



# Fuel Quality Monitoring Programme

**Test Results 2015–16**

TRADING STANDARDS



**Ministry of Business,  
Innovation & Employment**

New Zealand Government

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## Fuel Quality Monitoring Programme TEST RESULTS 2015–16

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## Executive Summary

The Fuel Quality Monitoring Programme (**the Programme**) is administered by the Trading Standards unit of the Ministry of Business, Innovation and Employment. Trading Standards maintains a comprehensive programme of sampling and assessing the quality of retail fuel in New Zealand and monitoring its compliance with the specifications set out in the relevant Engine Fuel Specifications Regulations (**the Regulations**). Currently, the Regulations of 2011 are in force<sup>1</sup>.

The main focus of the Programme is to monitor the quality of the fuel sold by retail fuel companies nationwide. It employs a statistically-based sampling scheme to ensure an acceptable probability of detecting any non-compliance is maintained. The Regulations specify limits on a number of properties for premium and regular petrol grades, diesel and biofuels such as biodiesel and ethanol.

A key element of the Programme is to sample and test the quality of fuels as they are sold to consumers, *i.e.* sampling is done from dispenser nozzles at the retail point of sale.

The sampling and testing programme is undertaken independent of the Fuel Industry and being focussed on retail sales, it compliments the extensive sampling and testing that the Fuel Industry itself carries out at various stages during the manufacture and supply processes. This provides confidence to consumers and all stakeholders around the quality and composition of petrol, diesel and biofuels.

This report is intended to give an overview of the results of the Programme from 1 July 2015

to 30 June 2016. During this period retail fuel samples were collected and tested from 115 of the approximately 1,200 fuel service stations in New Zealand.

Analysis of sampling and testing conducted during the period of this report has confirmed that on the whole, fuel sold in New Zealand was of good quality and compliant with specifications prescribed in the Regulations. In some instances samples were initially found to be marginally outside specifications but on subsequent investigation and analysis of the results they were found to be within established tolerance limits. These instances relate to ethanol content in premium petrol and sulphur content, as well as lubricity, flash point and cold filter plugging point in diesel.

In particular, one suspect non-compliant sample detected during the period of this report related to diesel where the cold filter plugging point on investigation was found to be  $-4.7^{\circ}\text{C}$  relative to the maximum specified limit of  $-6^{\circ}\text{C}$ . Since the result was below the testing tolerance limit of  $-4^{\circ}\text{C}$  the sample was deemed to be compliant.

Some biodiesel samples intended for non-retail sale were initially found to be non-compliant before supply to customers. None of the potentially non-compliant fuels identified by sampling and testing biofuels entered the retail fuel supply chain and they were subject to remedial action by the producers. The suspect non-compliant properties are discussed in a biofuel section.

For further explanation or to comment on the reported results please contact the Ministry:  
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<sup>1</sup> <http://www.legislation.govt.nz/regulation/public/2011/0352/latest/DLM4044701.html>





## Introduction

Trading Standards is an operational unit within the Market Services Group of the Ministry of Business, Innovation and Employment (MBIE). MBIE has national responsibility for a number of infrastructure areas that are fundamental to consumer safety, supporting consumer and business confidence and facilitating domestic and international trade. These areas are:

- **Legal Metrology (Trade Measurement)**
- **Consumer Product Safety**
- **Auctioneers Register**
- **Motor Vehicle Traders Register** and
- **Fuel Quality Monitoring (FQM)** – maintaining and administering a programme to monitor and ensure the quality and compliance of New Zealand’s retail fuel supply with the Engine Fuel Specifications Regulations.

In the fuel quality monitoring area activities include:

- Sampling, testing and analysing fuel quality including: routine samples taken in accordance with a statistical sampling plan and samples taken as part of targeted projects or in response to complaints or emerging issues;
- Investigating consumer and trader complaints and responding to enquiries;
- Advising on and facilitating improvement of fuel industry ‘best practice’;

- Developing and conducting projects in response to emerging issues;
- Contributing to work on regular amendments and updates to the Engine Fuel Specifications Regulations;
- Maintaining strong and effective relationships (as regulator) with fuel company technical managers, fuel retailers, industry associations and stakeholders within NZ and internationally;
- Representing New Zealand on international standards committees relating to fuel quality.

These activities and the Programme are funded from a proportion of the *Petroleum or engine fuel monitoring levy* of 0.2 cents for each litre of petroleum or engine fuel that is supplied in accordance with the Energy (Petroleum or Engine Fuel Monitoring Levy) Regulations 2015<sup>2</sup>.

The main focus of the Programme is to sample and test the quality of fuels as they are sold to consumers, *i.e.* sampling is done from dispenser nozzles at the point of sale. Trading Standards employs a statistically-based sampling scheme to ensure an acceptable probability of detecting non-compliance is upheld. The Regulations specify limits for a number of critical properties of premium and regular petrol grades, diesel and biofuels such as biodiesel and ethanol blends.

<sup>2</sup> <http://www.legislation.govt.nz/regulation/public/2015/0304/latest/whole.html>



This report sets out the results of the Programme from 1 July 2015 to 30 June 2016.

The key principles and structure of the Programme remain the same as in previous years. References to legislation related to engine fuel quality may be found on the Ministry web site<sup>3</sup> or in previous FQM Programme annual reports for the period from 2008 to 2015.

Collection of fuel samples during this period was carried out under the direction of Trading Standards. The samples were then tested by Independent Petroleum Laboratory Ltd and the results subsequently analysed by Trading Standards.

Any non-compliance or abnormalities identified through testing were subject to analysis and follow-up investigation by Trading Standards. The focus of any investigation is to confirm the validity of the results, identify any potential issues and implement an appropriate and timely response if required. Attention is also given to ensuring the underlying cause of any non-compliance is understood and remedied to prevent recurrence.

The samples were collected from 11 designated regional areas nationwide (see following Table) serviced by specific fuel supply terminals. The samples were taken from various fuel service stations according to a plan based on a statistical model which takes into account each retail fuel company's market share in that area.

In total, 115 sample sets were collected from retail sites and each set, except four, included samples of regular and premium grade petrol and a sample of diesel. The number of samples collected and tested this year was similar to the previous years.

Additional resources were also allocated to small projects focused on investigating specific issues. In particular, a project focused on dry vapour pressure in petrol was continued in response to detection of several non-compliant samples during previous years.

A limited number of additional tests were added to the routine list of tests conducted. This included a test on appearance for diesel which is not specified in the Regulations but was completed in the routine list of diesel properties tested to enhance the confidence that water in bulk and/or other contamination, if present, were detected and categorised.

Four retail sites in New Zealand offer ethanol blended petrol with an ethanol content from 70 to 85% labelled as E85. This fuel is mainly used for motor vehicle racing. While fuel for motor racing is exempt from the Regulations there are flexible fuel vehicles available in New Zealand which are able to use E85. Since E85 dispensers at these sites are accessible to the public, and therefore the product available to retail customers, it was deemed prudent to test its properties.

As a result of collaborative work with the industry, the rate of suspect non-compliances has further decreased this year compared to the previous one.

Statistical analysis of the Programme data from previous years with regard to estimating the proportion of non-compliance detected has allowed Trading Standards to estimate the proportion of potentially suspect non-compliant samples that would be found if all batches of fuel in the retail sector were tested.

The key assumption in this analysis was that the true proportion of suspect non-compliances can be taken as constant across terminals and brands. Taking this assumption

<sup>3</sup> <http://www.mbie.govt.nz/tradingstandards>



into account it was concluded that no significant increase in the total number of routine samples is needed compared to that in the previous three to four years to retain an appropriate level of confidence.

The seasonal and regional distribution of fuel ‘sample sets’ is shown in the table below.

The results of subsequent testing of these ‘sample sets’, have been reported in accordance to their relevant specification limits set out in the Regulations. Testing tolerance limits were derived according to the ISO Standard 4259:2006<sup>4</sup> as described in previous annual test result reports. Accordingly, the tolerance limit for each property is derived through the calculated tolerance margin. Further, the ‘corrected tolerance limit’ in this report is defined for two test results under the repeatability conditions (Section 7.2.3, EN ISO 4259:2006).

## Conclusion

The Programme has confirmed that throughout the year the retail fuel supplied in New Zealand was of good quality, fit for purpose and compliant with the performance and quality specifications prescribed in the Regulations.

In this report, the anonymity of the source of the samples is maintained due to the commercial sensitivity of this information.

Terminal/Month	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Total
Whangarei	1	2	0	0	0	0	2	2	0	1	0	0	8
Auckland	2	4	3	2	2	2	1	1	4	5	2	3	31
Mt Maunganui	0	1	2	0	1	2	3	0	3	2	3	1	18
New Plymouth	0	0	0	0	1	1	0	0	1	0	0	0	3
Napier	1	0	0	1	0	0	0	1	0	0	0	2	5
Wellington	1	0	2	2	1	2	1	1	1	0	0	0	11
Nelson	0	0	0	0	1	1	0	0	0	3	2	1	8
Lyttelton	0	2	0	2	0	0	0	2	3	0	2	2	13
Timaru	0	0	0	0	0	1	1	0	0	0	2	1	5
Dunedin	0	0	1	1	1	0	0	2	0	1	0	3	9
Bluff	1	1	0	0	1	0	0	0	0	0	1	0	4
<b>Total</b>	<b>6</b>	<b>10</b>	<b>8</b>	<b>8</b>	<b>8</b>	<b>9</b>	<b>8</b>	<b>9</b>	<b>12</b>	<b>12</b>	<b>12</b>	<b>13</b>	<b>115</b>

<sup>4</sup> BS EN ISO 4259:2006, BS 2000-367:2006 *Petroleum products – Determination and application of precision data in relation to methods of test.*





# Petrol

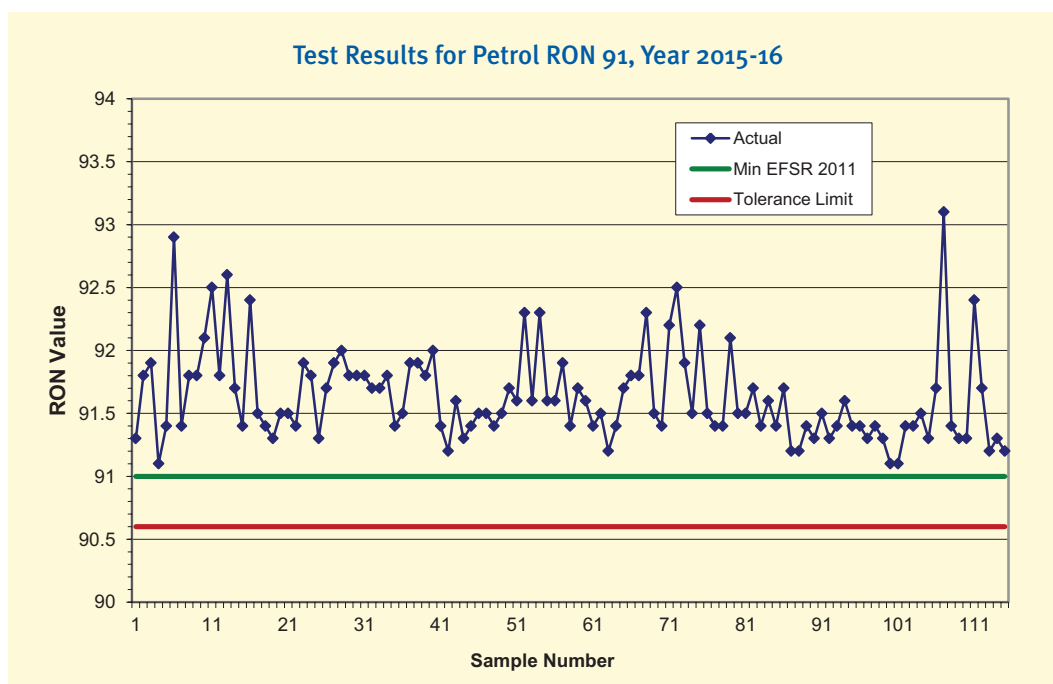
## Research Octane Number (RON) and Motor Octane Number (MON)

### RON 91

In total, 115 samples of regular petrol were collected and tested. Fig. 1a and 1b below show the testing results for RON and MON respectively.

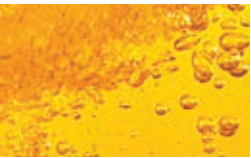
All samples were found to be above the minimum specification limit of 91.0 for RON<sup>5</sup>.

Fig. 1a



Here and below: The abbreviation 'EFSR' stands for the specification limit prescribed in the Regulations. Each individual result is independent from others although they are connected in the graphs for the ease of interpretation.

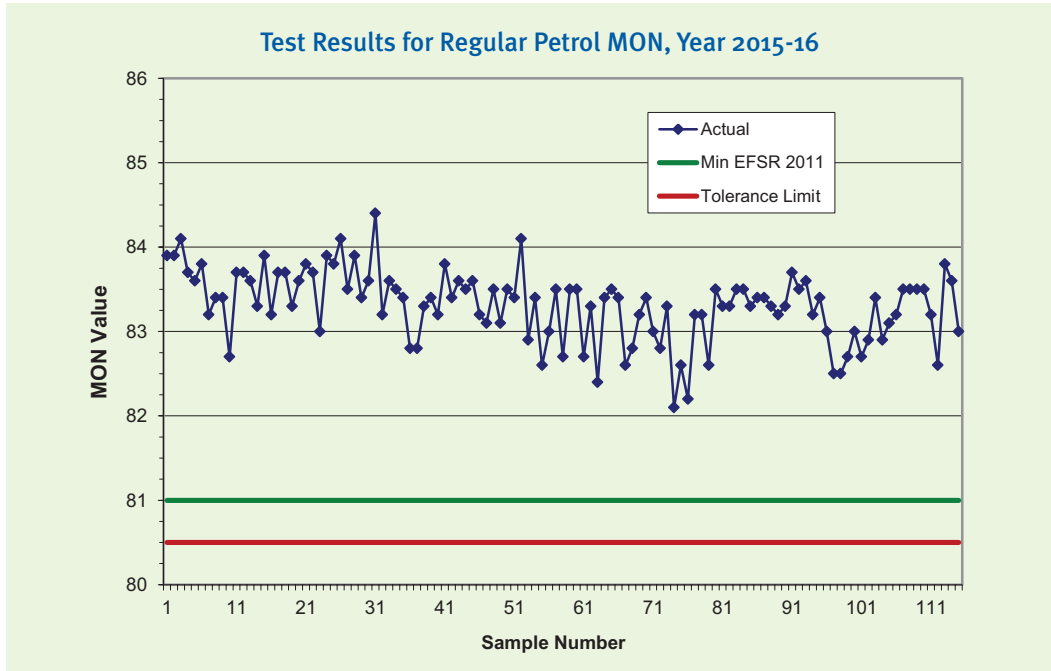
<sup>5</sup> ASTM D2699-15a Standard Test Method for Research Octane Number of Spark-Ignition Engine Fuel.



All samples were found to be above the minimum specification limits of 81.0 for MON<sup>6</sup>.

All samples were found to be compliant with the Regulations.

Fig. 1b



<sup>6</sup> ASTM D2700-14 Standard Test Method for Motor Octane Number of Spark-Ignition Engine Fuel.

## RON 95

In total, 91 samples of premium grade petrol with RON 95, were collected and tested. Fig. 2a and 2b below show the testing results for RON and MON respectively.

All samples were found to be above or on the minimum specification limit of 95.0 for RON.

Samples 31, 80, 82, 84 and 91 were found to be on the specification limit.

All samples were found to have MON above the minimum specification limit of 85.0 for premium petrol.

Fig. 2a

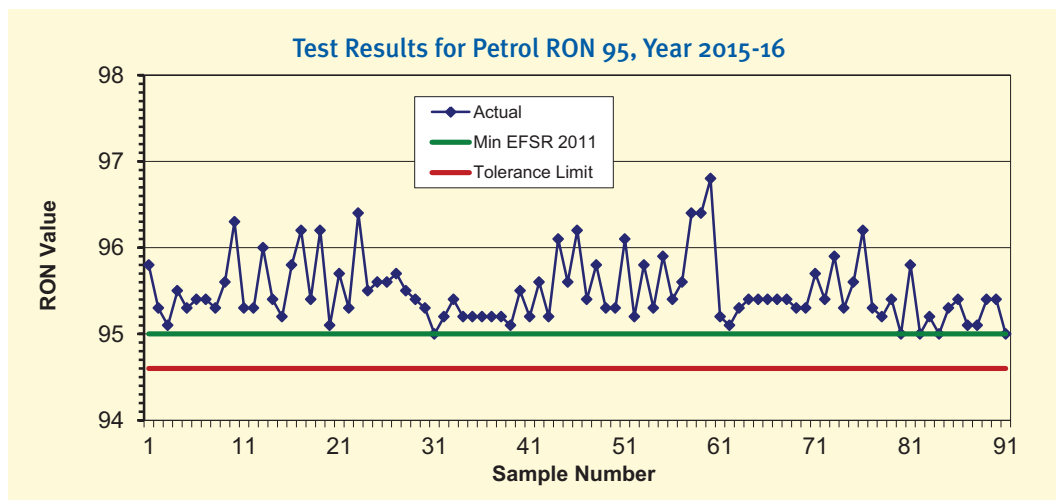
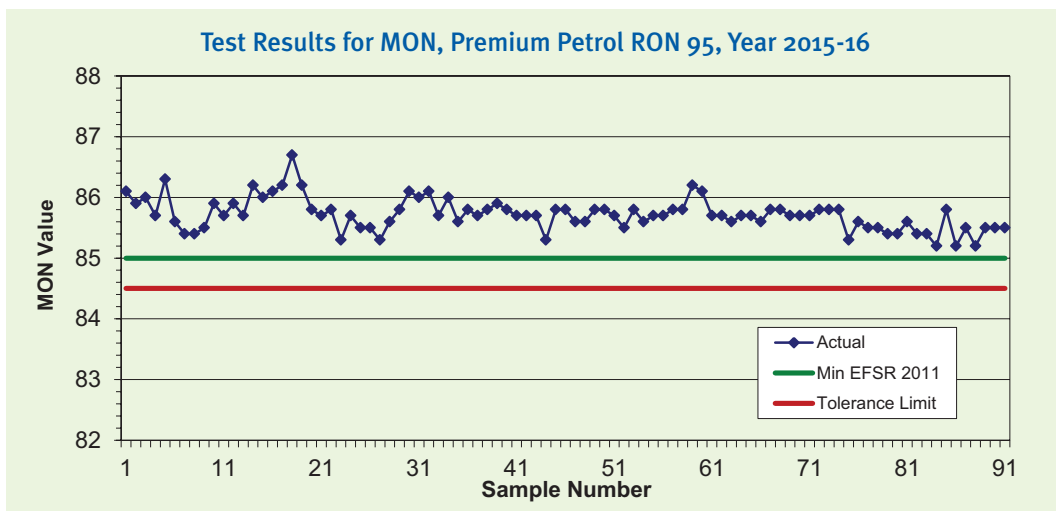


Fig. 2b





## RON 98

No minimum value is specified in the Regulations for premium petrol with RON 98. This fuel is advertised as having properties that are superior or in addition to the regulated limits. In particular, with an “advertised RON 98 minimum” which is referred to in Fig. 3a, it must conform, according to Section 11 of the Regulations, to those advertised properties when tested using the test methods specified in Schedule 1 in the Regulations.

This advertised limit is also enforceable under the provisions of the Fair Trading Act 1986 in relation to mis-description. Under this approach it is also deemed that the actual figures of RON must not be lower than 98.

For premium petrol with RON 98, a minimum limit for MON is neither specified in the Regulations nor advertised. In the absence of a specified minimum limit for MON the limit for premium petrol has been used as a benchmark.

In total, 20 samples of petrol with RON 98 were collected and tested. Fig. 3a and 3b below show the testing results for RON and MON respectively.

All samples with the advertised RON of 98.0 were found to be above the advertised minimum limit.

All samples were found to have MON above the specification limit of 85.0 for premium petrol.

Fig. 3a

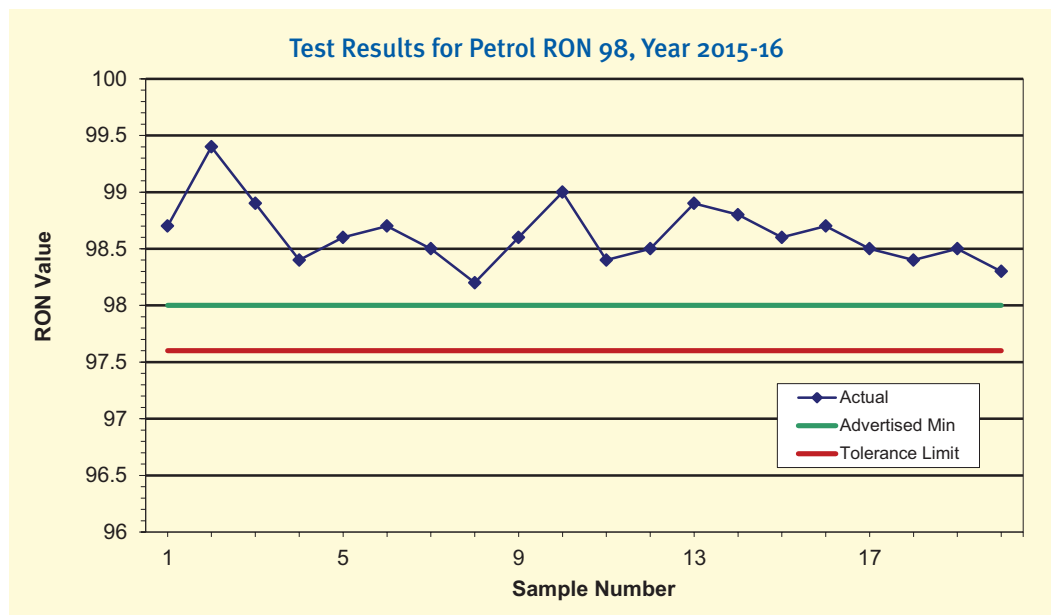
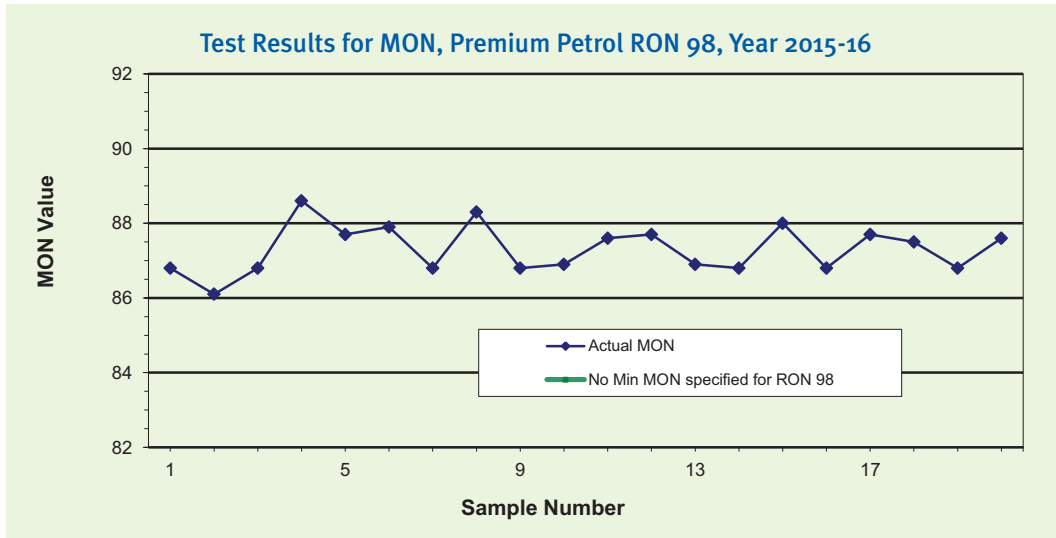


Fig. 3b



## Evaporation Percentage

The test method ASTM D86<sup>7</sup> is prescribed in the Regulations for definition of the volume percentage of evaporated petrol at the three fixed temperatures: at 70°C, 100°C and 150°C. Respectively, there are three categories for evaporation percentage limits in the Regulations: E70, E100 and E150. These categories are analysed below separately for regular petrol (RON 91) and for premium petrol (RON 98 data is included with RON 95 data).

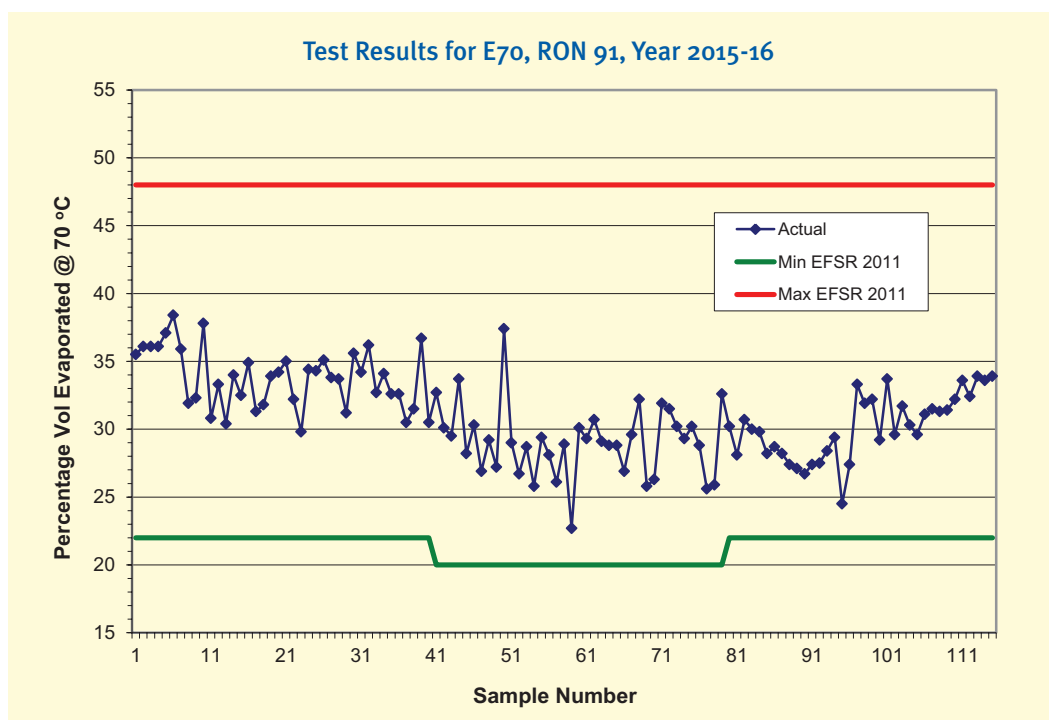
## RON 91

### Percentage Volume Evaporated @ 70°C

For petrol not containing ethanol, the minimum specification limit is 22% (a minimum of 20% E70 permitted for the summer season – see Footnote 1 in Schedule 1, the Regulations) and maximum specification limit is 48% while the relevant minimum tolerance limits are 20.5% (18.5% in summer) and 49.2% respectively.

All samples were found to be within the prescribed specification limits above the minimum limit of 22% at all seasons including the summer period when the specified minimum limit for E70 is permitted to be 20% (see Fig. 4a).

Fig. 4a



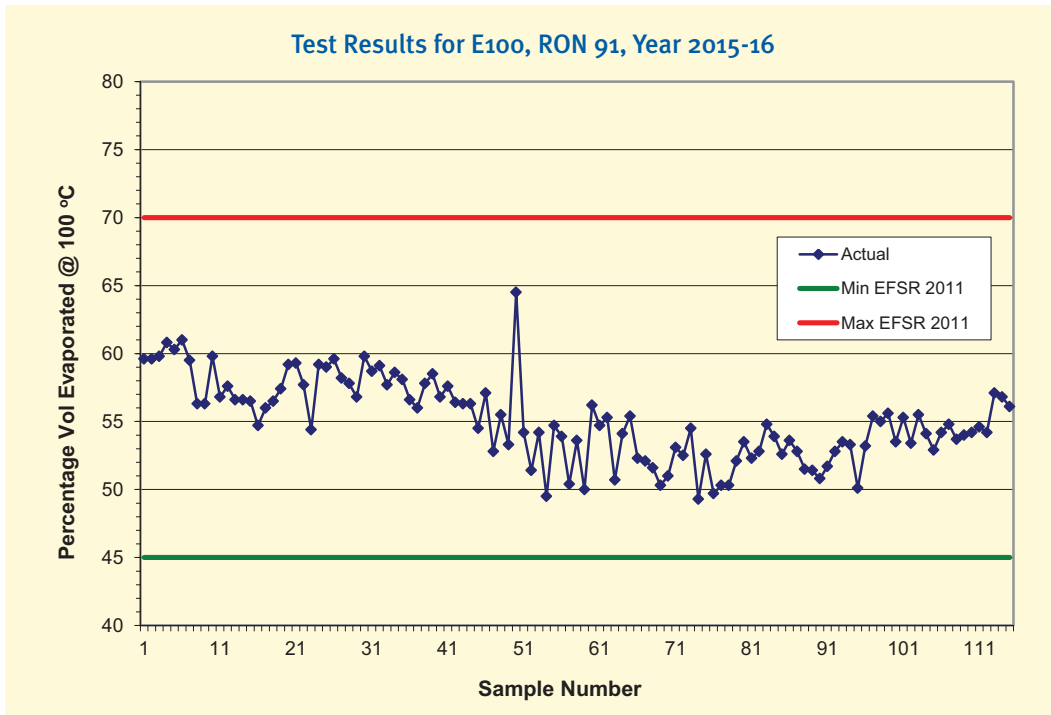
<sup>7</sup> ASTM D86-15 Standard Test Method for Distillation of Petroleum Products at Atmospheric Pressure.

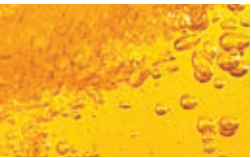
### Percentage Volume Evaporated @ 100°C

All samples were found to be well within the specification limits from 45% to 70%.

The minimum tolerance limit is 43.8% and maximum tolerance limit is 70.9%.

Fig. 4b



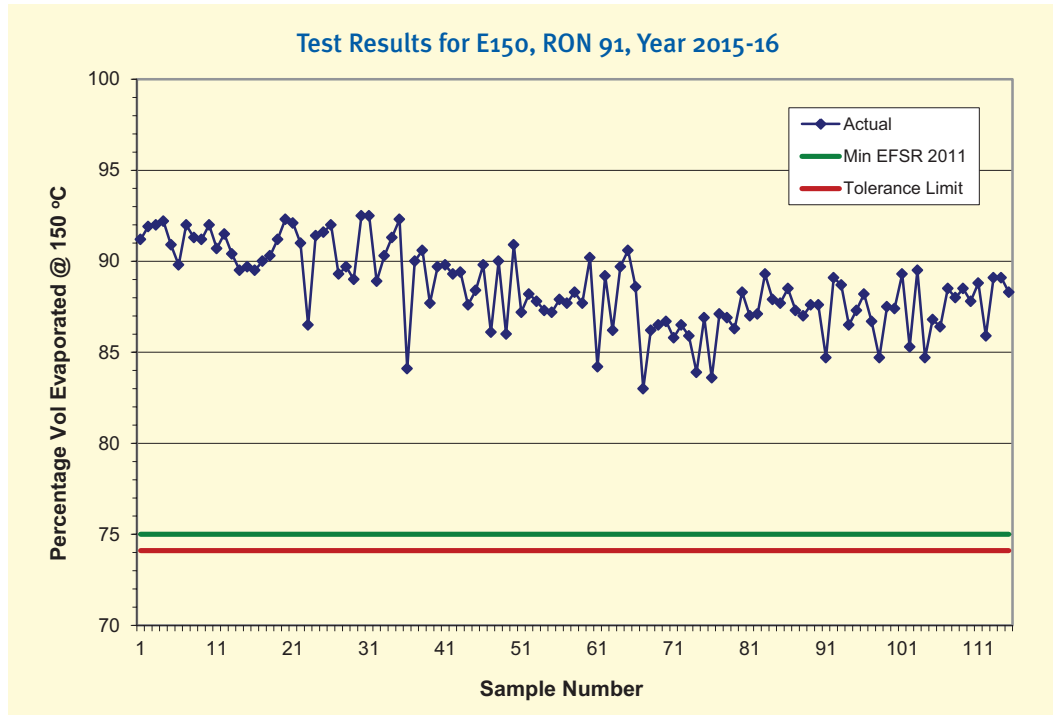


### Percentage Volume Evaporated @ 150°C

All samples were found to be well above the minimum specification limit of 75%. The minimum tolerance limit is 74.1%.

No maximum is prescribed by the Regulations for this parameter.

Fig. 4c



### RON 95 & 98

#### Percentage Volume Evaporated @ 70°C

For premium petrol not containing ethanol, as in case of regular petrol, the minimum specification limit is 22% (a minimum of 20% E70 permitted for the summer season – see Footnote 1 in Schedule 1, the Regulations) and maximum specification limit is 48% while the minimum tolerance limit is 20.5% (18.5% in summer) and maximum tolerance limit is 49.2%.

The majority of results were found to be within the specification limits of 22% to 48% with the exception of a number of ethanol blended samples. According to the Regulations (Footnote 2 in Schedule 1), the maximum allowed percentage of volume evaporation at 70°C (E70) is increased by 1% per each 1% volume ethanol in the blend.



Table 1

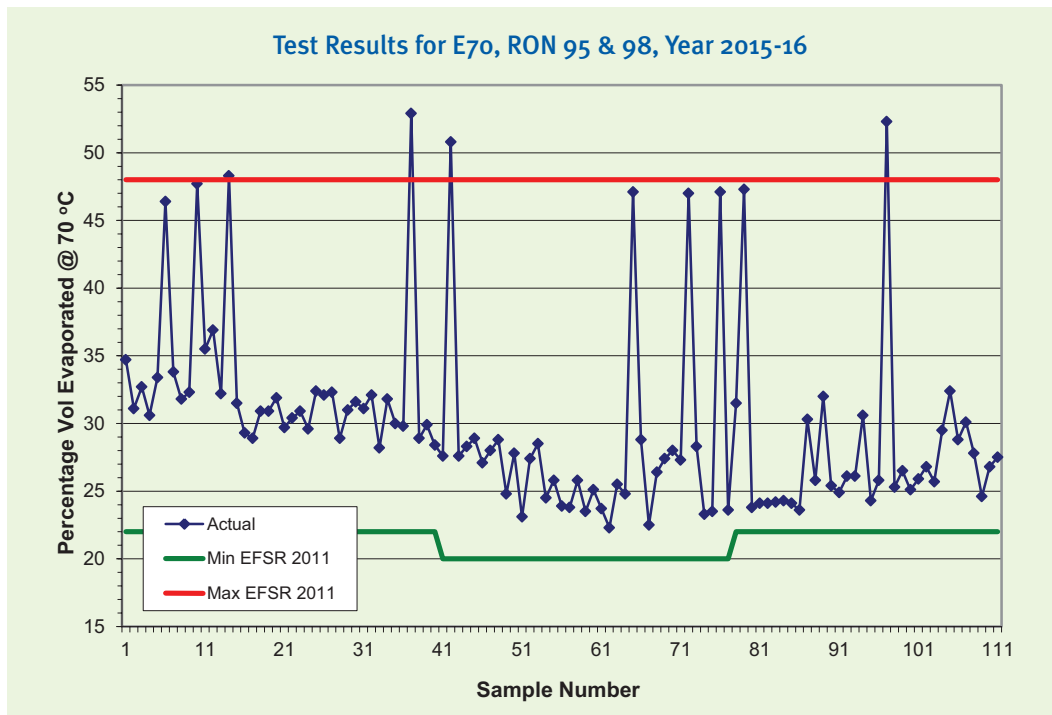
Sample	Ethanol Content, % Vol	Maximum E70 allowed, % Vol	E70 actual, % Vol
14	9.92	58	48.3
37	9.78	58	52.9
42	9.83	58	50.8
97	10.00	58	52.3

All E70 results above 48% for premium petrol samples with ethanol, are set out in a Table 1 above.

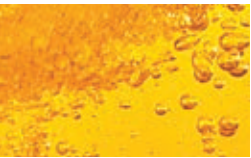
prescribed specification limits with the minimum limit of 22% at all seasons including the summer period when the specified minimum limit for E70 is permitted to be 20%.

As in the case with regular petrol (see above), all samples were found to be within the

Fig. 5a



Sample 10 is within the specification with the result of 47.7 % at the maximum allowed E70 of 58% for ethanol blend.

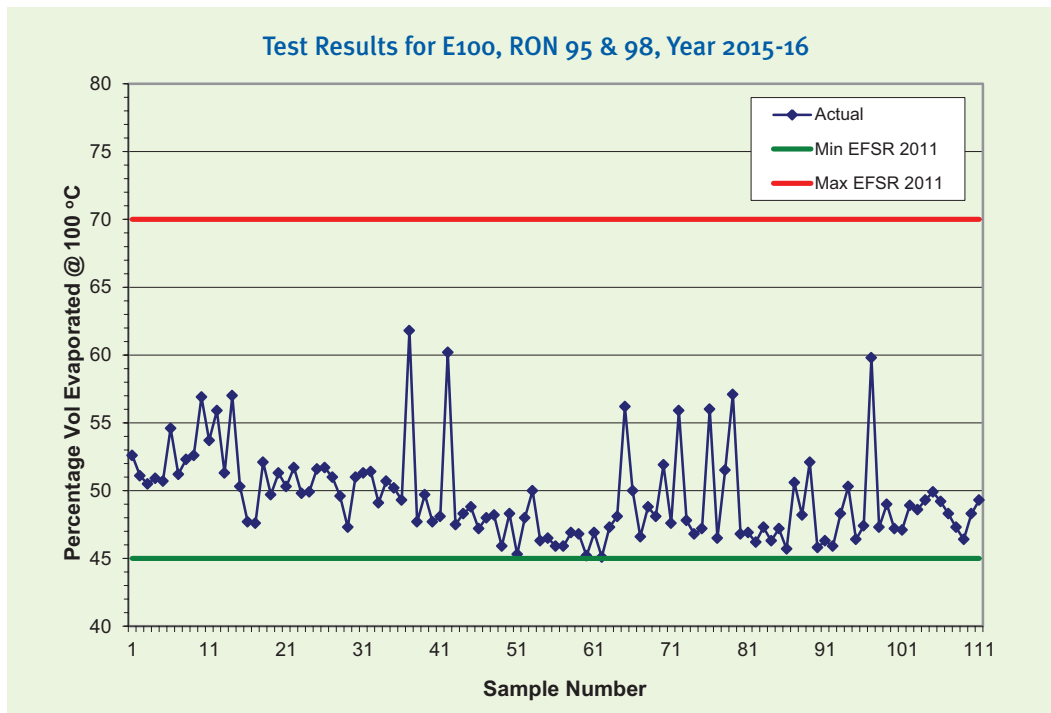


### Percentage Volume Evaporated @ 100°C

All samples were found to be within the specification limits from the minimum of 45% to the maximum of 70%. Samples 51, 60 and 62 were found to be the three lowest, respectively, 45.3, 45.2 and 45.1%.

As in case of regular petrol, the tolerance limits (not shown in Fig.5b) 43.8% and 70.9% respectively.

Fig. 5b



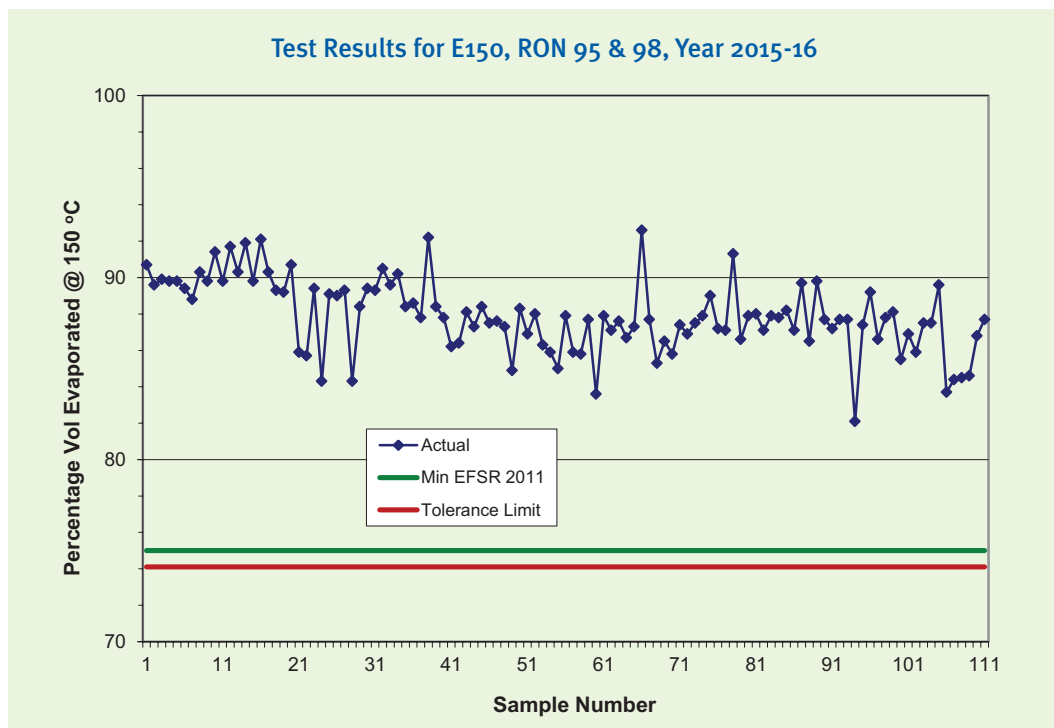
### Percentage Volume Evaporated @ 150°C

All samples were found to be well above the minimum specification limit of 75%.

As in case of regular petrol, the minimum tolerance limit is 74.1%.

No maximum is prescribed by the Regulations for this parameter. All samples were found to be above 80% (Fig. 5c). The lowest figure of 82.1% was found for Sample 94.

Fig. 5c



### Final Boiling Point

The test method ASTM D86<sup>8</sup> is prescribed in the Regulations for distillation end point (or 'final boiling point') in petrol.

All samples were found to be within the specification maximum limit of 210°C for both regular and premium grades (Fig.6). The tolerance limit is 214°C.

The largest figure for final boiling point of 208.7°C was found for Sample 43 of regular petrol.

<sup>8</sup> ASTM D86-15 Standard Test Method for Distillation of Petroleum Products at Atmospheric Pressure.

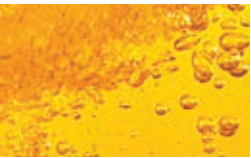
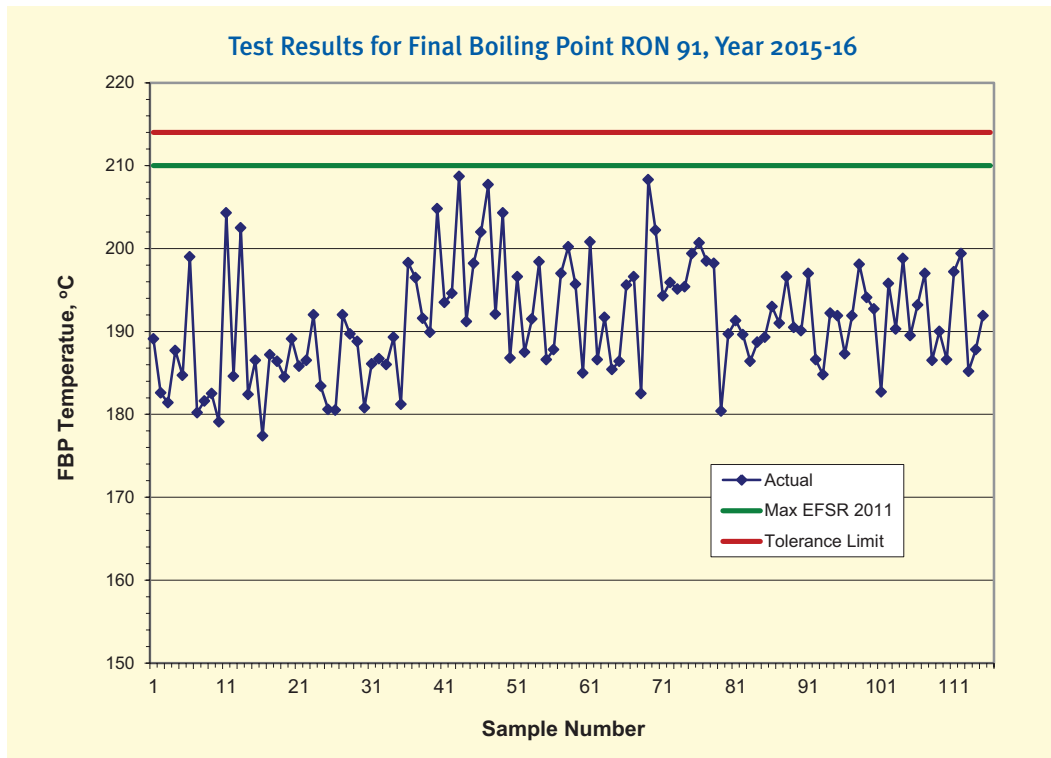
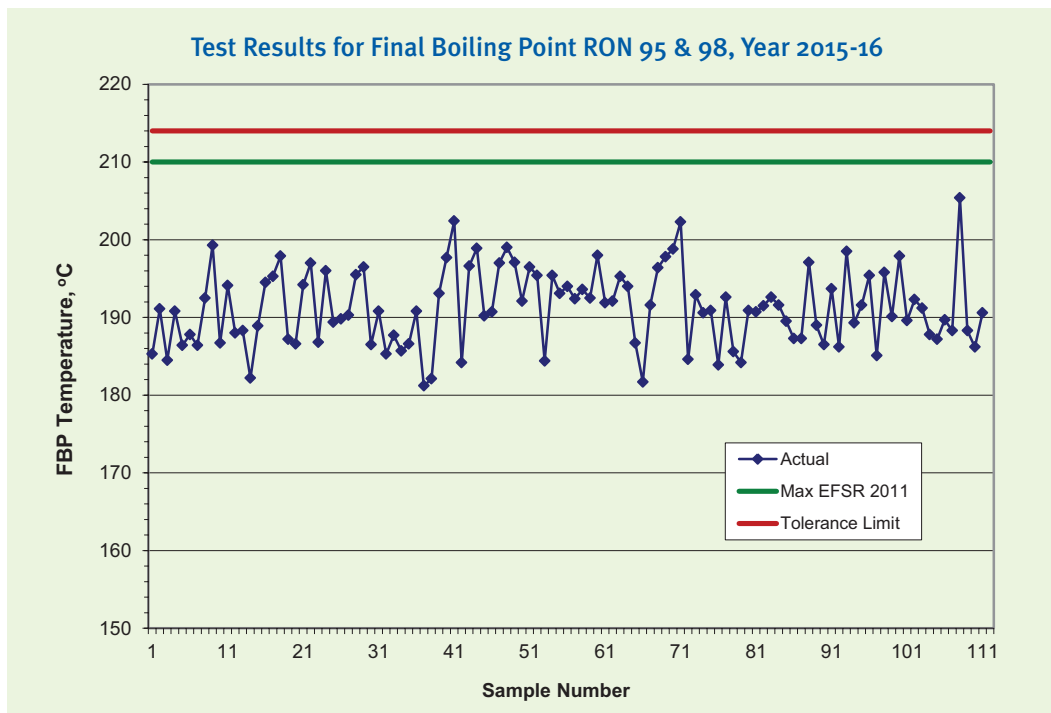


Fig. 6a



The largest figure for final boiling point of 205.4°C was found for Sample 108 of premium petrol.

Fig. 6b



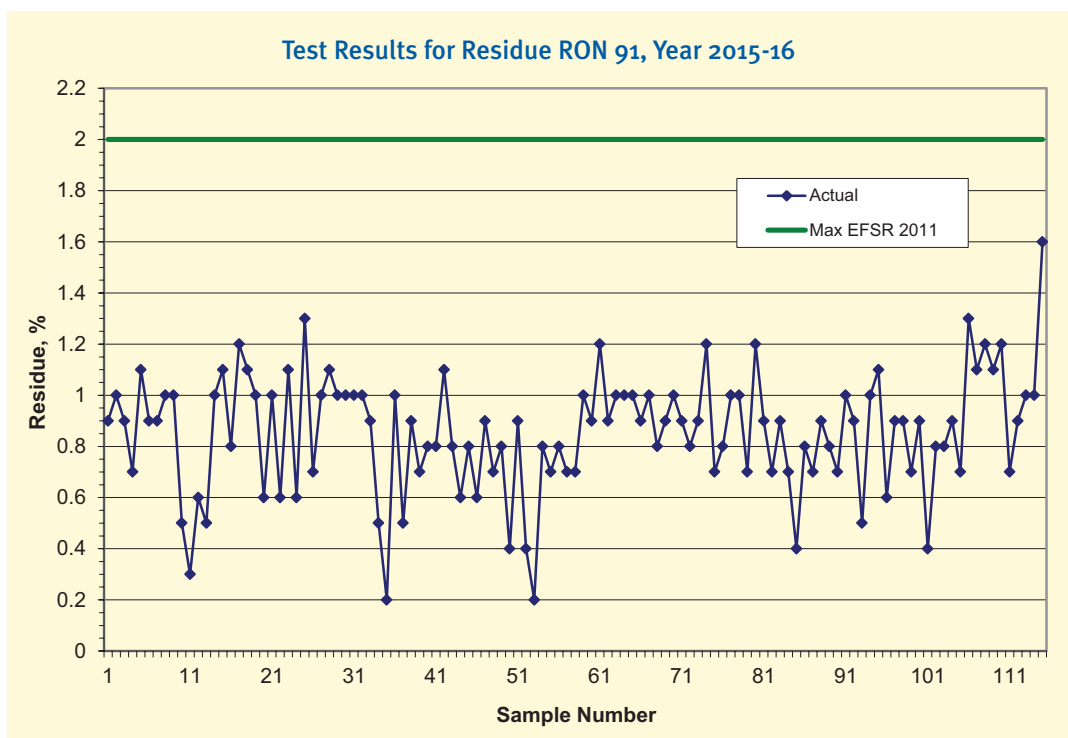
## Residue

All samples were found to be well within the limits for both regular and premium grades (Fig. 7).

No tolerance limit for residue could be defined due to the lack of data for the reproducibility of this parameter in ASTM D86<sup>9</sup>. Fortunately,

residue content was found to be well below the specified maximum limit of 2% volume. The largest figure for residue of 1.6% was found for Sample 115 of regular petrol. All other results for both regular and premium petrol were found to be not higher than 1.3%.

Fig. 7a



<sup>9</sup> ASTM D86-15 Standard Test Method for Distillation of Petroleum Products at Atmospheric Pressure.



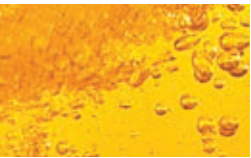
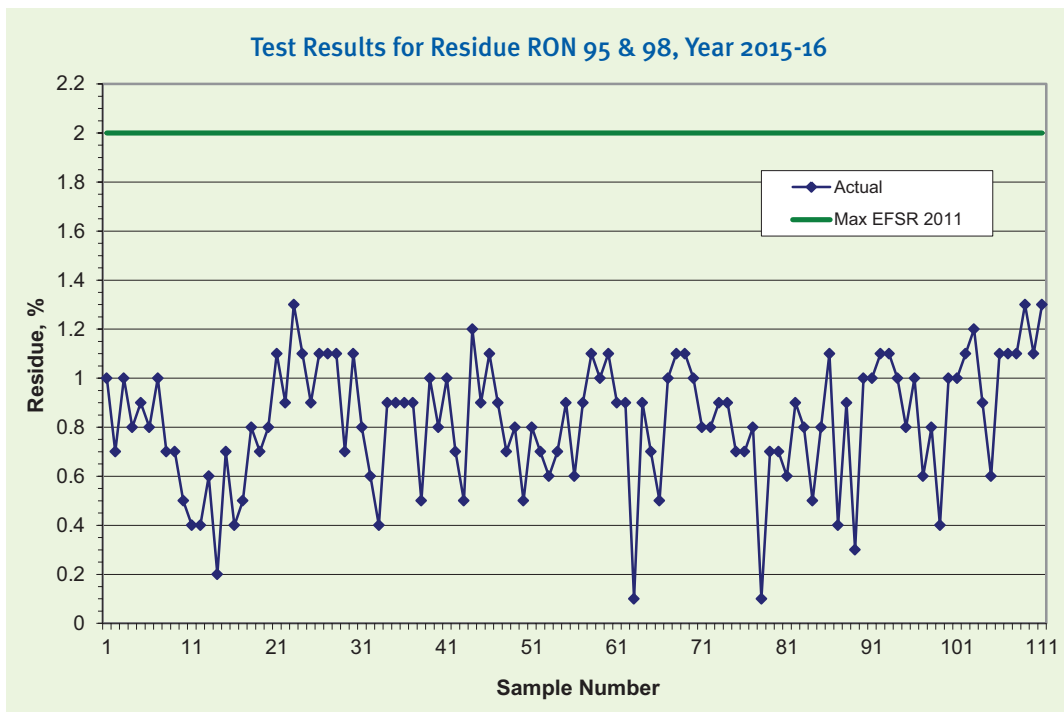


Fig. 7b



### Dry Vapour Pressure Equivalent

The test method ASTM D5191<sup>10</sup> is prescribed in the Regulations for vapour pressure in petrol.

All samples tested for Dry Vapour Pressure Equivalent (DVPE) were found to be above the prescribed minimum limit of 45 kPa.

The cumulative results for the maximum limit are presented below in a simplified way by combining the lowest prescribed maximum limits for all seasons in one graph. Generally, if results were below the lowest maximum limit established for an area then they definitely complied with the Regulations in all other areas.

For the period of summer in Schedule 1 (season definitions in Section 5, the Regulations) from 1 December to 31 March inclusive, the lowest maximum limit of pressure 65 kPa is prescribed for Auckland and Northland. This is shown on the Fig. 8 by a square dip.

The top line before and after the dip, is the next lowest maximum, 80 kPa, which is prescribed for the North Island, for the autumn and spring periods.

The maximum limits prescribed for winter in all three designated regions are equal to or above 90 kPa and not shown in the graph.

<sup>10</sup> ASTM D5191-15 Standard Test Method for Vapor Pressure of Petroleum Products (Mini Method).

Each sample within the relevant season which appeared to be above the lowest maximum limit line was individually analysed.

Tolerance limits related to the maximum specification limits are not shown since they are only approx. 2% above each relevant limit.

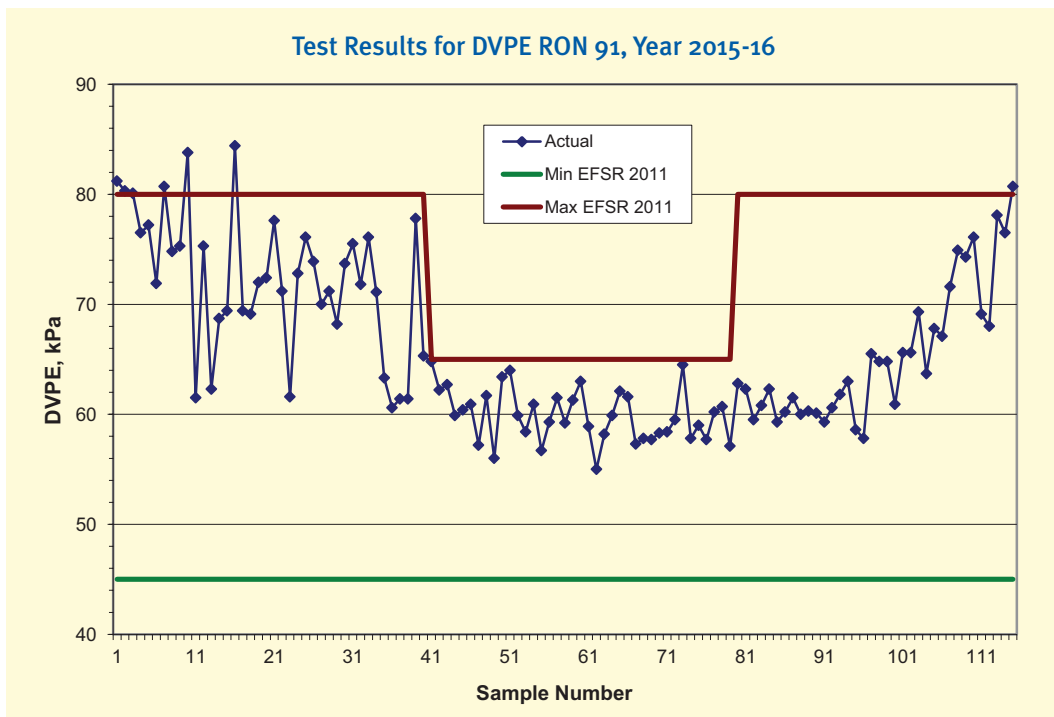
### RON 91

In various periods, several samples were initially found to be above the lowest maximum at the time. However, all they were found to be within the specification limits.

Of those, Samples: 1, 2, 3, 10, 16, and 115, were found to be in the range from 80.1 kPa to 84.4 kPa *i.e.* well within<sup>11</sup> the maximum limit of 90 kPa for winter in North Island.

Sample 7 which was drawn from South Island, was found to be 80.7 kPa, *i.e.* well within the maximum limit of 95 kPa for the region in the winter season.

Fig. 8a



<sup>11</sup> 'Well within the limit' in this Report means a compliant result which is away from the prescribed limit farther than three tolerance margins. Here, the limit is 90 kPa so that minus three tolerance margins gives 85.8 kPa.

### RON 95 & 98

All samples were found to be within the specification limits for premium petrol (Fig. 8b). However, as in case with regular petrol, in various periods, several samples were initially found to be above the lowest maximum at the time.

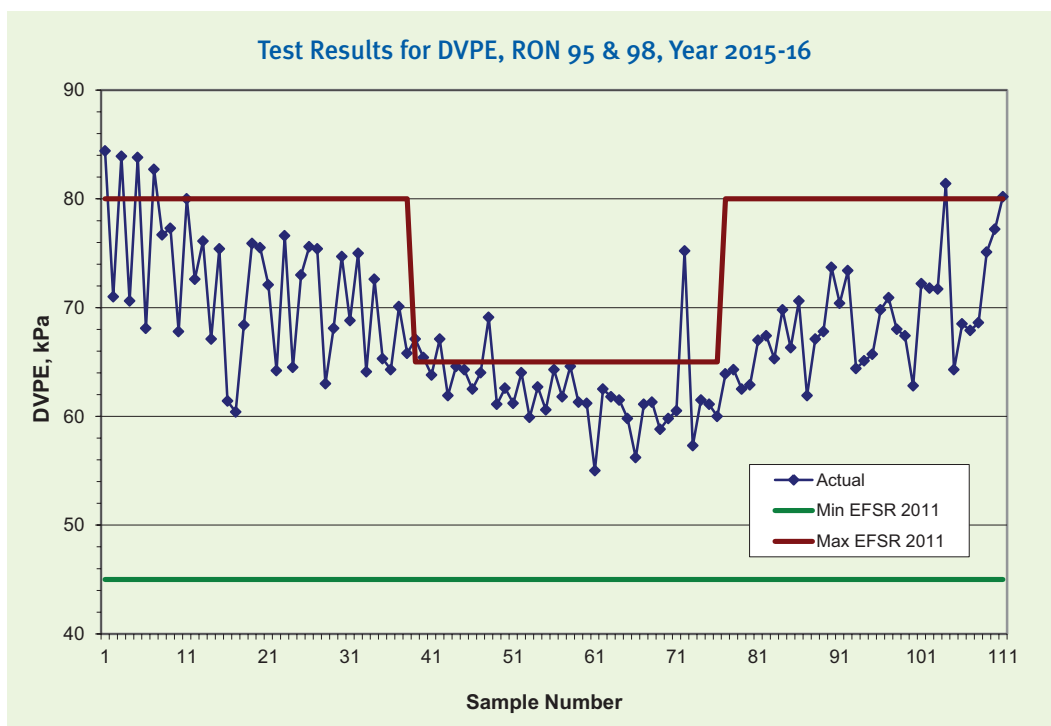
Of those, four samples: 1, 3, 104, and 111, which were found to be in the range from 80.2 kPa to 84.4 kPa, were well within the regional maximum limits for winter 90 kPa for North Island. Samples 5 and 7 were found to be respectively 83.8 and 82.7 kPa, were well within the regional maximum limit for winter 95 kPa for South Island.

There were also five samples found to be above the lowest maximum in the summer period.

Samples: 39, 40, and 48, which were found to be in the range from 65.4 kPa to 69.1 kPa, were within the maximum limit of 75 kPa for South Island in summer.

Finally, two other samples, 42, and 72, which were found to be, respectively, 67.1 and 75.2 kPa, were ethanol blends (see Table 1 above). They were found to be well within the seasonal maximum limits of 75 kPa and 80 kPa for 10% ethanol blends, respectively, for Auckland and for North Island.

Fig. 8b



## Flexible Volatility Index

The Flexible Volatility Index (FVI) is a derived parameter which is calculated from the measured value of DVPE (see above) and the value of E70, as

$$FVI = DVPE + (0.7 \times E70)$$

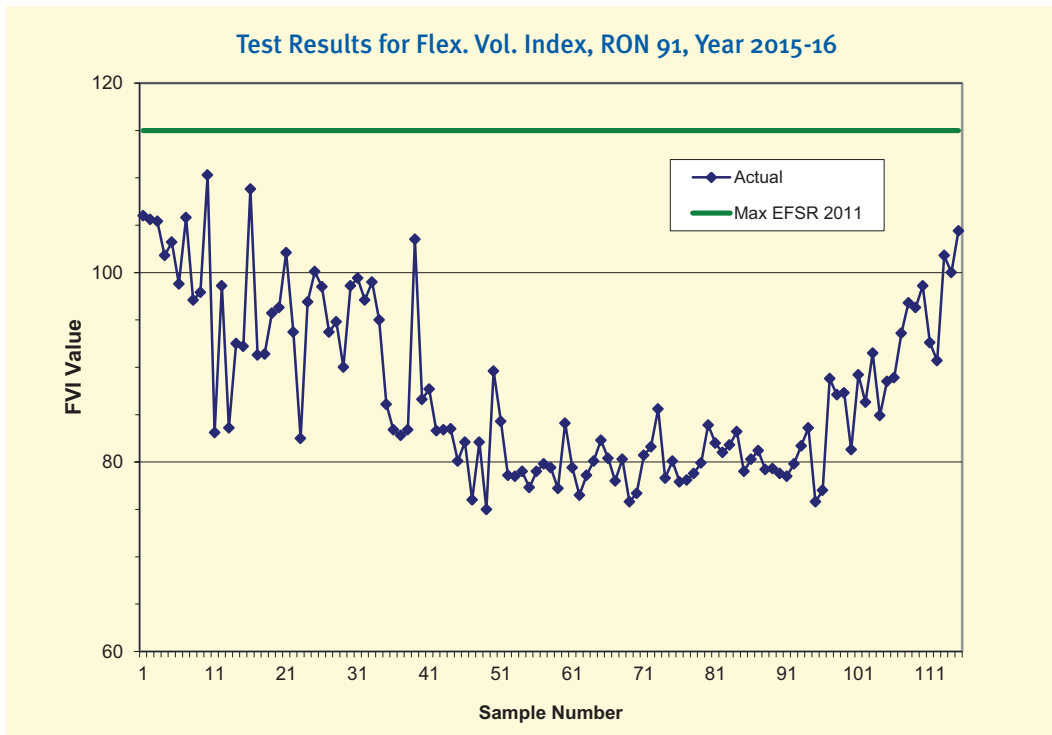
FVI serves as an indicator of the hot running performance (the tendency for vapour lock). No definition of the FVI value is given in the related ASTM Standards prescribed in the

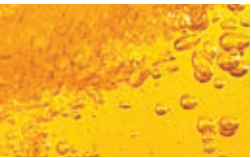
Regulations (D86 and D5191) and as a consequence no reproducibility value is identified. As a result of this the FVI serves only as a helpful indicator but cannot be used in a strict compliance analysis.

### RON 91

All samples were found to be within the specification maximum limit of 115.0.

Fig. 8c

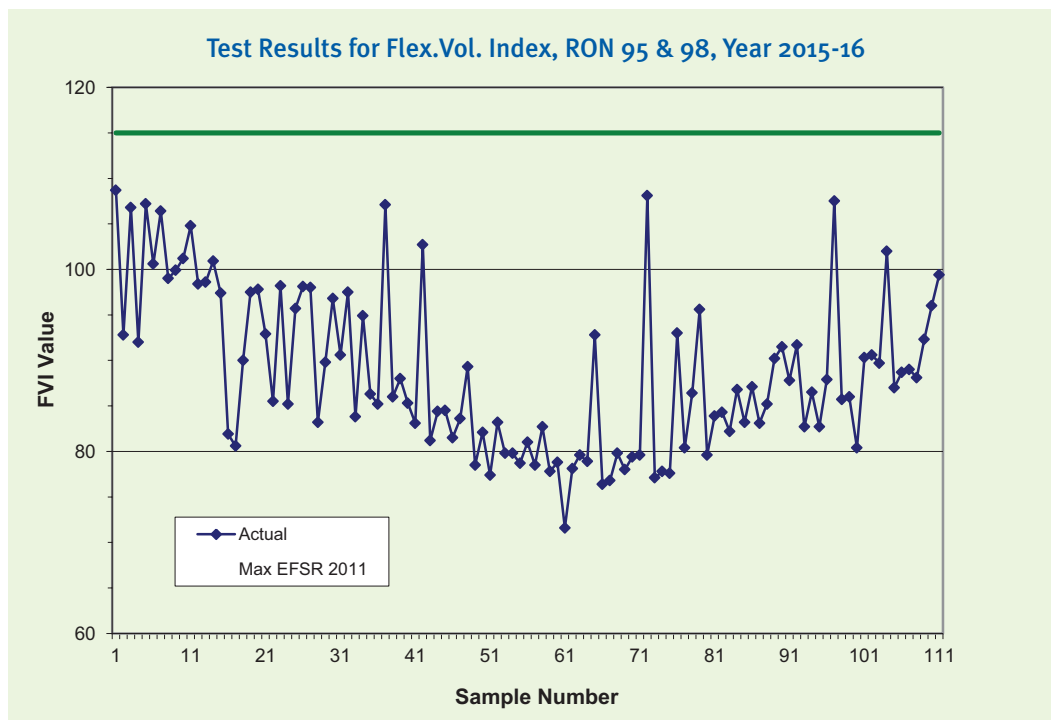




### RON 95 & 98

All samples were found to be within the prescribed maximum limit of 115.0 irrespectively of the ethanol content in blend.

Fig. 8d



## Sulphur

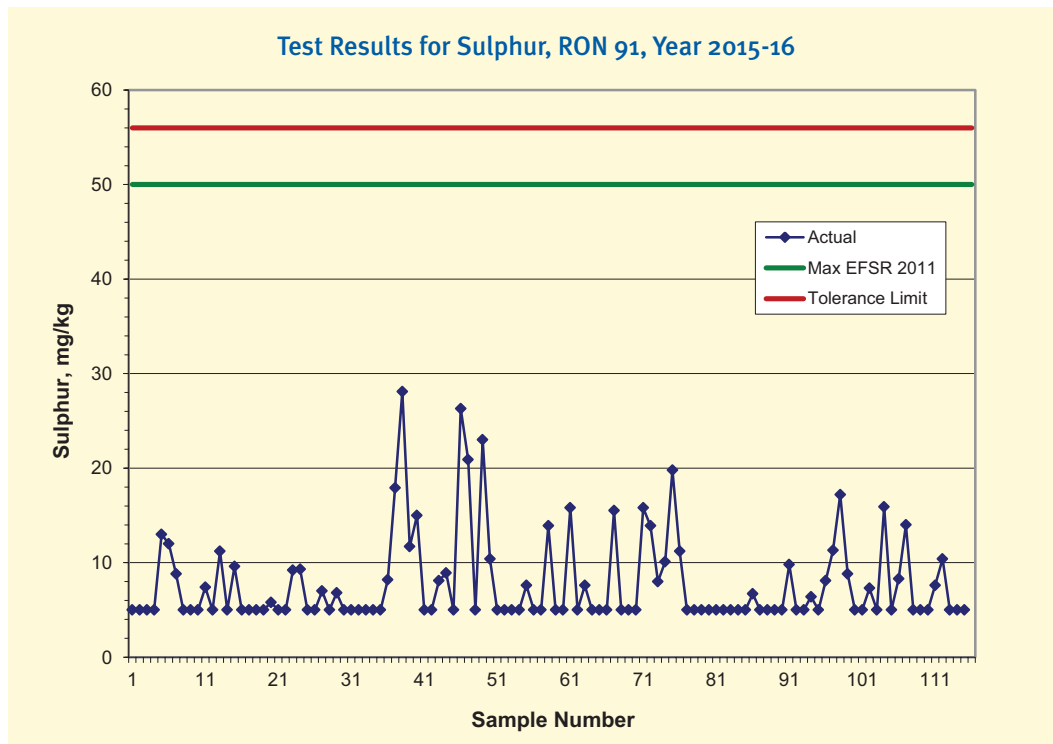
The scope of the test method IP 497<sup>12</sup> prescribed in the Regulations, is from 5 to 60 mg/kg. Accordingly, the lowest line of testing results by this method is 5 mg/kg where the actual figures were found to be on or below this indicative level at the specified maximum limit of 50 mg/kg with the tolerance limit of 56 mg/kg.

The ASTM standard D5453<sup>13</sup> which is also prescribed in the Regulations along the IP 497, give results down to a fraction of 1 mg/kg although it wasn't used by the testing laboratory this year.

### RON 91

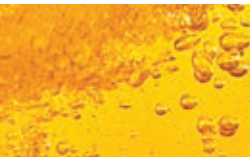
All samples for regular petrol were found to be within the prescribed maximum limit. All results were between 5 and 30 mg/kg.

Fig. 9a



<sup>12</sup> BS EN ISO 20884:2011, BS 2000-497:2011 *Petroleum products. Determination of sulfur content of automotive fuels. Wavelength-dispersive X-ray fluorescence spectrometry.*

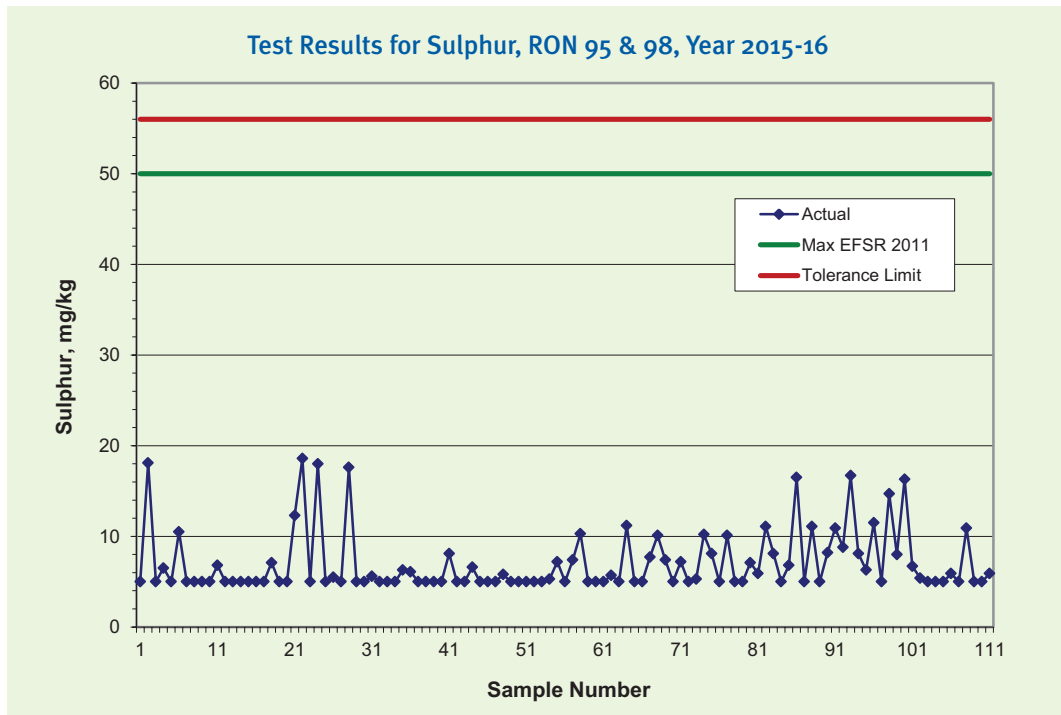
<sup>13</sup> ASTM D5453-12 *Standard Test Method for Determination of Total Sulfur in Light Hydrocarbons, Spark Ignition Engine Fuel, Diesel Engine Fuel, and Engine Oil by Ultraviolet Fluorescence.*



### RON 95 & 98

All results for premium petrol were found to be well within the prescribed maximum limit not exceeding 20 mg/kg.

Fig. 9b



## Benzene and Total Aromatics

The test method ASTM D5580<sup>14</sup> is prescribed in the Regulations for aromatic compounds including benzene.

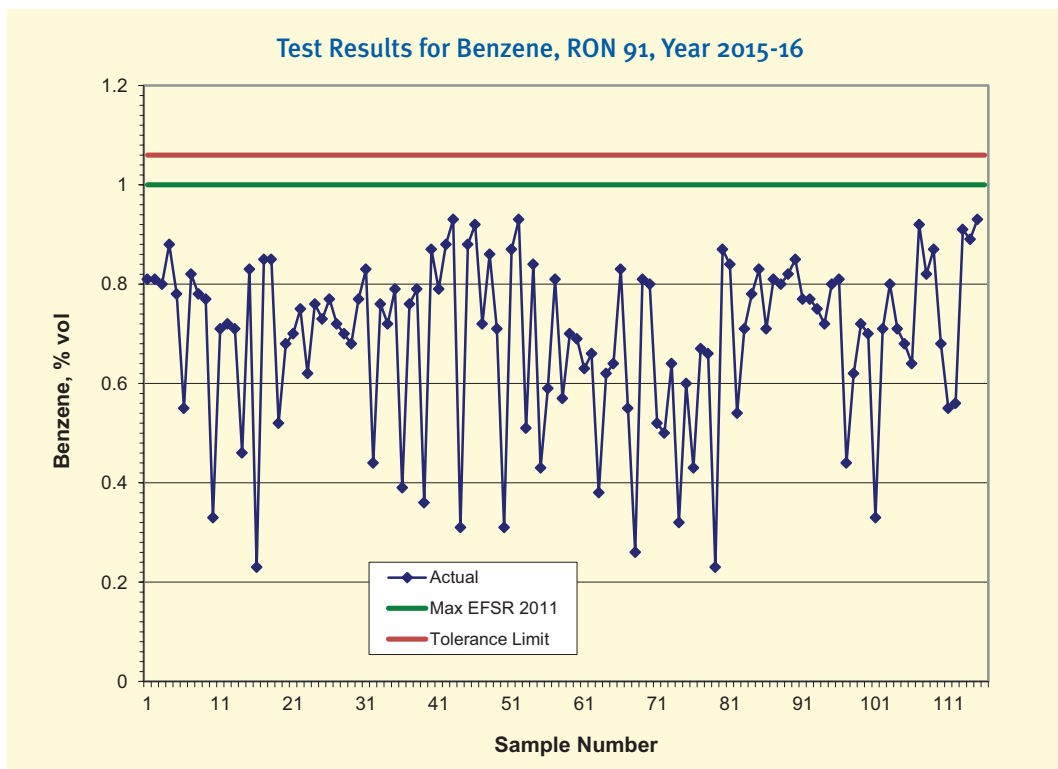
All samples were found to be within the prescribed maximum limits, for both benzene (maximum 1% vol) and total aromatic compounds (45% vol maximum cap) for regular as well as premium grade of petrol with the tolerance limits, respectively, of

1.06% for benzene and of 46.03% for the maximum cap in total aromatics.

### RON 91

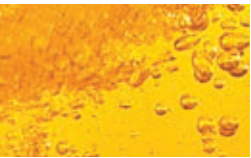
All results for benzene content in regular petrol were found to be below 0.95% with the largest figure of 0.93% for Samples 43 and 52 (Fig.10a).

Fig. 10a



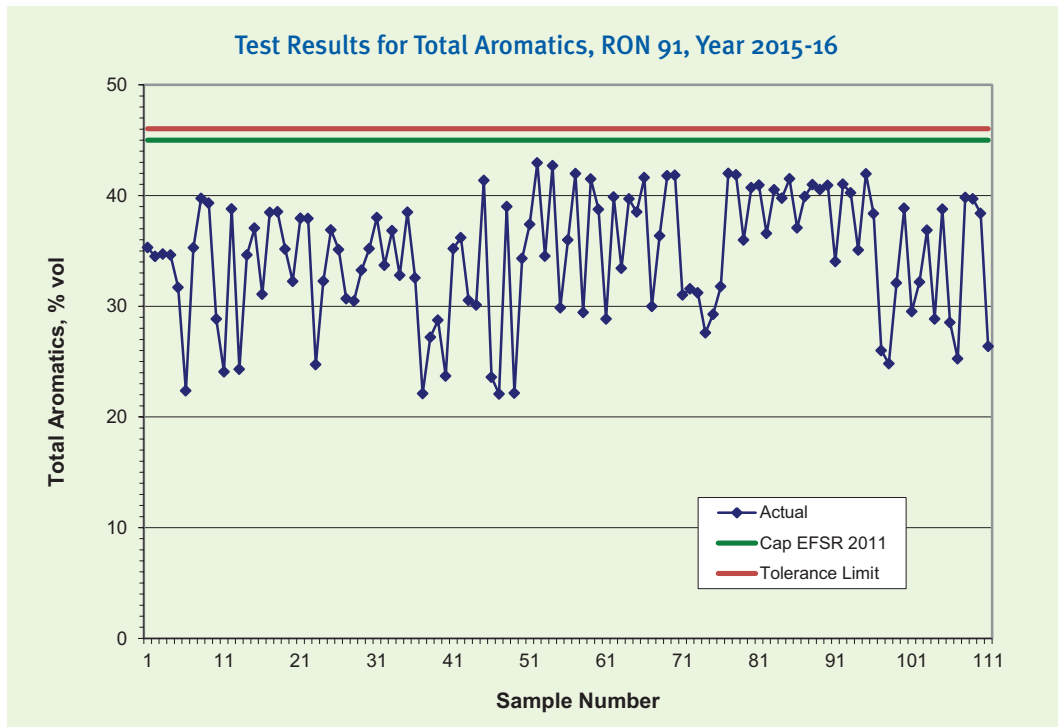
<sup>14</sup> ASTM D5580 – 13 Standard Test Method for Determination of Benzene, Toluene, Ethylbenzene, *p/m*-Xylene, *o*-Xylene, *C9* and Heavier Aromatics, and Total Aromatics in Finished Gasoline by Gas Chromatography.





All results on total aromatics were found to be below 43% with the largest figure of 42.94% for Sample 52 (Fig. 10b).

Fig. 10b



### RON 95 and 98

All samples of premium petrol were found to be well within the prescribed maximum limit for benzene with largest results not higher than 0.90% except Sample 49 which was found to be 0.94%.

For premium petrol, all results on total aromatics were below 44% with the largest result on total aromatics was found to be 43.67% for Sample 49 (Fig. 10d).

According to Section 19 of the Regulations, actual amounts of petrol which were produced or imported, must be accounted, to calculate 'pool average' figures for the total aromatic compounds for each calendar month. The pool average specification for total aromatics is 42% vol maximum.

Data on 'pool average' was collected from five major fuel retail companies and from The New Zealand Refining Company Ltd for the one year period ending on 30 June 2016. The actual results were found to be within the required limits. Due to the commercial sensitivity of the calculation process, the actual results were not included in this report.

Fig. 10c

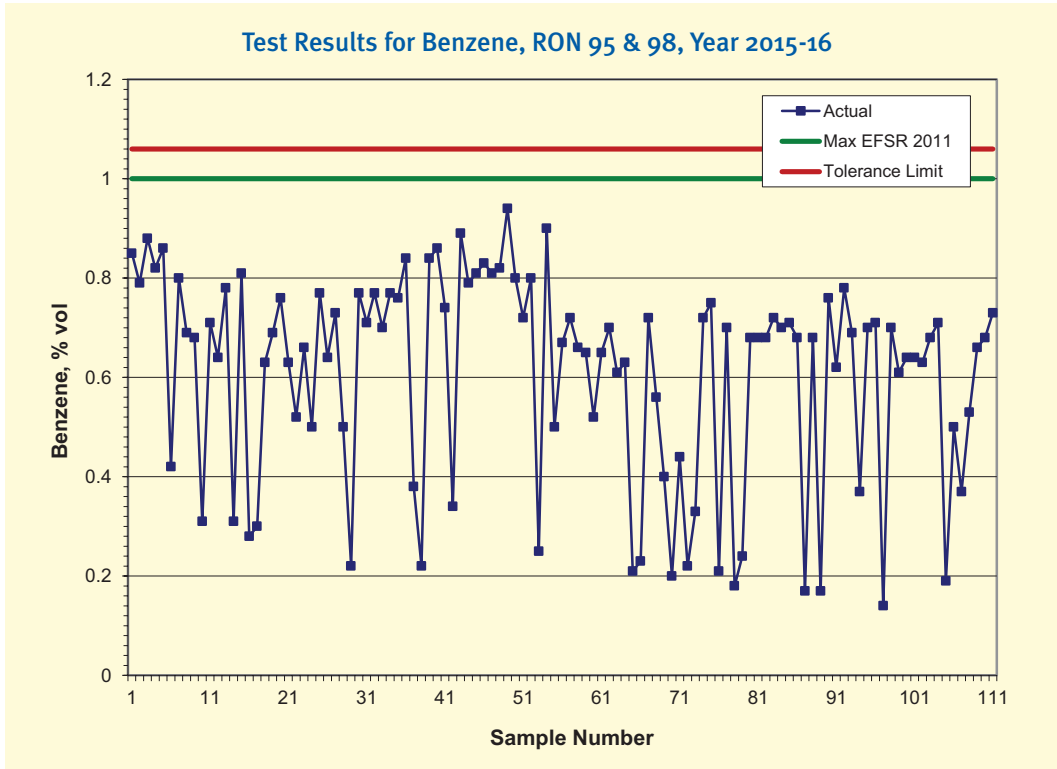
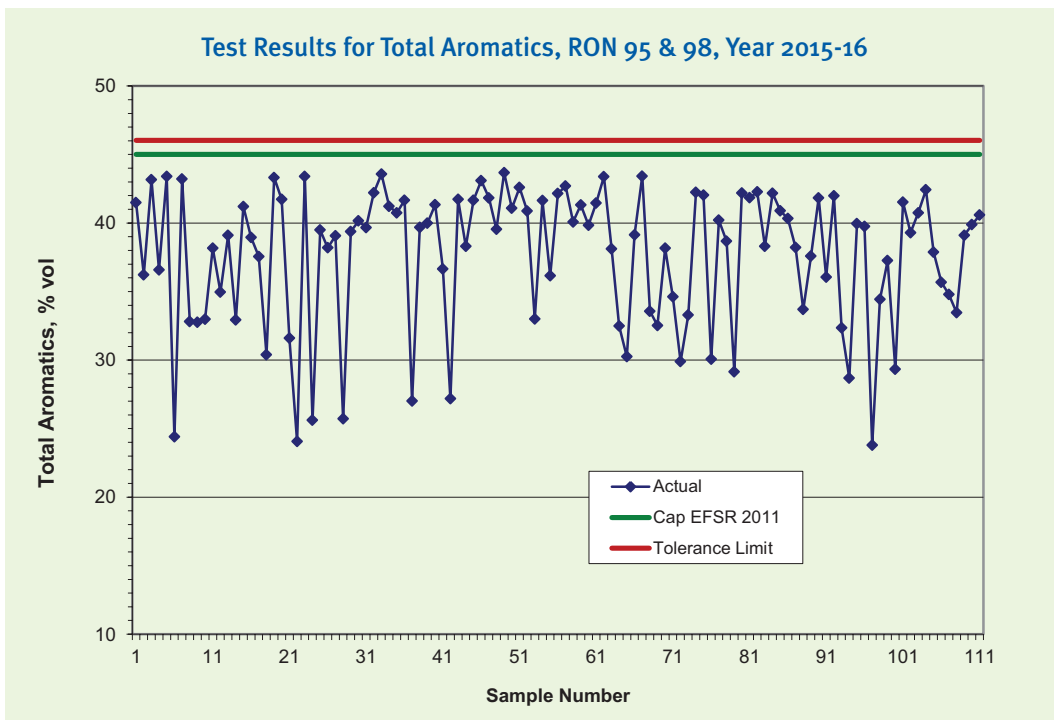
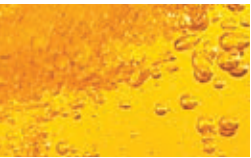


Fig. 10d





## Olefins

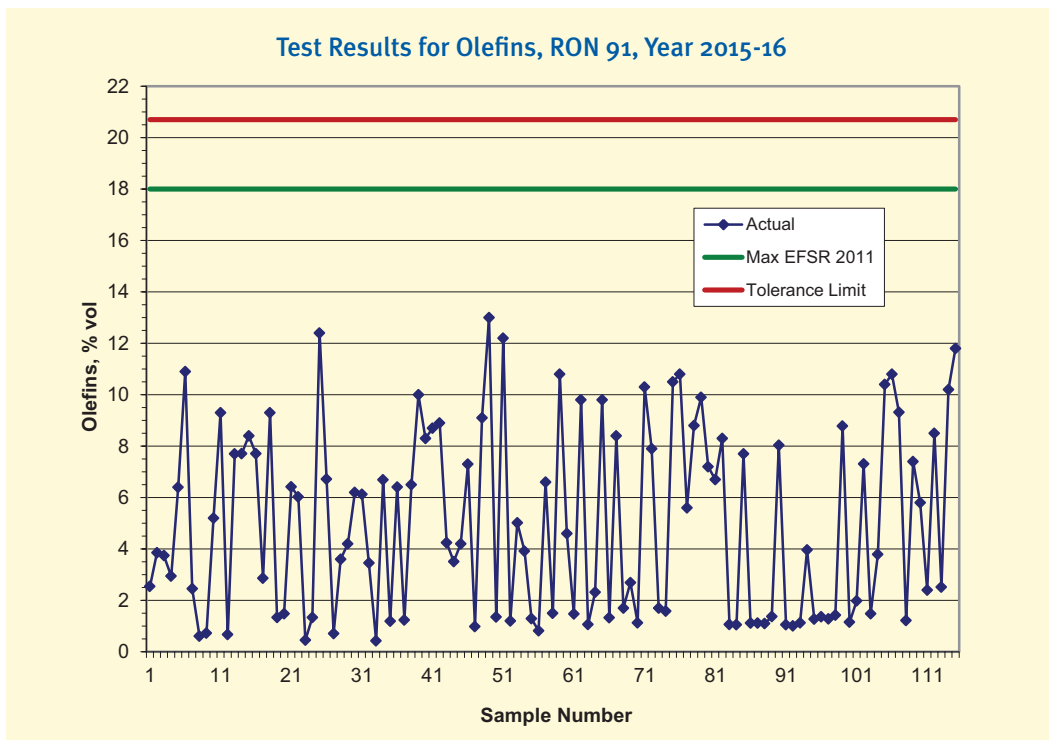
The test method ASTM D1319<sup>15</sup> is prescribed in the Regulations for olefins content.

All samples were found to be within the specification maximum limit of 18% vol with the tolerance limit of 20.7%.

### RON 91

For RON 91, all results were found to be below 14% (Fig. 11a) with the largest result of 13.0% for Sample 47.

Fig. 11a

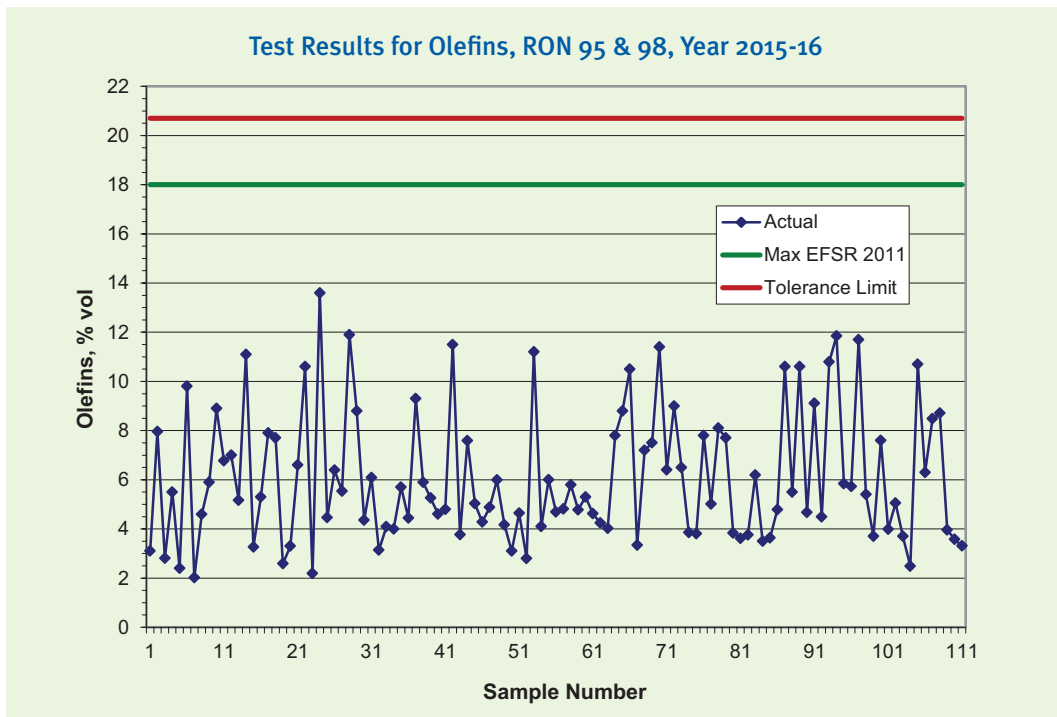


<sup>15</sup> ASTM D1319-14 Standard Test Method for Hydrocarbon Types in Liquid Petroleum Products by Fluorescent Indicator Adsorption.

### RON 95 & 98

For premium petrol, all results were also found to be below 14% (Fig. 11b) with the largest result of 13.6% for Sample 24.

Fig. 11b



## Existent Gum (solvent washed)

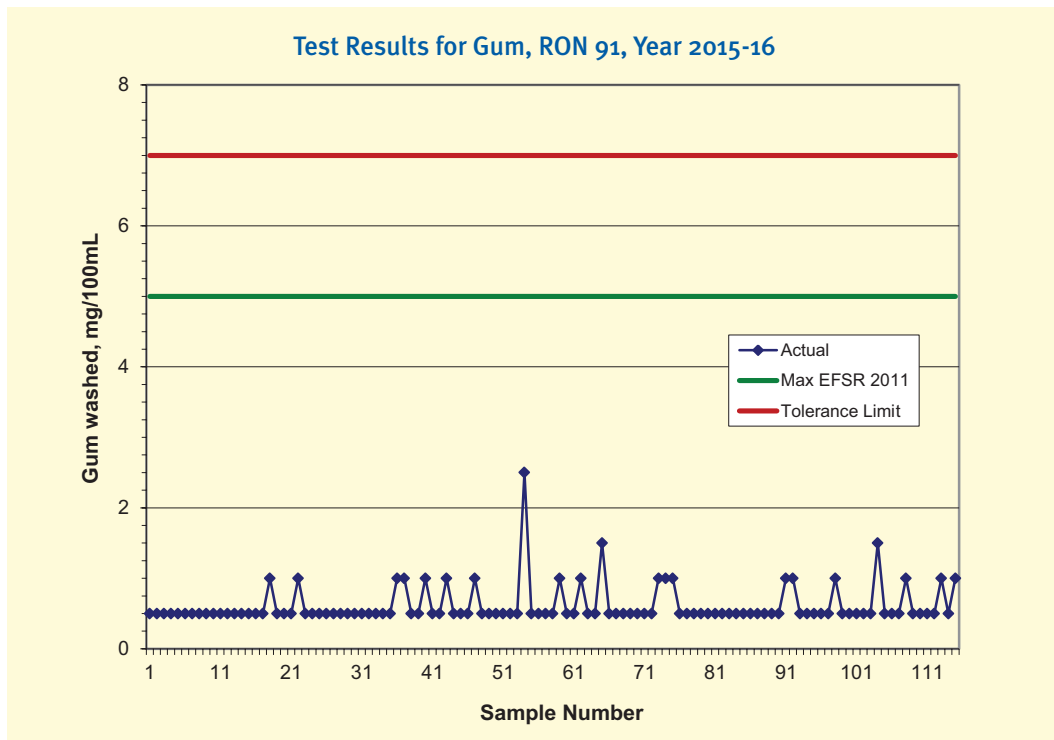
The threshold of the test method ASTM D381<sup>16</sup> prescribed in the Regulations, is 0.5 mg/100mL. Accordingly, the lowest line of testing results as prescribed by this method is 0.5 mg/100mL where the actual figures were found to be on or below this indicative level at the specified

maximum limit of 5 mg/100mL. The tolerance limit is 7.0 mg/100mL.

For regular petrol, all results except one were found to be not higher than 2 mg/100mL with the largest result of 2.5 mg/100mL for Sample 54 (Fig. 12a).

## RON 91

Fig. 12a

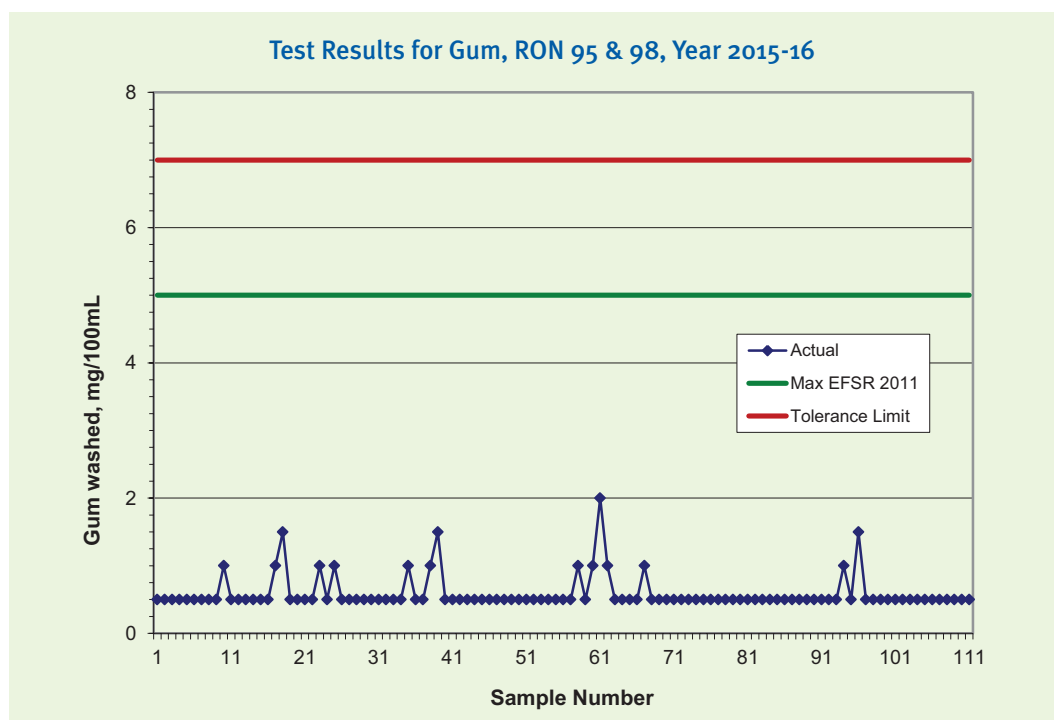


<sup>16</sup> ASTM D381-12 Standard Test Method for Gum Content in Fuels by Jet Evaporation.

## RON 95 & 98

For premium petrol, all results were found to be not higher than 2 mg/100mL (Fig. 12b).

Fig. 12b



## Other Specification Parameter Testing

Testing and analysis, at a lower frequency, was also conducted on other parameters and properties prescribed in the Regulations. This included screening for the content of contaminants which are not expected to be present in fuel: lead, manganese and phosphorus. This is done by means of an initial identification of their presence on the threshold of resolution by each relevant method. These tests' results have not been included in this report as they were usually found to be below the threshold and well within the specification limits.

Testing for oxidation stability has been done with a special testing frequency of three tests per month in the period from December 2015 to June 2016. All results were found to invariably exceed the specified induction period of 360 minutes, *i.e.* tests were usually stopped when the induction time period would exceed the tolerance limit of 381 minutes.

The ethanol content in petrol blends was also tested and found to be within the testing tolerance limit. All results for samples with the marked ethanol content of 10%<sup>17</sup>, are set out in a Table 2 below.

<sup>17</sup> ASTM D4815-15a Standard Test Method for Determination of MTBE, ETBE, TAME, DIPE, tertiary-Amyl Alcohol and C<sub>1</sub> to C<sub>4</sub> Alcohols in Gasoline by Gas Chromatography.

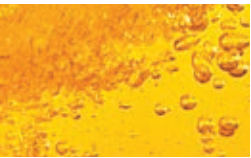


Table 2

Sample	6	10	14	37	42	65	72	76	79	97
Ethanol Content, % Vol	8.94	9.99	9.92	9.78	9.83	10.12	9.76	10.00	9.75	10.00

Eight of them were found to be within the prescribed limit for ethanol blends. Sample 76 was found to be on the specification limit. Samples 65 and 97 were tested for ethanol content twice by the same operator each, with 10.12% being the average of two identical results for Sample 65 and 10.00% being the

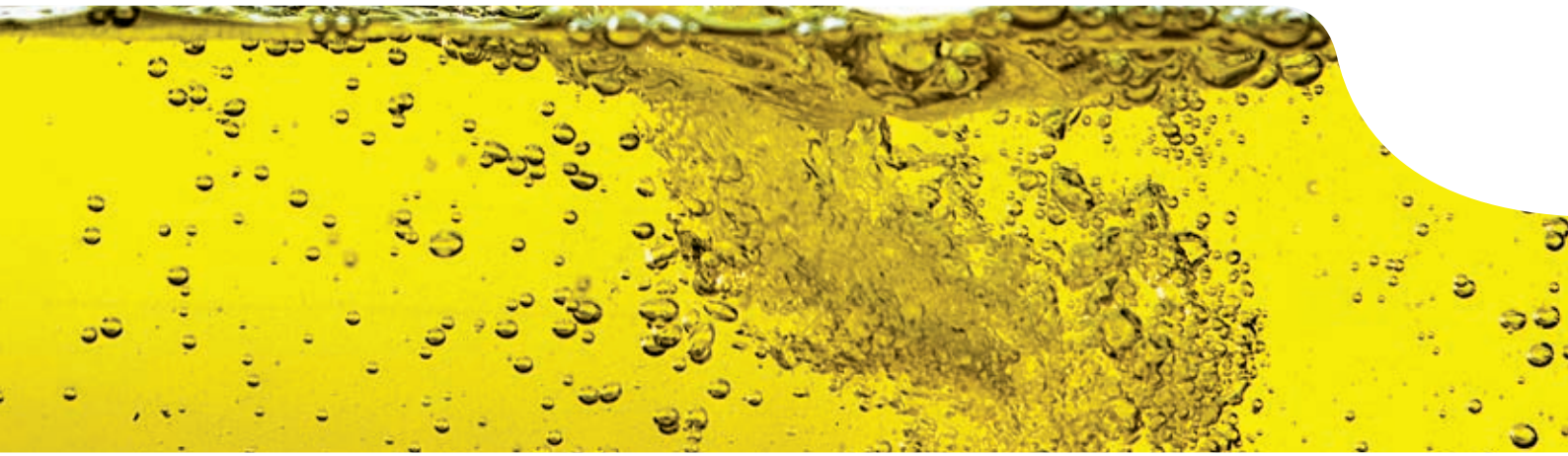
average of two results, 10.08 and 9.92%, for Sample 97, at the testing tolerance limit of 10.49%. Sample 65 was found to be below the testing tolerance limit so, according to the established policy, it was deemed to be compliant.

### Summary for Petrol Test Results

All petrol samples except two were found to be within or on the specification limit.

There were only two suspected non-compliance cases related to samples of premium petrol where the ethanol content initially was found to be above the specified limit of 10% with actual figures of 10.12% and 10.08%. One of this samples was found

to be outside specification after subsequent additional testing and analysis however the average of 10.12% was within the testing tolerance limit of 10.49%. Another average result was found to be on the specification. Therefore the product was deemed to be compliant in both instances.



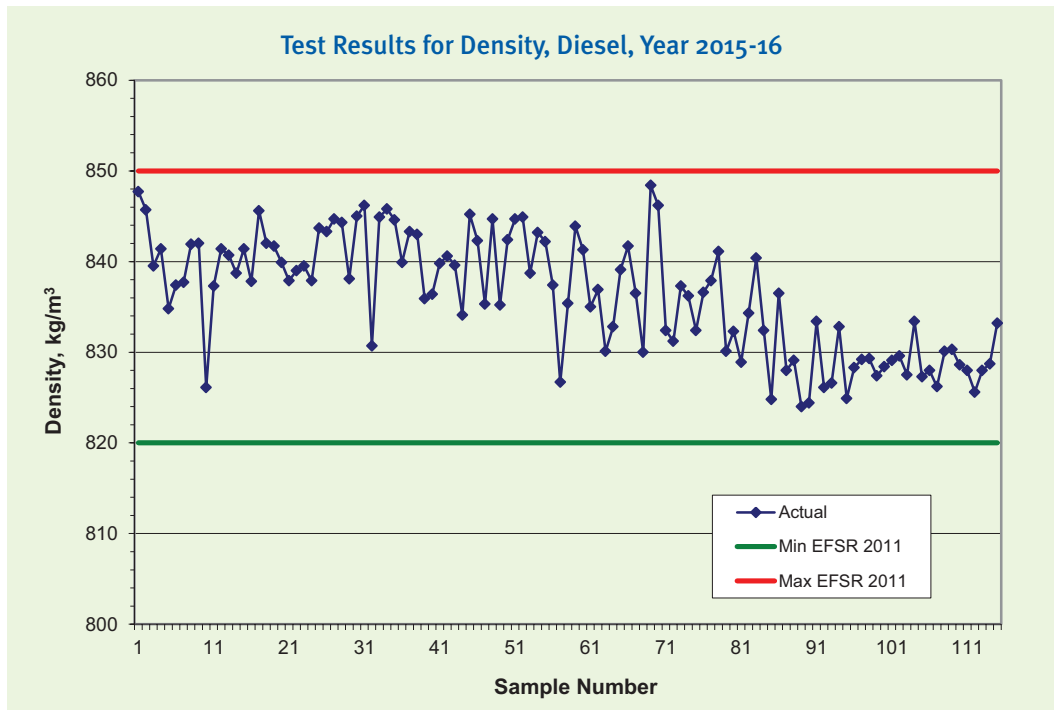
# Diesel

## Density

Density of diesel at 15°C can be tested according to ASTM D1298<sup>18</sup> or ASTM D4052<sup>19</sup> prescribed in the Regulations. Respectively, there are two pairs of tolerance limits identified using the two methods for the minimum limit of 820 kg/m<sup>3</sup> and for the maximum limit of 850 kg/m<sup>3</sup>.

All results were found to be well within the specification limits with the minimum figure of 824.0 kg/m<sup>3</sup> for Sample 89 at the minimum tolerance limit of 819.7 kg/m<sup>3</sup> and the maximum figure of 848.4 kg/m<sup>3</sup> for Sample 69 at the maximum tolerance limit of 850.3 kg/m<sup>3</sup> for ASTM D4052-2015 which was used throughout the period of this report.

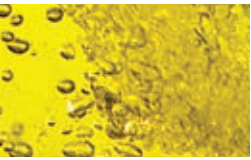
Fig. 13



<sup>18</sup> ASTM D1298-12b Standard Test Method for Density, Relative Density, or API Gravity of Crude Petroleum and Liquid Petroleum Products by Hydrometer Method.

<sup>19</sup> ASTM D4052-15 Standard Test Method for Density, Relative Density, and API Gravity of Liquids by Digital Density Meter.





## Distillation

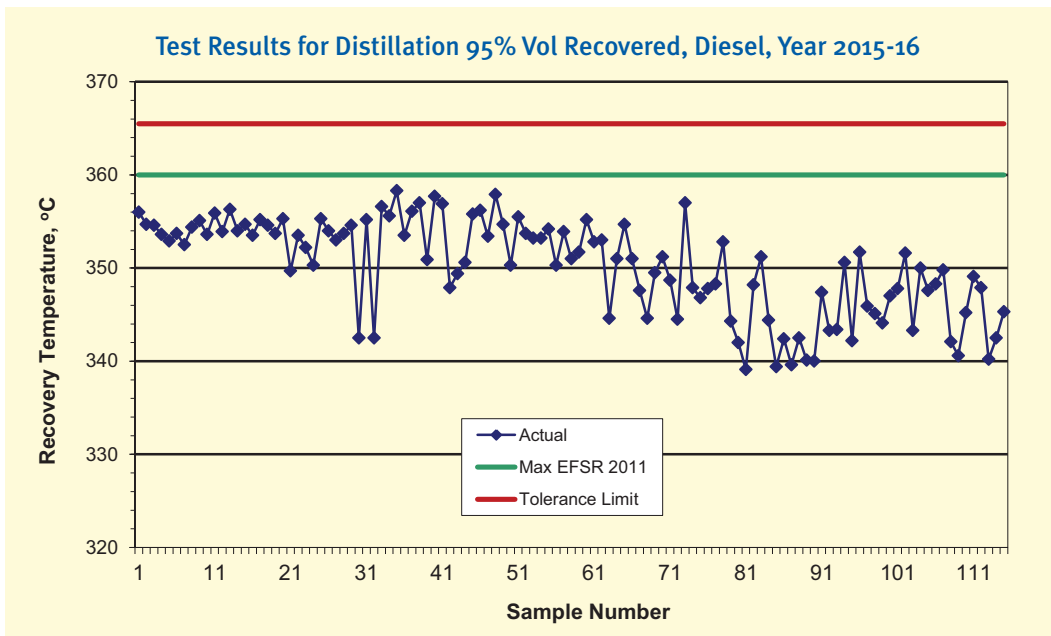
The Distillation test means definition of temperature (°C) at which 95% volume is recovered. The temperature should be tested by ASTM D86<sup>20</sup> prescribed in the Regulations.

All samples were found to be below the specification maximum limit of 360°C for distillation at 95% volume recovered (T<sub>95</sub>).

Sample 35 was found to be the closest to the limit with the actual result of 358.3°C (Fig. 14). The tolerance limit is 365.5°C.

Sample 24 was found to be the lowest with the actual figure of 340.7°C although there is no prescribed minimum limit for this property.

Fig. 14



<sup>20</sup> ASTM D86-16a Standard Test Method for Distillation of Petroleum Products at Atmospheric Pressure.

## Cetane Index

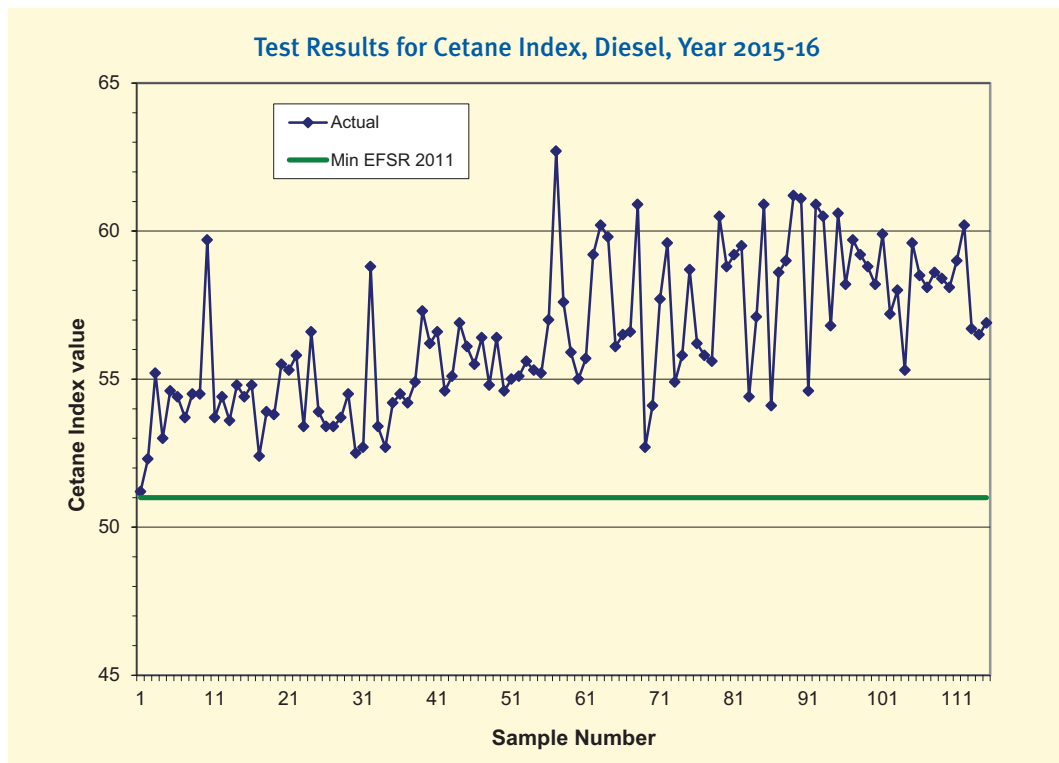
The cetane index, according to ASTM D4737<sup>21</sup> prescribed in the Regulations, is not tested for but calculated from density and distillation recovery temperature measurements. The calculated cetane index is a tool for estimating cetane number when a test engine for determining cetane number is not available and/or cetane improvers are not used.

All samples were found to be above the minimum limit of 51 (Fig.15).

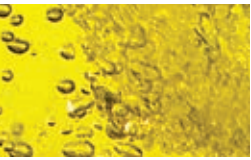
Sample 1 was found to be the lowest with the actual figure of 51.2.

Since the reproducibility for cetane index is not defined in the ASTM D4737, it is impossible to exactly define a tolerance limit. However, the Standard specifies that 'the expected error of prediction of Procedure A will be less than  $\pm 2$  cetane numbers for 65% of the distillate fuels evaluated'. On these grounds, an estimate for the tolerance limit would be derived as 49.8.

Fig. 15



<sup>21</sup> ASTM D4737-10 Standard Method for Calculated Index by Four Variable Equation.



## Water

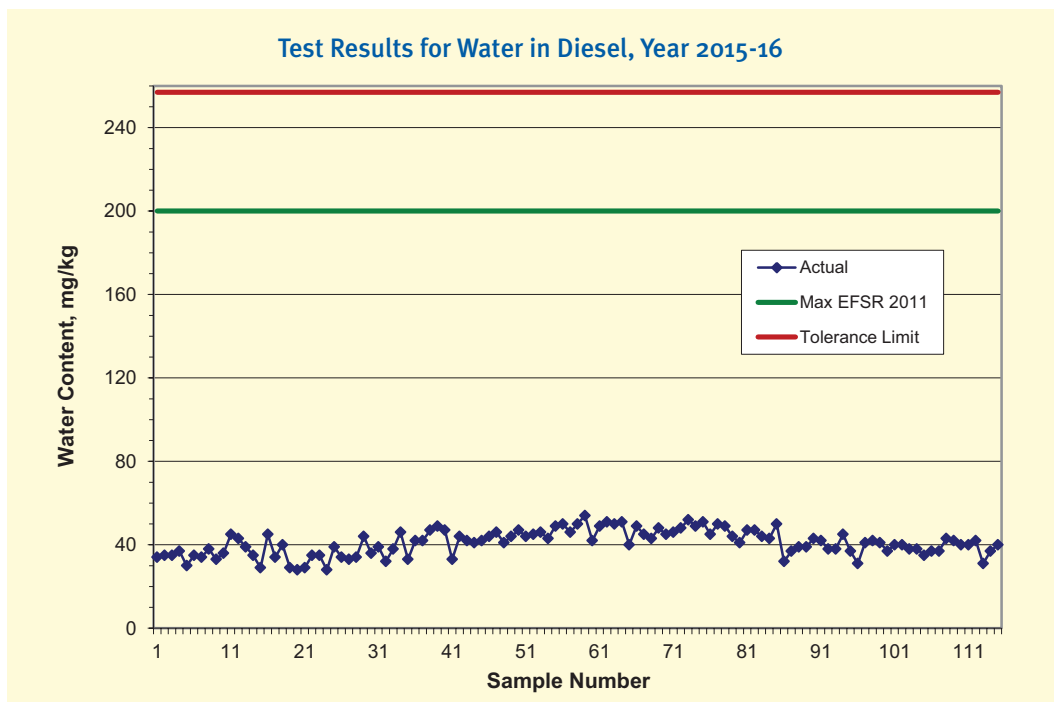
The test for water content is done according to IP 438<sup>22</sup> which determines the total water present in diesel sample held either in solution or in solution and free water.

Water is soluble to some extent in hydrocarbons. The amount of water that is held in solution will be dependent on the temperature and the composition of the hydrocarbon. At typical ambient temperatures

in New Zealand the expected concentration of water dissolved in diesel, is around 30 to 40 mg/kg.

The water content in all the tested samples was found to be well within the specification limit of 200 mg/kg with actual testing results not exceeding 60 mg/kg. Sample 59 was found to be the largest with the results of 54 mg/kg.

Fig. 16



<sup>22</sup> BS EN ISO 12937:2001, BS 2000-438:2001. Petroleum products. Determination of content. Coulometric Karl Fischer titration method.

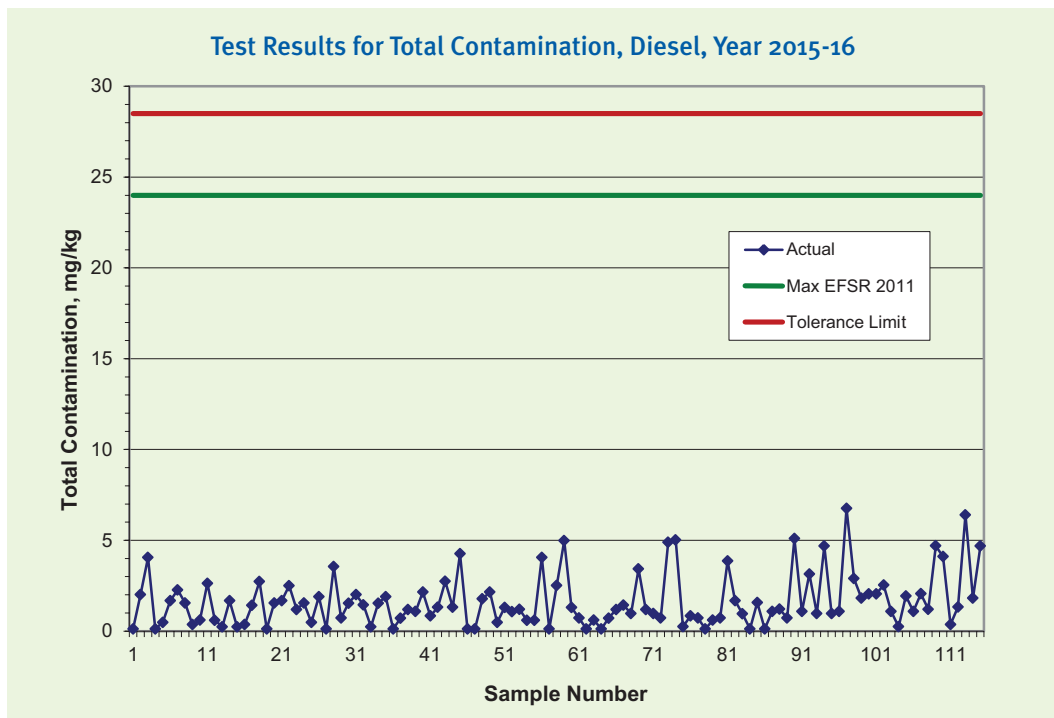
## Total Contamination

The Total Contamination should be tested by IP440<sup>23</sup> prescribed in the Regulations.

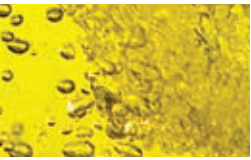
Regulations (Fig. 17). The tolerance limit is 28.5 mg/kg.

All samples were found to be well below the maximum limit of 24 mg/kg specified in the

Fig. 17



<sup>23</sup> BS EN 12662:2014, BS 2000-440:2014. *Liquid petroleum products. Determination of total contamination in middle distillates, diesel fuels and fatty acid methyl esters.*



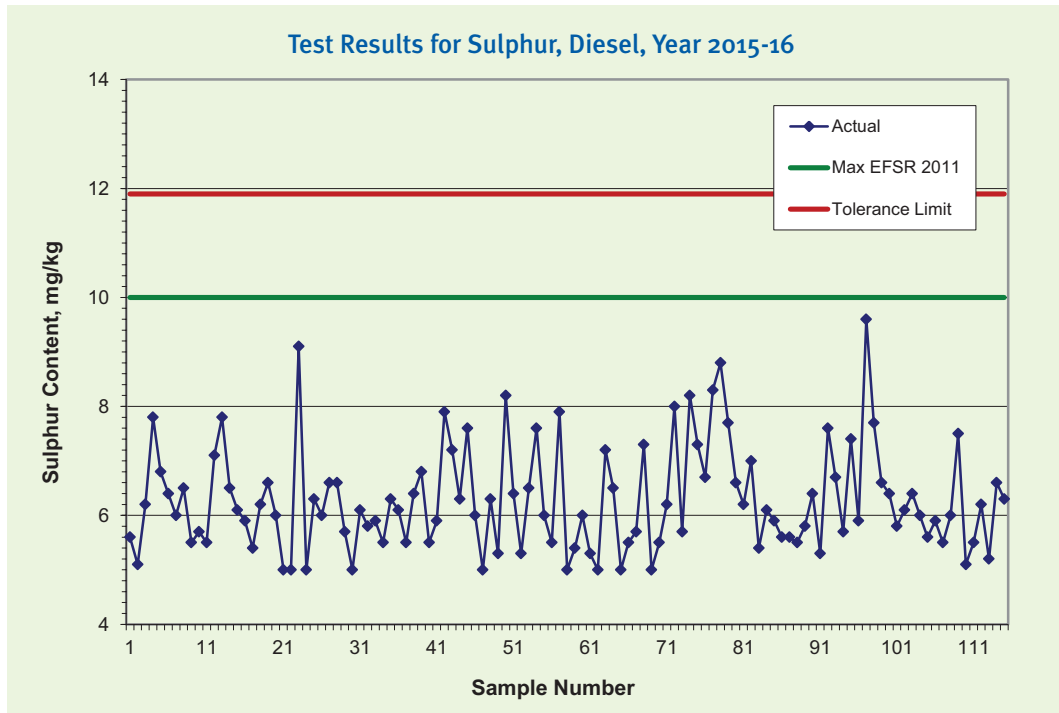
## Sulphur

Sulphur content can be tested according to IP 497<sup>24</sup> or ASTM D5453<sup>25</sup> prescribed in the Regulations. Respectively, there are two slightly different tolerance limits identified for the two methods: 11.8 mg/kg for IP497:2011 and 11.9 mg/kg for D5453-12.

All samples were found to be below the maximum limit of 10 mg/kg specified in the Regulations (Fig. 18).

Sample 97 was tested by IP497 and was initially found to be 10.3 mg/kg at the tolerance limit of 11.8 mg/kg for a single test. The tests repeated by the same operator returned the figure of 8.9 mg/kg with the repeatability condition satisfied,  $r=1.9$  mg/kg. A corrected tolerance limit for two results is 11.6 mg/kg. The average of 9.6 mg/kg was found to be on the specification.

Fig. 18



<sup>24</sup> BS EN ISO 20884:2011, BS 2000-497:2011 Petroleum products. *Determination of sulfur content of automotive fuels — Wavelength-dispersive X-ray fluorescence spectrometry.*

<sup>25</sup> ASTM D5453-12 *Standard Test Method for Determination of Total Sulfur in Light Hydrocarbons, Spark Ignition Engine Fuel, Diesel Engine Fuel, and Engine Oil by Ultraviolet Fluorescence.*

## Cloud Point

Cloud point of diesel should be tested according to ASTM D5773<sup>26</sup> prescribed in the Regulations.

The cumulative results for Cloud Point (CP) are presented below by combining the lowest prescribed maximum limits for each season in one graph (Fig.19). Generally, if results were below the lowest maximum limit established for an area they definitely complied with the Regulations in all other areas.

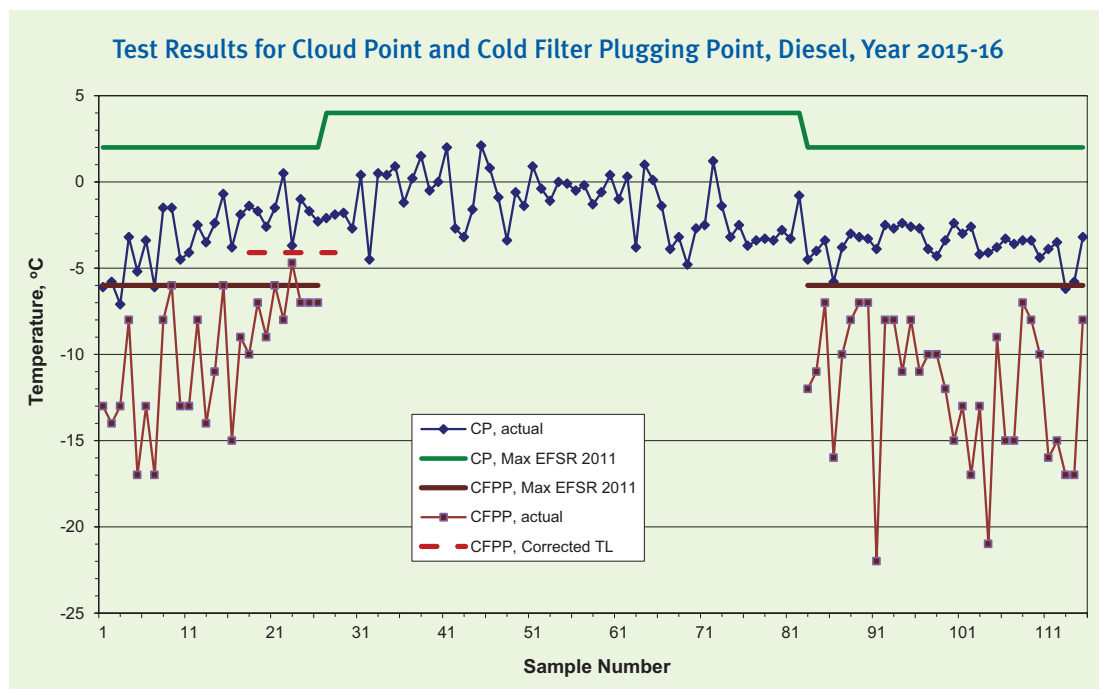
For the period of summer in Schedule 2 (season definitions in Section 5, the Regulations) from 15 October to 14 April inclusive, the lowest maximum limit of CP +4°C is prescribed for all New Zealand excluding Auckland and Northland.

The bottom line before and after the pedestal, is the next lowest maximum, +2°C, which is prescribed for all New Zealand in winter, from 15 April to 14 October inclusive. The maximum limit prescribed for summer in Auckland and Northland, is +6°C and not shown in the graph. All tolerance limits are 0.5°C above each specified limit.

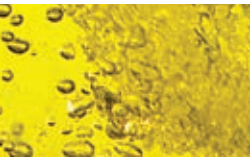
All samples within the relevant seasons appeared to be below the lowest maximum limit. Sample 45 returned the highest testing result for summer, +2.1°C, at the maximum limit of +4°C.

The lowest figure for CP was found to be -7.1°C for Sample 3 from Northland.

Fig. 19



<sup>26</sup> ASTM D5773-15 Standard Test Method for Cloud Point of Petroleum Products (Constant Cooling Rate Method).



## Cold Filter Plugging Point

Cold filter plugging point of diesel should be tested according to IP309<sup>27</sup> prescribed in the Regulations.

The test results for Cold Filter Plugging Point (CFPP) are set out on the same graph as that for CP (Fig.19). This gives an advantage to see the data 'at glance' and compare the two sets where necessary.

CFPP is defined only for the winter season with maximum limit of  $-6^{\circ}\text{C}$ .

All samples except one were found to be below the maximum limit specified in the Regulations for the winter season. Samples 9, 15 and 21 were found to be on the limit.

Sample 23 was initially found to be  $-4^{\circ}\text{C}$ , *i.e.* on the tolerance limit of  $-4.0^{\circ}\text{C}$  for a single test. The tests repeated by the same operator again returned the figure of  $-4^{\circ}\text{C}$  with the repeatability condition obviously satisfied,  $r=1.3^{\circ}\text{C}$ . This result was found to be marginally above the maximum tolerance limit, with the corrected tolerance limit for two results of  $-4.1^{\circ}\text{C}$ . Since the test was repeated not immediately after the initial testing, another operator also repeated the test with the result of  $-6^{\circ}\text{C}$ , with the reproducibility condition satisfied,  $R=3.3^{\circ}\text{C}$ . On investigation it was found that the average of the three results,  $-4.7^{\circ}\text{C}$ , was below the testing tolerance limit of  $-4^{\circ}\text{C}$  so, according to the established policy, Sample 23 was deemed to be compliant.

Sample 91 was found to have the lowest CFPP of  $-22^{\circ}\text{C}$  with a result for CP of  $-3.9^{\circ}\text{C}$ .

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<sup>27</sup> BS EN 116:2015, BS 2000-309:2015 *Diesel and domestic heating fuels. Determination of cold filter plugging point. Stepwise cooling bath method.*

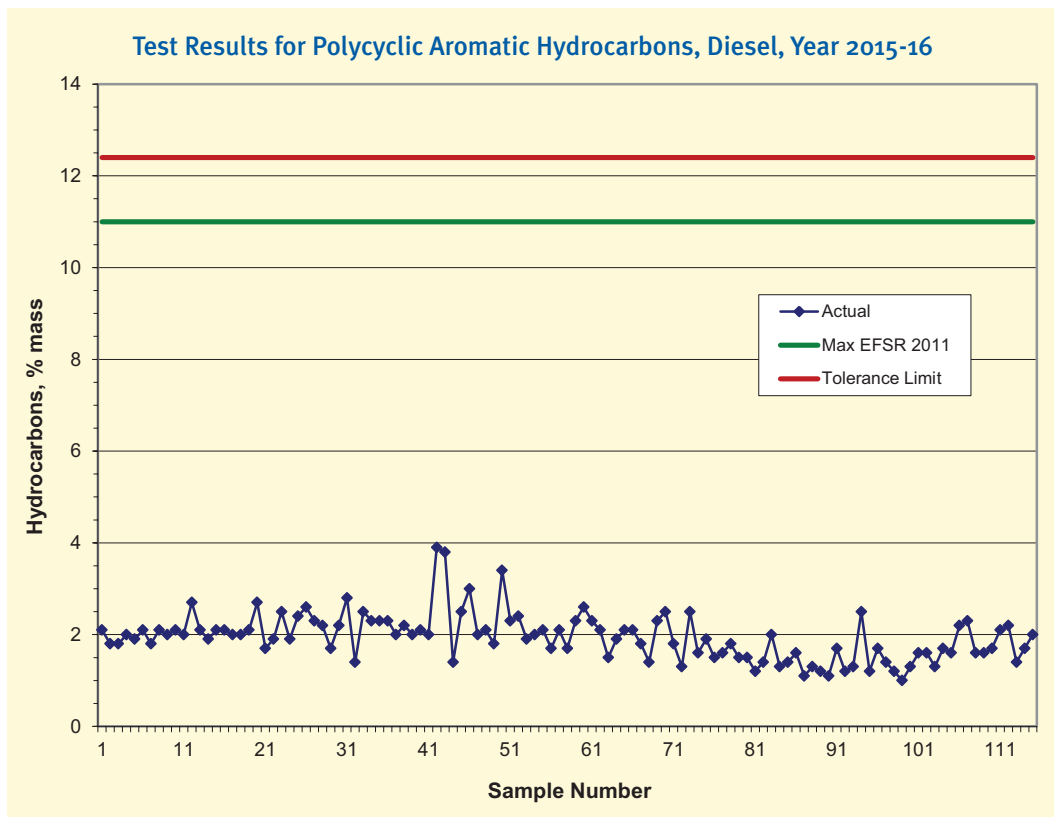
## Polycyclic Aromatic Hydrocarbons

Polycyclic aromatic hydrocarbons should be tested by IP391<sup>28</sup> prescribed in the Regulations.

All testing results were found to be below 4% at the tolerance limit of 12.4%.

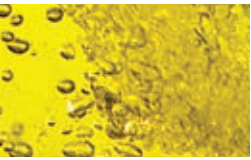
All samples were found to be well below the maximum limit of 11% specified in the Regulations.

Fig. 20



<sup>28</sup> BS EN 12916:2006, BS 2000-391:2006 *Petroleum products. Determination of aromatic hydrocarbon types in middle distillates. High performance liquid chromatography method with refractive index detection.*





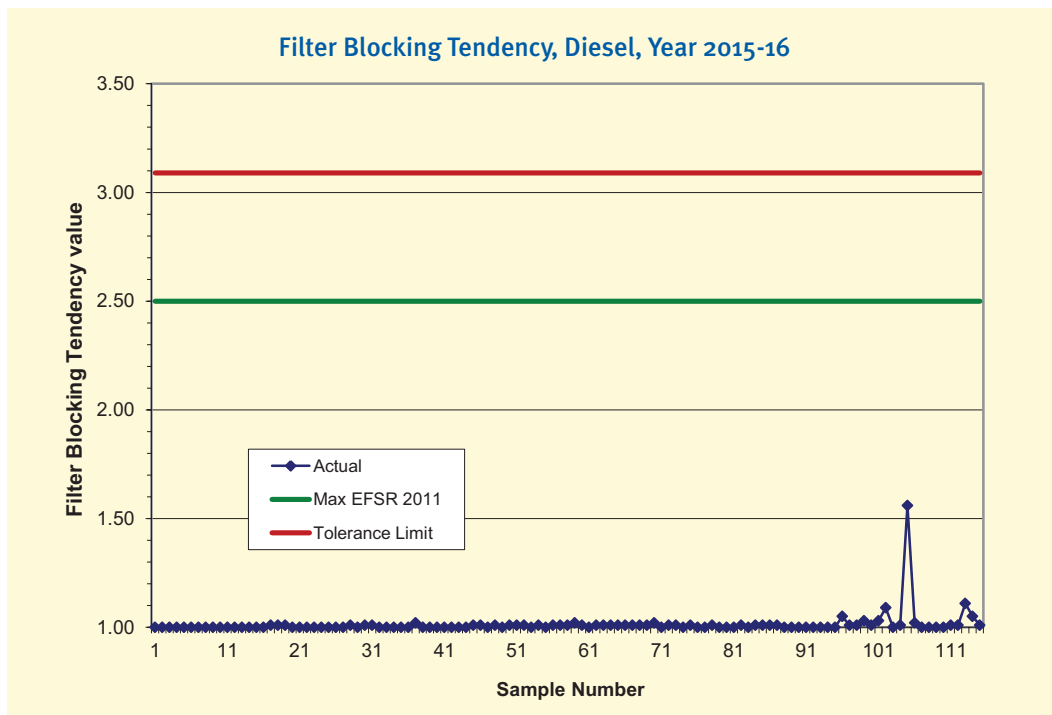
## Filter Blocking Tendency

Filter blocking tendency can be tested by IP387<sup>29</sup> or ASTM D2068<sup>30</sup> prescribed in the Regulations.

All samples were found to be within the specified maximum limit of 2.5 for filter

blocking tendency at the tolerance limit of 3.09. Further, all actual figures except two were in the range from 1.00 to 1.10 which means practically perfect filtering of the product. Samples 105 and 113 were found to be respectively to 1.56 and 1.11.

Fig. 21



<sup>29</sup> IP 387:2014 Determination of filter blocking tendency.

<sup>30</sup> ASTM D2068-14 Standard Test Method for Determining Filter Blocking Tendency.

## Lubricity

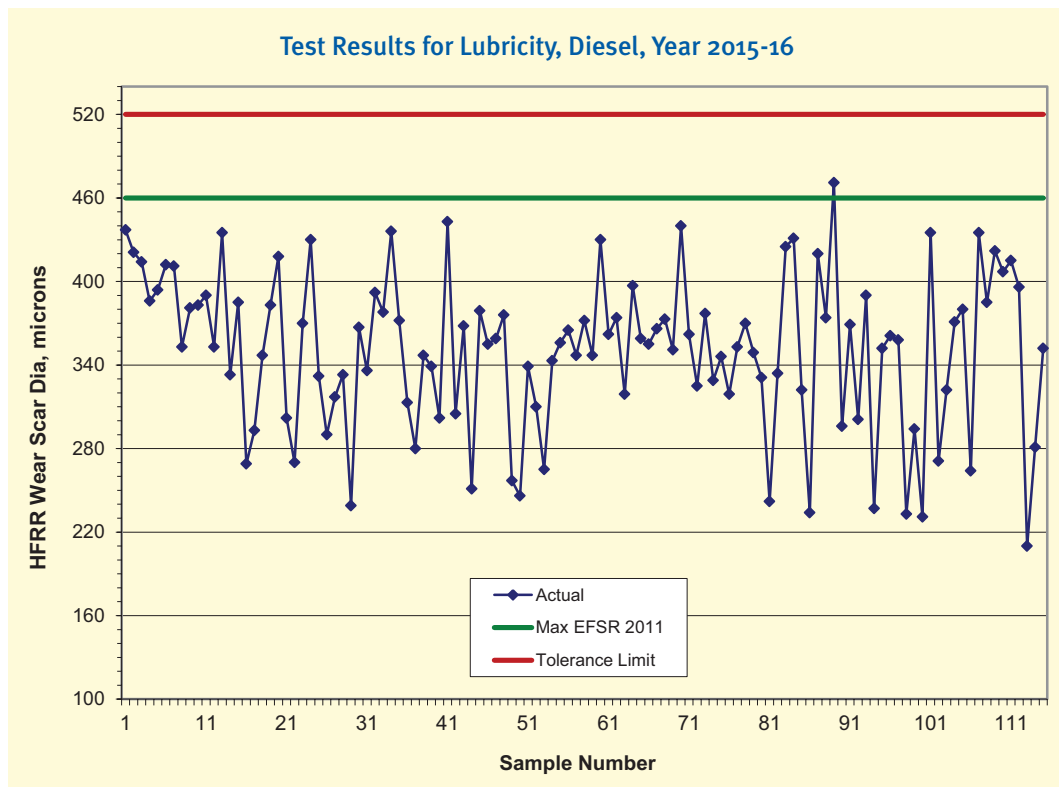
Lubricity should be tested by IP450<sup>31</sup> prescribed in the Regulations.

All samples except one were found to be below the specification maximum limit for the lubricity identified as a diameter of the wear scar produced on an oscillating ball from contact with a stationary plate immersed in the fluid. The diameter is usually measured in microns: the specification maximum limit is 460  $\mu\text{m}$ . The tolerance limit is 520  $\mu\text{m}$ .

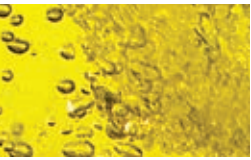
Two exceptions were Samples 87 and 89 which were initially found to be respectively 461 and

469  $\mu\text{m}$ , *i.e.* above the specification limit although within the test tolerance limit *i.e.* well below 520  $\mu\text{m}$ . The tests repeated by another operator returned for Sample 87 the figure of 380  $\mu\text{m}$ , and respectively for Sample 89 the figure of 474  $\mu\text{m}$ , with the reproducibility condition satisfied in both cases,  $R=102 \mu\text{m}$ . The average of 420  $\mu\text{m}$  for Sample 87 was found to be on the specification while the average of 471  $\mu\text{m}$  for Sample 89 was found to be above the specification but well within the tolerance limit therefore Sample 89 was also interpreted as compliant.

Fig. 22



<sup>31</sup> BS 2000-450:2000 *Methods of test for petroleum and its products. Diesel fuel. Assessment of lubricity using the high-frequency reciprocating rig (HFRR). Test method.*



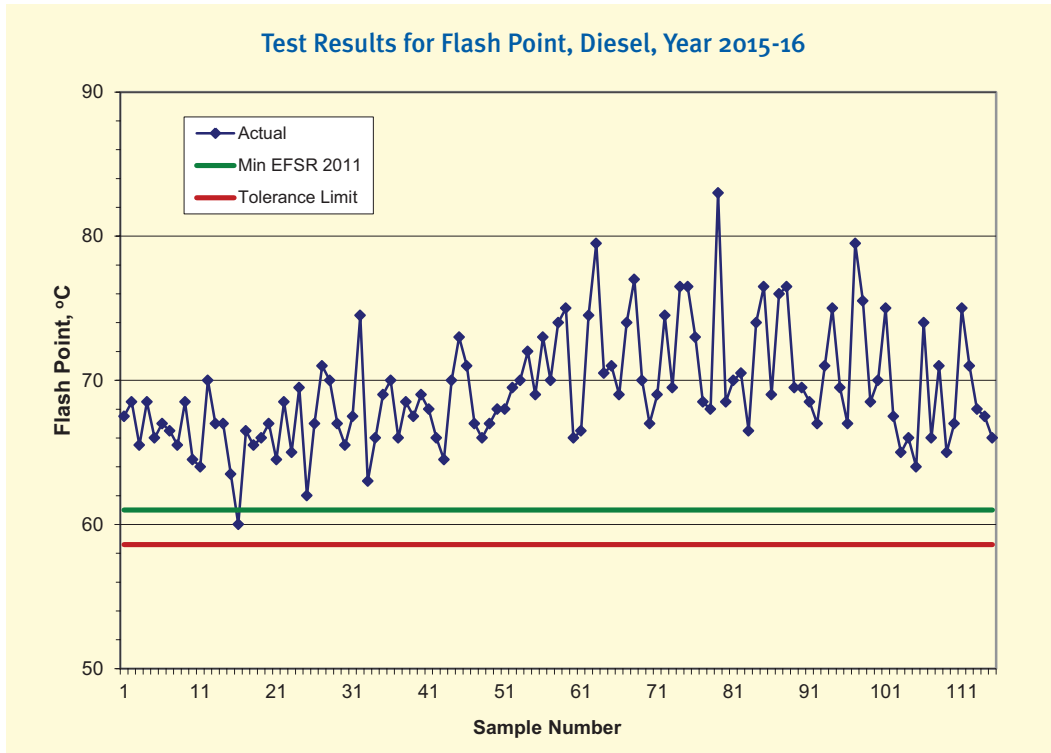
## Flash Point

Flash point should be tested by ASTM D93<sup>32</sup> prescribed in the Regulations.

All samples except one were found to be well above the specified minimum limit of 61°C for flash point of diesel. The tolerance limit is 58.6°C.

Sample 16 was initially found to be 60.0°C at the tolerance limit of 58.6°C for a single test. The tests repeated by the same operator returned the same figure of 60.0°C, with the repeatability condition obviously satisfied,  $r=1.7^{\circ}\text{C}$ . A corrected tolerance limit for two results is also approx. 58.6°C. On investigation it was found that the average of 60.0°C was above the testing tolerance limit so, according to the established policy, Sample 16 was deemed to be compliant.

Fig. 23



<sup>32</sup> ASTM D93-15a Standard Test Methods for Flash Point by Pensky-Martens Closed Cup Tester.

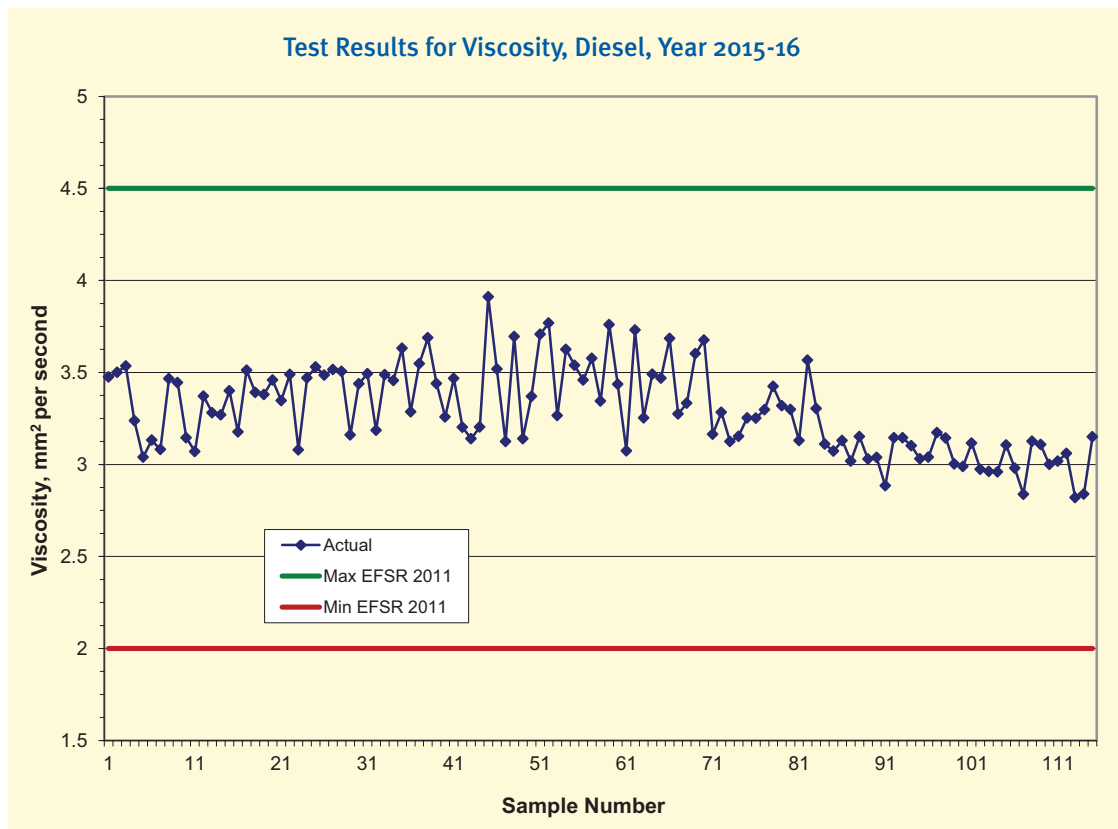
## Viscosity

The viscosity should be tested at 40°C by ASTM D445<sup>33</sup> prescribed in the Regulations.

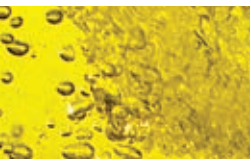
All samples were found to be well above the specified minimum limit of 2.0 mm<sup>2</sup> per second and below the specified maximum limit of 4.5 mm<sup>2</sup> per second for viscosity of diesel.

The vast majority of the test results were in the range between 3.0 and 4.0 mm<sup>2</sup> per second with the minimum result of 2.820 mm<sup>2</sup> per second for Sample 113 and the maximum result of 3.911 mm<sup>2</sup> per second for Samples 45. The minimum tolerance limit is 1.974 mm<sup>2</sup> per second and the maximum tolerance limit is 4.559 mm<sup>2</sup> per second (not shown on Fig.24).

Fig. 24



<sup>33</sup> ASTM D445-15 Standard Test Method for Kinematic Viscosity of Transparent and Opaque Liquids (and Calculation of Dynamic Viscosity).



## Summary for Diesel Test Results

There were five suspected non-compliance cases.

One suspect non-compliant sample detected during the period of this report related to a sample of diesel where the sulphur content on investigation was initially found to be above the specified limit of 10 mg/kg with an actual figure of 10.3 mg/kg. This sample was found to be on the specification after subsequent additional testing.

Another suspect non-compliant sample related to a sample of diesel where the cloud filter plugging point on investigation was initially found to be on the tolerance limit of  $-4^{\circ}\text{C}$ . The test was repeated by the same operator and by another operator with the results respectively of  $-4^{\circ}\text{C}$  and  $-6^{\circ}\text{C}$ . This sample was found to be outside specification after subsequent additional testing and analysis however the average of three results of  $-4.7^{\circ}\text{C}$  was within the maximum tolerance limit of  $-4^{\circ}\text{C}$  therefore the product was deemed to be compliant.

Other two suspect non-compliant samples detected during the period of this report related to samples of diesel where the lubricity on investigation was initially found to be above the specified limit of  $460\ \mu\text{m}$  with actual figures of 461 and  $469\ \mu\text{m}$ . The first sample was found to be on the specification after additional testing while the second sample was found to be outside

specification after subsequent additional testing and analysis however the average of  $471\ \mu\text{m}$  was well within the tolerance limit of  $520\ \mu\text{m}$  therefore the product was deemed to be compliant.

Finally, one suspect non-compliant sample related to a sample of diesel where the flash point on investigation was initially found to be below the specified limit of  $61^{\circ}\text{C}$  with an actual figure of  $60^{\circ}\text{C}$ . This sample was found to be outside specification after subsequent additional testing and analysis however the average of  $60^{\circ}\text{C}$  was above the corrected tolerance limit of  $58.6^{\circ}\text{C}$  therefore the product was deemed to be compliant.

Testing for oxidation stability has been done with a special testing frequency of three tests per month in the period from December 2015 to June 2016. All results were found to be well within the maximum specified limit of  $25\ \text{g}/\text{m}^3$ , with actual figures not exceeding  $1\ \text{g}/\text{m}^3$ .

This year, testing diesel for appearance according to the ASTM standard D4176<sup>34</sup> which is not listed in the Regulations, was continued. This was done in order to maintain confidence that water in bulk and/or other contamination, if present, would be identified. No test results were found to be suspect on appearance.

<sup>34</sup> ASTM D4176-04(2014) *Standard Test Method for Free Water and Particulate Contamination in Distillate Fuels (Visual Inspection Procedures)*.



## Biofuels

### Summary of Testing

Various fuels such as biodiesel as well as ethanol blended petrol, were tested throughout the period of this report. As in previous annual reports, not all actual results are shown due to the commercial sensitivity of the data.

### Retail Fuel Sampling and Testing

#### *Biodiesel B5*

Like last year, this blend was tested six times throughout the year at retail sites. The product falls into the category of diesel by definition in the Regulations, with FAME (Fatty Acid Methyl Esters) content up to 5%. All samples were found compliant with the relevant specifications in the Regulations.

#### *Ethanol blended petrol E3 and E10*

This year, a project on ethanol blended petrol was continued with the intention to verify that blended petrol was within specifications. It was focussed on dry vapour pressure in particular because some samples had in the past been found outside specification. Nine samples of regular petrol blended with ethanol and labelled as E3 and 17 samples of premium petrol blended with ethanol and labelled as E10, were sampled and tested from the retail sites of two fuel retail companies.

The overall result of this project was that the dry vapour pressure was found within the prescribed specifications, for all the samples.

#### *Ethanol blended petrol E85*

Four retail sites in New Zealand now offer fuel ethanol *i.e.* blend with an ethanol content from 70 to 85% labelled as E85. This product is mainly intended for motor sport cars and its dispenser is distinctively labelled to differentiate the product from traditional retail fuels. Fuel for motor vehicle racing is exempt from the Regulations although there are flexible fuel vehicles available in New Zealand which are able to use E85.

Since the E85 dispensers at these sites are accessible to the public, and therefore the product available to retail customers, it was deemed prudent to test its properties.

Currently, parameters for E85 blends are not specified in the Regulations although they are currently under consideration by the government to be included in the updated Regulations. Since this type of fuel is specified by the Standard ASTM D5798<sup>35</sup> this standard was temporarily chosen as an indicative standard for the list of properties to be tested. Five samples taken during the report period were all found to be above the prescribed maximum specifications according to ASTM D5798, with the ethanol content from 85.32% to 86.88%, with the provisional tolerance limit of 85.64%. This information was passed over to the company with a recommendation to adopt the specification limit which is going to be likely prescribed in the updated Regulations. In two follow-up sampling and testing instances it was found that ethanol content was below 85.0%.

<sup>35</sup> ASTM D5798-15 *Standard Specification for Ethanol Fuel Blends for Flexible-Fuel Automotive Spark-Ignition Engines.*



## Non-Retail Fuel Sampling and Testing

This year, the Ministry continued sampling and testing biodiesel, in particular, B100 (pure biodiesel) and B10 as well as B20 (10% or 20% blend with mineral diesel). Biodiesel B100 was tested according to the requirements of Schedules 3 in the Regulations while B10 blend was tested according to the Regulation 17.

In total, eight samples of biodiesel were collected from production plants or non-retail refuelling sites and tested. These include four samples of B100 and four samples of B10.

### *Biodiesel B100*

Problems with accurate measurement of FAME content remained in the focus of the testing programme. The Ministry in collaboration with IPL continues to contribute to the on-going review of the standard by international standard committees such as CEN and ISO. One sample out of three was found to be below the specified minimum limit but within the tolerance limit.

In the recent past, total contamination had often been found above the specified maximum limit. This year total contamination was found to be on specification in two out of three instances. Corrective actions were implemented by the producer in the instance when the parameter was found above the specification.

Further, total acid number was once found to be above the specified maximum limit but well within the testing tolerance limit.

### *Biodiesel B10 and B20*

These blends were considered to be a final product supplied to customers and therefore the properties listed in Regulation 17 were tested along with a few additional properties such as the filter blocking tendency. Filter blocking tendency is deemed to be an essential parameter for the product to be 'fit for purpose'.

Two samples of B10 and two samples of B20 were collected either at the plant dispenser or at the non-retail point of sale.

In all instances the FAME content was found to be within the stated maximum of 10% with the actual figures of 9.1% and 8.4% for B10 samples and, respectively, 19.5% and 18.2% for B20.

The filter blocking tendency for B10 samples was found to be 1.11 and 1.47, and respectively, 1.00 and 1.01 for B20 samples, at the maximum limit of 2.5.

All findings on suspect non-compliance however marginal were discussed with the producers in detail and adjustments to the production processes were identified and implemented.

**NOTE:** It must be noted that none of the potentially non-compliant fuels identified by sampling and testing biofuels ever entered the retail fuel supply chain and they were subject to remedial action by the producers before subsequent release or disposal.

The specifications for properties of biofuels are still under review and development by the international standardisation committees (CEN and ASTM technical committees in particular). The Ministry continues to monitor and contribute to this work to ensure New Zealand has sufficient technical knowledge in this area and our perspectives and issues are represented and considered internationally.

