2,4,4,6,8,8-*heptamethylnonane* (also called isocetane or HMN). This chemical had better oxidation stability and was easier to use in the CFR engine. When measured against the original *1-methylnaphthalene* and n-cetane standards, 2,2,4,4,6,8,8-heptamethylnonane was assigned a Cetane Number of 15.

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[0012]   Thus, when a fuel has the same ignition delay period as a mixture of the two Primary Reference Fuels (n-cetane + HMN), its Cetane Numer is derived from the volume percent of Cetane and HMN, as follows:

Cetane Number = % n-cetane + 0.15 (% HMN) = 15 + 0.85 (% n-cetane)

[0013]   It has been difficult to produce pure HMN in large quantities, of the right purity, at reasonable cost. Therefore, in routine operations, the two Primary Reference Fuels (n-cetane and HMN) are replaced by two Secondary Reference Fuels: T-fuel and U-fuel. Large batches of Secondary Reference Fuel pairs are calibrated against the Primary Reference Fuels and made available to testing labs. The fuel supplier provides blend ratio instructions to achieve Cetane Numbers bounded by the values for the U and T fuels.

[0014]   Each set consists of a "T Fuel" having a relatively high Cetane Number (typically 72-76) and a "U Fuel" which has a relatively low Cetane Number (typically 18-20). The Cetane Numbers assigned to each batch are based on a testing program conducted by the Diesel NEG in which blends of the T and U Fuels are engine tested against the ASTM D613-10a Primary Reference Fuels (PRF) n-cetane and 2,2,4,4,6,8,8-heptamethylnonane (HMN).

[0015]   Seven Secondary Reference Fuels (T and U fuel) are engine tested (ASTM D613) by various labs as follows:

Blend No.	% T	% U
1	20	80
2	40	60
3	50	50
4	60	40
5	70	30
6	80	20
7	100	0

[0016]   Each blend of T and U fuels is tested by bracketing the blend against the known Cetane Number blend of Primary Reference Fuels n-cetane and HMN. A regression equation for Cetane Number as a function of %T Fuel is then developed. Typical correlations for the pairs of T and U Secondary Reference Fuel batches developed by the industry over the years are listed below:

T-24 / U-17 (2007)	Cetane Number = 0.554513 (% T) + 19.50861
T-23 / U-16 (2002)	Cetane Number = 0.568440 (% T) + 19.25631
T-22 / U-15 (1997)	Cetane Number = 0.560351 (% T) + 18.72438
T-21 / U-14 (1994)	Cetane Number = 0.554019 (% T) + 18.27033
T-20 / U-13 (1990)	Cetane Number = 0.527952 (% T) + 19.92739

[0017]   These equations were then used to generate the tables of accepted reference value Cetane Numbers for various blends of T and U fuel pairs as shown, typically, in Table A.

Table A
CETANE NUMBER for BLENDS OF T-24 AND U-17

% T-24	CN	% T-24	CN	% T-24	CN
0	19.5	34	38.4	68	57.2
1	20.1	35	38.9	69	57.8
2	20.6	36	39.5	70	58.3
3	21.2	37	40.0	71	58.9
4	21.7	38	40.6	72	59.4
5	22.3	39	41.1	73	60.0
6	22.8	40	41.7	74	60.5
7	23.4	41	42.2	75	61.1
8	23.9	42	42.8	76	61.7
9	24.5	43	43.4	77	62.2
10	25.1	44	43.9	78	62.8
11	25.6	45	44.5	79	63.3
12	26.2	46	45.0	80	63.9
13	26.7	47	45.6	81	64.4
14	27.3	48	46.1	82	65.0
15	27.8	49	46.7	83	65.5
16	28.4	50	47.2	84	66.1
17	28.9	51	47.8	85	66.6
18	29.5	52	48.3	86	67.2
19	30.0	53	48.9	87	67.8
20	30.6	54	49.5	88	68.3
21	31.2	55	50.0	89	68.9
22	31.7	56	50.6	90	69.4
23	32.3	57	51.1	91	70.0
24	32.8	58	51.7	92	70.5
25	33.4	59	52.2	93	71.1
26	33.9	60	52.8	94	71.6
27	34.5	61	53.3	95	72.2
28	35.0	62	53.9	96	72.7
29	35.6	63	54.4	97	73.3
30	36.1	64	55.0	98	73.9
31	36.7	65	55.6	99	74.4
32	37.3	66	56.1	100	75.0
33	37.8	67	56.7		

[0018]   The diesel fuel industry today continues to be burdened by the complex program of producing and validating T and U Secondary Fuel pair batches every one or two years for use in measurement of Cetane Numbers of diesel fuels and diesel components using the CFR engines and ASTM test method D613-10a.

[0019]   As mentioned earlier, the low Cetane Number Primary Reference Standard, HMN of the 98% minimum purity level required is not currently available in large quantities. Also, the very small laboratory quantities that are available are cost prohibitive. The diesel fuels industry has therefore resorted to using Secondary Reference T and U Fuels. Ideally, the industry requires a substitute for HMN that can be produced in large quantities at reasonable cost so that the HMN

substitute can be used not only to standardize the T and U Secondary Fuel blends, but the CFR engines of the ASTM D613 could be standardized to utilize blends of Primary Reference Fuels, n-cetane and a HMN replacement.

[0020]   In addition to the CFR engine test as specified in ASTM D613, there are other alternatives to describe ignition quality. These tests include Cetane Index, which is calculated from other fuel properties such as density and volatility, and Derived Cetane Number (DCN) calculated from the ignition delay time measured using a constant volume combustion chamber method. Cetane Index is based on the fact that ignition quality is linked to hydrocarbon composition: n-paraffins have high ignition quality, and aromatic and naphthenic compounds have low ignition quality. Cetane Index being a calculated value, only provides an approximate indication of actual ignition quality.

[0021]   The DCN is determined by measuring ignition delay in a constant chamber method. One method that has emerged is a combustion-based analytical method that was originally developed at Southwest Research Institute (ASTM D6890). It is referred to as the Constant Volume Combustion Apparatus (CVCA). A commercial apparatus utilizing this technique, introduced by Advanced Engine Technologies, is known as the Ignition Quality Tester (IQT). In this test, a small specimen of diesel fuel is injected into the heated, temperature controlled constant volume chamber which has previously been charged with compressed air. Ignition delay is measured using sensors that detect the start of fuel injection and the start of combustion for each cycle. Calibration of the apparatus is carried out with two reference materials: n-heptane and methylcyclohexane. The heptane is assigned an average ignition delay of 3.78 ± 0.01 ms while the methylcyclohexane is assigned an ignition delay of 10.4 ± 0.6 ms. The DCN is calculated using an equation that correlates a combustion ignition delay result to actual Cetane Number measured in the engine (ASTM D613).

[0022]   Another test based on Ignition Delay to determine the DCN is ASTM D7170. The instrument to perform the DCN test here is offered by Waukesha and is known as the Fuel Ignition Tester (FIT). FIT also uses n-heptane and methylcyclohexane for calibration.

[0023]   Yet another method for DCN is the Cetane ID (CID) 510 by PAC. This method is outlined in ASTM D7668 and uses the Ignition Delay measurement in a CVCA and correlates it to Cetane Number measured in an engine (ASTM D613).

[0024]   An objective of certain aspects of this disclosure involves replacing mixtures of n-cetane and HMN as Primary Reference Fuels for calibration of the CFR engines (ASTM D613) and the calibration of the IQT (ASTM D6890), FIT (ASTM D7170) and CID (ASTM D7668) with mixtures of n-cetane and a lower cost, more easily available compound than HMN, but which has a

Cetane Number that is nearly the same as that of HMN, and which produces blends having performance characteristics similar or substantially the same as HMN/n-cetane blends.

SUMMARY OF THE DISCLOSURE

[0025]   Since HMN of required purity is not available in large quantities and is expensive, the industry is in need of another chemical that can be easily produced and can be a direct replacement for HMN. Disclosed herein is a chemical substance whose combustion properties under compression ignition were similar to HMN.

[0026]   It has been found that, surprisingly, 2,2,4,6,6-pentamethylheptane (PMH) behaves very similar to HMN in a CFR engine as described in ASTM D613. Accordingly, this disclosure is directed to use of PMH and/or other isoparaffins having 12 carbon atoms as low-cost Primary Reference standard for determining Cetane Number and/or Derived Cetane Number, such as in any of the processes previously discussed which use HMN as a Primary Reference standard.

BRIEF DESCRIPTION OF THE DRAWINGS

[0027]   Figure 1 is a graph comparing hand-wheel readings, an arbitrary numerical value related to compression ratio, obtained from a micrometer scale that indicates a position of a variable compression plug in a precombustion chamber of a test engine, for various blends of n-cetane and HMN to hand-wheel readings of blends of n-cetane and PMH using the same test equipment and conditions.

[0028]   Figure 2 is a graph of Cetane Number versus hand-wheel readings for blends of n-cetane and 2,2,4,4,6,8,8-heptamethylnonane (HMN) for the test engine and apparatus used throughout this disclosure.

DETAILED DESCRIPTION

[0029]   The compositions disclosed herein consist essentially of a blend of n-hexadecane and an isoparaffin having 12 carbon atoms or a mixture of isoparaffins having 12 carbon atoms. This means that the compositions do not include any materials, whether deliberately added or inadvertent impurities, that would substantially adversely affect the ability to use the compositions as standards for determining Cetane Number. Both the n-hexadecane and isoparaffin(s) having 12 carbon atoms should have a purity level that does not adversely affect their utility as a standard for evaluating Cetane Number. As indicated in ASTM D613-10a, the n-cetane (n-hexadecane) should have a minimum purity of 99% as determined by chromatographic analysis. In the case of the isoparaffin(s)

having 12 carbon atoms, testing quality comparable to the established ASTM D613-10a standard

using heptamethylnonane (2,2,4,4,6,8,8-heptamethylnonane) at a minimum purity of 98% as

determined by chromatographic analysis can be achieved with a modified procedure substituting

isoparaffin(s) having 12 carbon atoms for the heptamethylnonane used in ASTM D613-10a, wherein

the purity of the isoparaffin(s) is a minimum of 98% or 99% by weight as determined by

chromatographic analysis. It has been found that a process of oligomerizing isobutylene to produce

triisobutylene, distilling the product to separate the C-12 components, and subsequently

hydrogenating the purified triisobutylene, can be used to obtain 2,2,4,6,6-pentamethylheptane at

purity levels in excess of 98% or 99% by weight. In these processes, impurities are limited to very

small amounts of intermediates and by-products and small traces of other impurities such as water

and sulfur (in the parts per million range) that do not adversely affect the ability to use the

isoparaffins having 12 carbon atoms as a primary standard in a modified ASTM D613-10a test

procedure for determining Cetane Number.

[0030]   Test procedures, equipment, conditions, etc. in accordance with ASTM D613-10a

were used to compare the combustion characteristics of various blends of n-cetane (nHD) and HMN

to blends of n-cetane and PMH. In these tests, an operator of a CFR engine uses a hand-wheel to

increase the compression ratio (and therefore the peak pressure within the cylinder) of the engine

until the time between fuel injection and ignition is 2.407ms. The resulting Cetane Number is then

calculated by determining which mixture of nHD and HMN will result in the same ignition delay.

The compositions of the blends are shown in Table 1. The results from the performance of various

mixtures of nHD-HMN and nHD-PMH are shown in Table 2.

Table 1

Blend	HMN	Volume Fraction PMH	nHD	calc. CN
1			1	100.0
2	0.2		0.8	83.0
3		0.2	0.8	
4		0.4	0.6	
5	0.4		0.6	66.0
6	0.6		0.4	49.0
7		0.6	0.4	
8		0.8	0.2	
9	0.8		0.2	32.0
10	1			15.0
11		1		

	HMN	PMH	nHD	1-Methylnaphthalene
Density (measured at 15.56°C)	0.7874	0.7484	0.7779	1.001
Molecular Wt.	226.44	170.33	226.44	142.2
Boiling Point (°C)	240	180	287	242
Blend size, mL	750			

Table 2

Comparison of PMH to HMN in Blends with nHD Hand-Wheel and Micrometer Readings for Program Samples

	Blend 1	T-25	Blend 1	T-25	Blend 1	T-25	Averages
Blend 1 Handwheel	2.153		2.194		2.194		2.180333
T-25 Handwheel		1.934		1.96		1.96	1.951333
Blend 1 Inj Adv Mic Setting	831		850		850		843.667
T-25 Inj Adv Mic Setting		853		855		855	854.333
Fuel Mic Setting	680	670					

	Blend 2	Blend 3	Blend 2	Blend 3	Blend 2	Blend 3	Averages
Blend 2 Handwheel	2.024		2.073		2.073		2.057
Blend 3 Handwheel		2.032		2.068		2.068	2.056
Blend 2 Inj Adv Mic Setting	855		850		850		851.667
Blend 3 Inj Adv Mic Setting		844		840		840	841.333
Fuel Mic Setting	675	675					

	Blend 4	Blend 5	Blend 4	Blend 5	Blend 4	Blend 5	Averages
Blend 4 Handwheel	1.815		1.8		1.792		1.802
Blend 5 Handwheel		1.808		1.808		1.808	1.808
Blend 4 Inj Adv Mic Setting	852		846		846		848.000
Blend 5 Inj Adv Mic Setting		872		865		865	867.333
Fuel Mic Setting	670	670					

	Blend 6	Blend 7	Blend 6	Blend 7	Blend 6	Blend 7	Averages
Blend 6 Handwheel	1.519		1.534		1.527		1.527
Blend 7 Handwheel		1.548		1.537		1.55	1.545
Blend 6 Inj Adv Mic Setting	859		854		861		858.000
Blend 7 Inj Adv Mic Setting		852		833		838	841.000
Fuel Mic Setting	670	665					

	Blend 8	Blend 9	Blend 8	Blend 9	Blend 8	Blend 9	Averages
Blend 8 Handwheel	1.339		1.342		1.342		1.341
Blend 9 Handwheel		1.305		1.295		1.29	1.297
Blend 8 Inj Adv Mic Setting	859		859		859		859.000
Blend 9 Inj Adv Mic Setting		846		846		836	842.667
Fuel Mic Setting	665	675					

	Blend 10	Blend 11	Blend 10	Blend 11	Blend 10	Blend 11	Averages
Blend 10 Handwheel	0.767		0.782		0.7655		0.772
Blend 11 Handwheel		0.741		0.743		0.738	0.741
Blend 10 Inj Adv Mic Setting	680		644		643		655.667
Blend 11 Inj Adv Mic Setting		698		712		662	690.667
Fuel Mic Setting	670	670					

[0031]   As indicated in Figure 1, the combustion characteristics of PMH and HMN are essentially the same. Surprisingly, it was found that the performance of the HMN, a C-16 iso-paraffin and PMH, a C-12 iso-paraffin, are almost identical. Thus, Cetane Number can be accurately determined using a modified version of the ASTM-D613-10a standard in which PMH is used as a direct substitute for HMN.

[0032]   A graph correlating handwheel measurement to Cetane Number in accordance with the procedures of ASTM D613-10a for the engine used for generating the data in Table 2 is shown in Figure 2. A least squares method shows that the data can be accurately represented by the curve shown in Figure 2, which is a graphical representation of the equation CN=3.44 + 5.39 (HW) + 9.04 $(HW)^2$ + 3.85 $(HW)^3$, wherein CN is Cetane Number and HW is the Handwheel measurement.

Table 3

from Origin: $CN = 3.44165 + 5.38817 \cdot HW + 9.04211 \cdot HW^2 + 3.84683 \cdot HW^3$

n-cetane	HMN	PMH	HW	Assigned Cetane Number	Experimentally Determined Cetane Number for HMN/n-cetane Blends	Experimentally Determined Cetane Number for PMH/n-cetane Blends
100%	0	0	2.180	100.0	98.0	98.0
80%	20%	—	2.057	83.0	86.3	
80%	—	20%	2.056			86.2
60%	40%	—	1.802			65.0
60%	—	40%	1.808	66.0	65.5	
40%	60%	—	1.527	49.0	46.4	
40%	—	60%	1.545			47.5
20%	80%	—	1.341			36.2
20%	—	80%	1.297	32.0	34.0	
0%	100%	—	0.772	15.0	14.8	
0%	—	100%	0.741			14.0

[0033]   Table 3 shows the assigned or theoretical Cetane Number associated with the measured handwheel readings for the various blends in Table 1 compared with the experimentally determined Cetane Number based on correlating measured handwheel readings to Cetane Number using the equation developed from the data in Figure 2. The data indicate, among other things, that the experimentally determined Cetane Number for PMH is about 14.0. By repeating the experiments with different engines at different laboratory facilities, it will be possible to develop agreement in the industry as to the appropriate Cetane Number or Accepted Reference Value (ARV) to assign to PMH. This would allow PMH to be used as a primary standard in the various accepted standards for

determining Cetane Number or a Derived Cetane Number replacing the expensive HMN primary standard with inexpensive PMH and replacing the assigned Cetane Number for HMN (i.e., 15) with an Accepted Reference Value for the Cetane Number of PMH.

[0034]   This means that PMH can directly replace HMN as a Primary Standard for the measurement of Cetane Number (CN), Derived Cetane Number (DCN) and ignition delay of diesel fuels and diesel fuel blending components. Since PMH can be produced in large quantities and at reasonable cost compared to HMN, PMH can eliminate the need to use the Secondary T and U fuels currently used for standardizing diesel fuel combustion characteristics. The process of producing Secondary T and U fuels is complicated and involves the use of difficult to procure HMN to calibrate the T and U fuels.

[0035]   The advantage of using PMH instead of HMN is that PMH can be used directly as a Primary Standard for the measurement of Cetane Number (CN), Derived Cetane Number (DCN) and ignition delay of diesel fuels and diesel fuel blending components. There will be no need to produce Secondary Reference T and U fuel pairs.

[0036]   The disclosed reference standards can be used directly as substitutes for blends of n-hexadecane and 2,2,4,4,6,8,8-heptamethylnonane in ASTM D613-10a for determining Cetane Number, or in ASTM D6890, ASTM D7170 or ASTM D7668 to determine a Derived Cetane Number.

WHAT IS CLAIMED IS:

1.   A composition useful as a reference standard for measurement of a Cetane Number of a fuel, consisting essentially of a blend of (1) n-hexadecane and (2) an isoparaffin having 12 carbon atoms or a combination of isoparaffins having 12 carbon atoms.

2.   The composition of Claim 1, wherein the isoparaffin having 12 carbon atoms or a combination of isoparaffins has a purity level of at least 98% by weight as determined by chromatographic analysis.

3.   The composition of Claim 1, wherein the isoparaffin having 12 carbon atoms or a combination of isoparaffins has a purity level of at least 99% by weight as determined by chromatographic analysis.

4.   The composition of Claim 1, wherein the isoparaffin having 12 carbon atoms or a combination of isoparaffins comprises at least 98% by weight 2,2,4,6,6-pentamethylheptane.

5.   The composition of Claim 1, wherein the isoparaffin having 12 carbon atoms or a combination of isoparaffins comprises at least 99% by weight 2,2,4,6,6-pentamethylheptane.

6.   A process for determining the Cetane Number of a test sample, comprising:
       comparing the combustion characteristics of the test sample in a test engine with the combustion characteristics of a reference fuel consisting essentially of (1) a blend of n-hexadecane and (2) an isoparaffin having 12 carbon atoms or a combination of isoparaffins having 12 carbon atoms.

7.   The process of Claim 6, wherein the isoparaffin having 12 carbon atoms or a combination of isoparaffins has a purity level of at least 98% by weight as determined by chromatographic analysis.

8.   The process of Claim 6, wherein the isoparaffin having 12 carbon atoms or a combination of isoparaffins has a purity level of at least 99% by weight as determined by chromatographic analysis.

9.   The process of Claim 6, wherein the isoparaffin having 12 carbon atoms or a combination of isoparaffins comprises at least 98% by weight 2,2,4,6,6-pentamethylheptane.

10. The process of Claim 6, wherein the isoparaffin having 12 carbon atoms or a combination of isoparaffins comprises at least 99% by weight 2,2,4,6,6-pentamethylheptane.

11. The process of Claim 6 in which the Cetane Number is determined using a modified version of ASTM D613-10a test standard in which 2,2,4,6,6-pentamethylheptane is used as a substitute for 2,2,4,4,6,8,8-heptamethylnonane.

12. A process for determining a derived Cetane Number in accordance with ASTM D6890, ASTM D7170 or ASTM D7668 using a measurement characteristic of Ignition Delay and an equation correlating the measured characteristic of Ignition Delay to the measured Ignition Delay of a Reference Standard consisting essentially of (1) a blend of n-hexadecane and (2) an isoparaffin having 12 carbon atoms or a combination of isoparaffins having 12 carbon atoms.

13. The process of Claim 12, wherein the isoparaffin having 12 carbon atoms or a combination of isoparaffins has a purity level of at least 98% by weight as determined by chromatographic analysis.

14. The process of Claim 12, wherein the isoparaffin having 12 carbon atoms or a combination of isoparaffins has a purity level of at least 99% by weight as determined by chromatographic analysis.

15. The process of Claim 12, wherein the isoparaffin having 12 carbon atoms or a combination of isoparaffins comprises at least 98% by weight 2,2,4,6,6-pentamethylheptane.

16. The process of Claim 12, wherein the isoparaffin having 12 carbon atoms or a combination of isoparaffins comprises at least 99% by weight 2,2,4,6,6-pentamethylheptane.
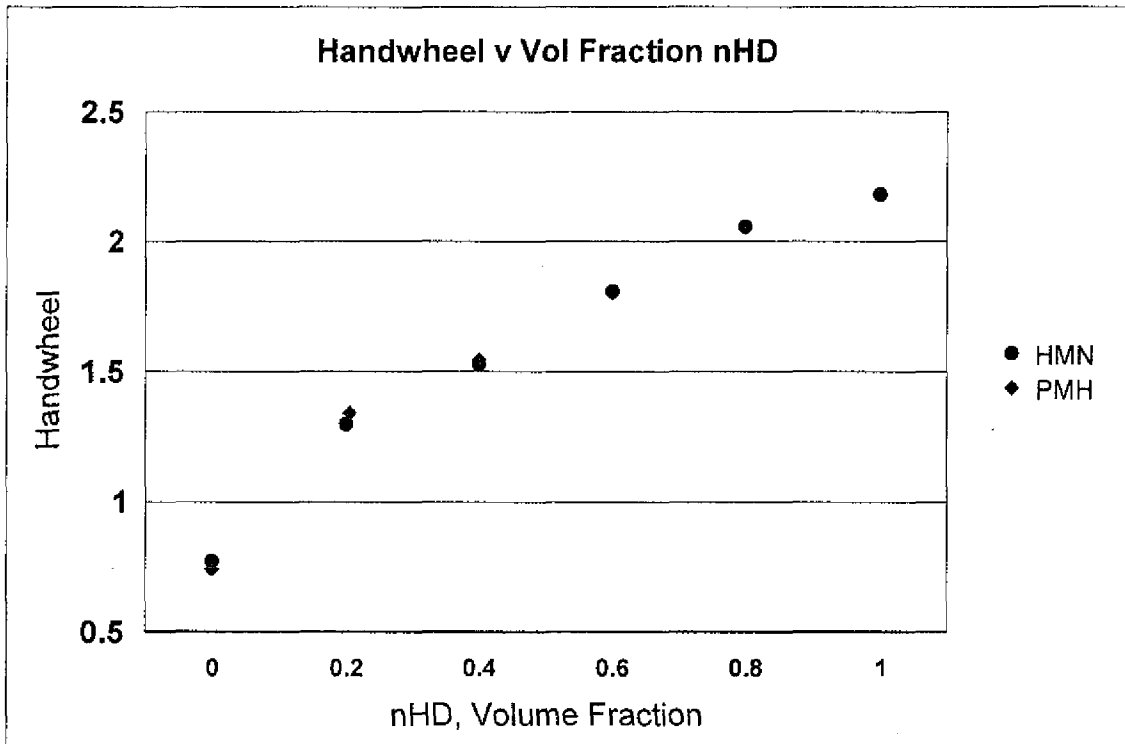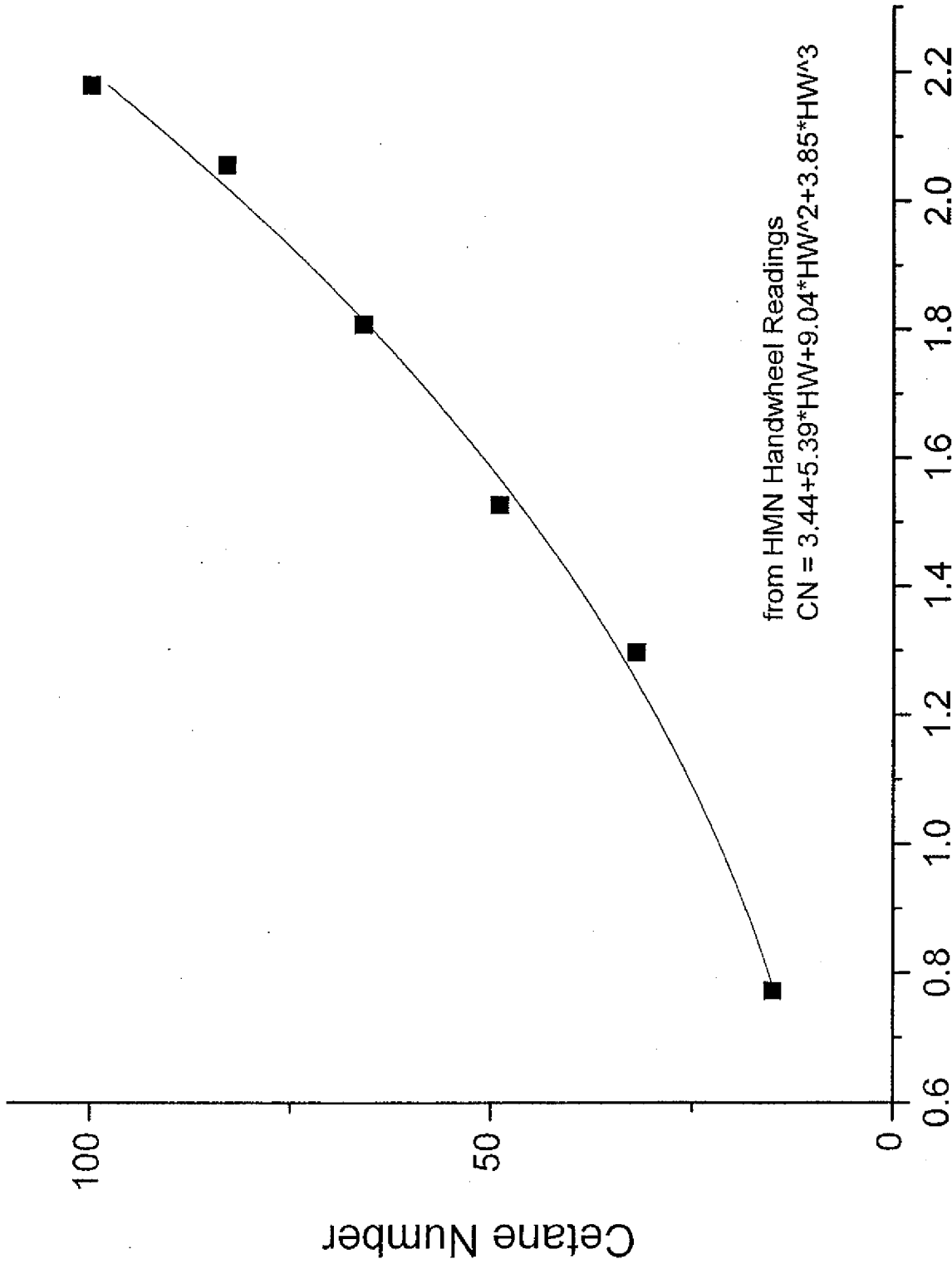
FIGURE 1

from HMN Handwheel Readings
CN = 3.44+5.39*HW+9.04*HW^2+3.85*HW^3

HANDWHEEL READINGS FOR HMN/N-CETANE BLENDS
FIGURE 2

A.   CLASSIFICATION OF SUBJECT MATTER

C10L 1/16(2006.01)i, C10L 10/18(2006.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B.   FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
  C10L 1/16; F02D 41/34; F02D 45/00; C10L 1/22; G01N 33/22; C10L 1/04; C10L 10/18

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
  Korean utility models and applications for utility models
  Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
  eKOMPASS(KIPO internal) & keywords: cetane number, reference standard, diesel fuel, n-hexadecane, isoparaffin, 2,2,4,6,6-pentamethylheptane, ignition delay

C.   DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2011-0192216 A1 (HUBER, K. et al.) 11 August 2011 See abstract; paragraphs [0003]-[0009]; claims 1, 3-7, 12.	1-16
A	Carr, M. A. et al. An Experimental and Modeling-Based Study Into the Ignition Delay Characteristics of Diesel Surrogate Binary Blend Fuels. Journal of engineering for gas turbines and power. July 2012, Vol. 134, Issue 7, pp. 072803-1-070803-10 See the whole document, especially pages 072803-3-032803-4.	1-16
A	Carr, M. A. et al. Understanding Ignition Delay Effects With Pure Component Fuels in a Single-Cylinder Diesel Engine. Journal of engineering for gas turbines and power. March 2011, Vol. 133, Issue 3, pp. 032803-1-032803-11 See the whole document, especially pages 032803-3-032803-4; table 3; figure 2.	1-16
A	US 5389111 A (NIKANJAM, M. et al.) 14 February 1995 See abstract; column 2, lines 1-42; column 2, lines 52-61.	1-16
A	JP 7-50101 B2 (COSMO SOGO KENKYUSHO K.K. et al.) 31 May 1995 See abstract; claims 1-3; column 3, line 18-column 4, line 35.	1-16

☒ Further documents are listed in the continuation of Box C.   ☒   See patent family annex.

*	Special categories of cited documents:	"T"	later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"A"	document defining the general state of the art which is not considered to be of particular relevance		
"E"	earlier application or patent but published on or after the international filing date	"X"	document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"L"	document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"Y"	document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents,such combination being obvious to a person skilled in the art
"O"	document referring to an oral disclosure, use, exhibition or other means		
"P"	document published prior to the international filing date but later than the priority date claimed	"&"	document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
03 July 2014 (03.07.2014)	**04 July 2014 (04.07.2014)**

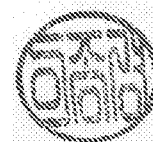| Name and mailing address of the ISA/KR	Authorized officer
International Application Division Korean Intellectual Property Office 189 Cheongsa-ro, Seo-gu, Daejeon Metropolitan City, 302-701, Republic of Korea Facsimile No. +82-42-472-7140	LEE, Jong Kyung Telephone No. +82-42-481-3360

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C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2011-0208408 A1 (HASKARA, I. et al.) 25 August 2011 See abstract; paragraphs [0017], [0022]-[0025]; claims 1, 7.	1-16

Form PCT/ISA/210 (continuation of second sheet) (July 2009)

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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US 5389111 A	14/02/1995	US 5389112 A	14/02/1995
JP 7-50101 B2	31/05/1995	None	
US 2011-0208408 A1	25/08/2011	CN 102162405 A DE 102011011371 A1 US 8532911 B2	24/08/2011 22/03/2012 10/09/2013

Form PCT/ISA/210 (patent family annex) (July 2009)