CRC/EI Research report

The quality of aviation fuel available in the United Kingdom

Annual survey 2015

CRC project AV-18-18

CRC/EI RESEARCH REPORT

THE QUALITY OF AVIATION FUEL AVAILABLE IN THE UNITED KINGDOM ANNUAL SURVEY 2015

October 2022

Published by
Energy Institute, London
The Energy Institute is a professional membership body incorporated by Royal Charter 2003
Registered charity number 1097899

and the
Coordinating Research Council, Inc.
5755 North Point Parkway, Suite 265, Alpharetta, GA 30022

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ISBN 978 1 78725 345 2

Published by the Energy Institute

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ABSTRACT

This report, jointly funded by the Coordinating Research Council (CRC) and the Energy Institute contains a summary of the data relating to the specification properties for AVTUR (Jet A-1) supplied in the United Kingdom during 2015. The data is expressed in the form of histograms and mean values, which are graphically compared over the period 1986–2015. This report is the 38th in a series of survey reports.

1 INTRODUCTION

Surveys relating to the specification properties of aviation turbine fuels supplied in the UK from 1974 onwards have been published annually by the Fuels and Lubricants Centre (FLC[A]).[1–25] This report covers a similar survey for aviation fuel (Jet A-1) supplied during the year 2015, including 1 087 batches complying with Defence Standard 91-91.[26] Historically, this survey was funded by the UK Ministry of Defence (MoD) in support of their specification development activities. In previous years the work was part-funded by the Energy Institute (EI). As the MoD ceased to fund the activity after the 2008 survey was produced, the EI and the CRC have jointly funded the survey in full.

The information contained in this report has been supplied by oil companies and associated test houses for batches of aviation fuel released during 2015. The data has been expressed in the form of histograms and mean values, which are graphically compared over the period of 1986 to 2015. Due to the variation in volume of each fuel batch, the mean values are expressed as weighted means according to the relative fuel volume associated with each data point.

Historically most batches of aviation fuel used for this survey were refined in the UK. However, over time many UK refineries have closed resulting in more finished fuels being imported into the UK. Whilst the data provided does not give exact details on the number of imports, it is expected that a large proportion of the data contained in this survey is from imported batches. Therefore, the data presented is likely to be at least partly representative of aviation fuel available worldwide.

In this survey, the percentage of results near to the specification limits are reported for selected properties, which were chosen for historical reasons (to allow comparisons with previous years) and include some properties that appear to limit aviation fuel production. For the purposes of this report 'near specification limit' results are those that lie within the reproducibility of the method at the specification limit.

This survey also contains a short discussion on each property and how results are changing. Results of interest, such as those that are close to, or outside, specification limits are noted. Other data points of interest, such as the distribution of results are also commented on. Changes and trends may be of interest and importance to specification authors, OEMs, users and refiners, and may be significant even though they do not approach current specification limits. It is expected that this survey will be of most use for specification development and the development of associated test methods.

A The Fuels and Lubricants Centre (FLC) was originally part of the UK Ministry of Defence (MoD), which then became an Agency of the MoD under the names DRA and DERA. The FLC then became part of QinetiQ and has been part of Intertek since 2011.

2 RESULTS

The data reported has been collated from test certificates, or from electronic data supplied by oil companies, for new batches of AVTUR, either produced in or imported into the UK during 2015. The data for all but four of the properties detailed in Defence Standard 91-91 for AVTUR are summarised in tables and figures in the annexes. The data for copper corrosion and thermal stability were not included as most results were identical. Copper corrosion results were typically 1A with a number of 1B results and thermal stability results were typically a <1 tube rating with no pressure drop. All thermal stability results were reported at 260 °C. The data for electrical conductivity was also not included as at the point of testing, the conductivity of many batches was below the specification limits. This is permitted on the condition that Static Dissipater Additive (SDA) is added further downstream to ensure that the conductivity limits are met at the point of delivery into aircraft.[26]

2.1 TABULATED DATA

Table A1 details the specification limits for each property from Defence Standard 91-91 compared to the maxima and minima of the 2015 AVTUR data collected.

2.2 HISTOGRAMS AND TREND GRAPHS FOR ANNUAL MEAN RESULTS

Figure B1 to Figure B49 are histograms and trend graphs. The histograms show the number of batches in each frequency class along with the percentage that this represents of the total number of batches included for that year. The trend graphs show the weighted mean results for each property plotted against year for the period 1986 to 2015.

Where the labels on the x-axis of the histograms refer to a range of results, the label signifies the middle of the range. For example, the x-axis label '10' on the aromatics histogram (Figure B3) includes a range of results from >9 to ≤11.

2.3 GRAPHS OF NEAR SPECIFICATION TRENDS FOR AVTUR PRODUCED FROM 1983 TO 2015

For seven specification properties, Figure B50 to Figure B52 show the percentage of batches that have results near the specification limits, plotted against year for the period 1986 to 2015. The properties the figures relate to are listed here:

– Figure B50 – acidity, aromatics;

– Figure B51 – mercaptan sulphur, flash point, freezing point, and

– Figure B52 – smoke point, naphthalenes.

3 DISCUSSION

In this section significant changes and points of interest for the aviation industry are discussed, as well as providing some details on limitations of the data provided. As already discussed in section 2, the data for thermal stability, copper corrosion and electrical conductivity are not included.

For batches containing more than 95 % hydroprocessed material, of which at least 20 % is severely hydroprocessed, BOCLE results should be reported. However, it was not possible to determine whether a BOCLE test was required for many batches as details about the refining process were not supplied.[B]

As a result, no BOCLE results were reported for the batches used in this survey.

3.1 SAMPLE SIZE

Data from 1 087 batches were included in this survey, representing 9 758 342 m^3 of AVTUR over the period from the start of 2015 to the end of 2015. This includes about 27 000 individual test results.

In some cases, the data in the tables and histograms for some properties have been derived from less than the total number of batches. This can be due to the specification, for various reasons, allowing waivers, or due to the data provided having a small number of results unavailable.

3.2 TOTAL ACIDITY

The volume weighted mean value in 2015 was 0,0046 mg KOH/g and this has been the largest result since 2010 (Figure B2). The percentage of batches 'near specification limit' has also increased to 9 %, the highest since 2012. No long term trends are evident

A number of results were reported as '<0,001' and, for the purposes of this survey, they have been recorded as '0,001'.

3.3 AROMATICS

The volume weighted mean value was 17,5 % v/v in 2015, a small decrease from the previous year. (Figure B3).

Aircraft operators are often concerned about the problems caused by different batches of fuel having large variations in aromatics. The aromatic content ranged from 11,3 % v/v to 24,7 % v/v with more than 99 % of batches in the range 13 % v/v to 25 % v/v. The small

B It should be noted that some of the data supplied for this survey was not in the form of test certificates, but supplied in spreadsheet format. Whilst electronic data does not provide all of the data found on batch test certificates, it does not suggest that the original certificate did not contain the correct information and does not suggest that the fuel did not comply with the requirements of Defence Standard 91-91.

number of batches with very low aromatics (<5 % v/v) that were observed in the 2009 and 2010 surveys were not evident in this data set. The percentage of batches 'near specification limit' decreased to 3 %, the lowest since 2005.

For the purposes of this report, any IP 436 / ASTM D6379 results have been converted to IP156 equivalent data.

3.4 TOTAL SULPHUR

The volume weighted mean value of 0,051 % m/m (Figure B5) showing a small decrease compared to 2014 (Figure B6). There appears to be an upward trend since 1999. However there has been significant variance in the weighted mean values in recent years making it difficult to highlight a definite trend. The total sulphur content also appears to show a multimodal distribution.

Defence Standard 91-91 allows several different methods for determining the sulphur content. Some laboratories use methods that can determine the sulphur content to three decimal places, whereas different methods or older equipment are only capable to report results to two decimal places. The most commonly used test method is IP 336, which is reportable to 0,01 % m/m (with a scope minimum of 0,03 % m/m).[27] Consequently, results for many batches are reported to two decimal places and those with low sulphur contents have been reported as '<0,01 % m/m'. For the purposes for this survey, to remain consistent with previous publications, such results have been recorded without the 'less than' sign.

The use of different methods mean that accurate determination of the sulphur content in batches with low levels of sulphur is not possible, and this – alongside how the results are reported – may have an effect on the apparent weighted mean value.

3.5 MERCAPTAN SULPHUR

Mercaptan sulphur was reported for approximately half of batches as mercaptan sulphur is not required to be reported if the Doctor test is negative. In 2015 the volume weighted mean was 0,0006 % mass, a decrease from the previous year. There appears to be a decreasing trend since 2002 (Figure B8). However, it should be noted that as all batches are not measured for this property, the true mean mercaptan content of jet fuel is likely to be lower than the mean recorded here.

Results for a number of batches showed the mercaptan sulphur content as '<0,001'. For the purposes of this survey, these results have been recorded as 0,001. As mentioned in 3.4, this may influence the weighted mean value.

3.6 DISTILLATION

The volume weighted mean value for Initial Boiling Point (IBP) was 147,9 °C, the lowest result since this record began in 1986 (Figure B9). The mean values in 2015 for 10 % (165,4 °C) (Figure B11), and 50 % (191,2 °C) (Figure B13) recovered are also the lowest recorded. These three properties show a reducing trend.

The 2015 weighted mean value for 90 % recovered of 233,3 °C is the lowest since 1986 and has shown a downward trend in recent years (Figure B16). The Final Boiling Point (FBP) mean of 255,8 °C shows no consistent trend (Figure B18).

Only 10 % recovered and FBP have limits specified, which are 205 °C and 300 °C respectively. All results were within these limits.

Aviation turbine fuels containing synthesized hydrocarbons, in accordance with ASTM D7566,[28] have extended requirements (over ASTM D1655 and Defence Standard 91-91) to ensure a sufficient distillation range.[C] The requirements for T50-T10 is a minimum of 15 °C, and for T90-T10 is a minimum of 40 °C.[D] Of the 1 087 batches in 2015, only one batch would not have met the T50-T10 (after studying other batches produced by this manufacturer around this time, it is the authors opinion that this anomaly is likely to have occurred due to a typing error for the T10 result by the manufacturer). The distribution of T50-T10 and T90-T10 results are shown in Figure B19 and Figure B20.

3.7 FLASH POINT

The volume weighted mean value for flash point was 40,9 °C (Figure B22). This is a 1 % decrease compared to the previous year and the lowest recorded since this record began in 1986. There appears to be a reducing trend in the mean flash point since 1991, but this trend is becoming less pronounced as the mean values approach the specification limit.

The 'near specification limit' analysis for flash point is shown in Figure B51. This year 49 % of batches were 'near specification limit' and, despite a reduction this year, there appears to be a rising trend in the number of flash point results near the specification limit. A precision study in 2008 led to the reproducibility of IP 170 being changed from 1,5 °C to 3,2 °C. Although there has been a reduction in the mean and generally more batches near to the specification limit, the large changes seen in Figure B51 are mostly due to the change in reproducibility.

One batch of fuel was reported with a flash point outside the specification limit (37,5 °C). This may have been typing error, but it was not possible to determine if this was the case.

The data indicate that flash point is a major restraining factor in jet fuel production.

3.8 DENSITY

The volume weighted mean for density was 799,2 kg/m^3 (Figure B23). This continues the decreasing trend observed since 2007. The minimum density was 780,8 kg/m^3. The specification limits are 775 kg/m^3 to 840 kg/m^3.

C It is likely that few, if any, batches included in this survey contained synthetic components. However it is difficult to be certain due to the data received not being complete, with regard to refining processes.

D T10, T50, and T90 are the distillation temperatures at 10 %, 50 %, and 90 % recovered respectively.

3.9 FREEZING POINT

The volume weighted mean value for 2015 was –54,5 °C and is a slight decrease from 2014. Nevertheless, it is one of the lowest values recorded since 1986, from which time there has been a slow downward trend (Figure B26).

The percentage of batches 'near specification limit' during 2015 was 3 %. There appears to be a decreasing trend in the number of batches near the specification limit. However, freezing point appears to be a major restraining factor in jet fuel production for some refineries.

3.10 KINEMATIC VISCOSITY

The volume weighted mean for 2015 was 3.56 cSt, which is the lowest recorded since 1986 (Figure B28). There appears to be a reducing trend in mean viscosity and there has been a significant reduction since 2010.

The specification limit is 8 cSt maximum at -20 °C. However, it should be noted that the industry has been considering more stringent requirements of 12 cSt at -40 °C to benefit Extended-range Twin-engine Operations Performance Standards. This is approximately equivalent to 5,5 cSt at -20 °C. This year there were no batches that exceeded 5,5 cSt, with the maximum result being 4,191 cSt.

3.11 SPECIFIC ENERGY

The volume weighted mean was 43,24 MJ/kg in 2015 and represents little change compared to recent years. Figure B30 shows no particular trend in mean value. Results are almost all between 43,0 MJ/kg and 43,5 MJ/kg. The specification minimum is 42,80 MJ/kg.

3.12 SMOKE POINT

The volume weighted mean for 2015 was 23,4 mm which was a 0,6 % decrease compared to the previous year. The smoke point specification limit was 19 mm minimum. The histogram shows an unusual distribution with regard to the high percentage of results at 25 mm. This may be linked to the specification requirement for the measurement of naphthalenes when the smoke point is less than 25 mm.

3.13 NAPHTHALENES

Not all batches had naphthalenes results reported as the specification only requires the determination of naphthalene content if the smoke point is less than 25 mm.

The mean for 2015 was 1,59 % vol, a 18 % increase from the previous year and the highest result since 2002. There appeared to be a downward trend from 1988 to 2014, but it suggests that this may increase or stabilise over time (Figure B34). The specification limit is 3 % vol maximum.

As naphthalene content is often only reported after a low smoke point result is obtained, the calculated mean value in this report is likely to be higher than the true mean value.

3.14 EXISTENT GUM

For the majority of batches, the existent gum results were reported as 0, <1, or 1 mg/100 ml. For results reported as 0 or <1, a value of 1 has been recorded in the histograms. The 2015 mean value was 1,2 mg/100 ml as shown in Figure B35. The precision for existent gum is very poor; it is likely that all batches contain virtually no gum and the range of results (up to a maximum of 3 mg/100 ml) is due to the test precision. The vast majority of the results are well below the 7 mg/100 ml maximum specification limit. There is no significant trend in mean value for existent gum.

3.15 MICROSEPAROMETER®

The 2015 mean MSEP® value of 91.3, which is a small decrease compared to the previous few years (Figure B38).

The Defence Standard 91-91 limits for MSEP® rating is a minimum of 85 without SDA, or 70 with SDA due to the over sensitivity of the test method to SDA (Stadis 450). This year there were no batches that had MSEP® results outside of the specification limits.

3.16 PARTICULATE CONTAMINATION

This is a relatively new requirement for Defence Standard 91-91 with a maximum limit of 1 mg/l. In this time the volume weighted mean results have been comparable and in 2015 the value was 0,26 mg/l (Figure B40). Results were reported for 68 % of the batches. As many batches were imported fuel, it is assumed that this testing was carried out at the point of manufacture (as required by the specification). There were no results reported outside of the specification limit.

3.17 SAYBOLT COLOUR

Similar to particulate contamination, Saybolt colour is a relatively new requirement for Defence standard 91-91. The 2015 volume weighted mean value was 26,7 and is comparable to results in recent years (Figure B42). For the purposes of this survey, results that were reported as '>30' were recorded as '30'.

3.18 PARTICLE COUNTS

For ease of producing histograms, ISO codes have been used to indicate particle numbers.[E,29] Histograms show the distribution of ISO codes for ≥4 μm, ≥6 μm, ≥14 μm, ≥21 μm, ≥25 μm, and ≥30 μm channels (Figures B43–B48). For low particle counts (and low ISO codes) repeatability is poor and many labs report ISO codes below 7 in a variety of ways. For the purposes of this report any value of less than 7 was recorded as 7.

E According to ISO 4406, codes are applicable to the ≥4μm, ≥6μm, and ≥14μm channels. However, for the purposes of Defence Standard 91-91, codes are reported using the same ISO 4406 coding table, for all six channels.

The mean values are shown in Figure B49 over the period of 2009 to 2015. Despite a slight drop in counts last year, the results for 2015 were comparable to previous years and no trends are apparent. No specification limits for this property have been set at the time of these analyses.

3.19 BOCLE

There were no BOCLE results reported in 2015.

3.20 NEAR SPECIFICATION TRENDS

Figure B50 to Figure B52 are graphs showing the percentage of batches with test results near the specification limit, against each year, for seven specification properties.

The properties with the highest percentage of batches with results near the specification limit in 2015 were flash point (49 %) and smoke point (20 %). It should be noted that the new precision for flash point (IP 170) has significant effects on the number of batches near specification limit as mentioned above.

4 SUMMARY OF CHANGES AND TRENDS

4.1 TREND DATA

Table 1: Properties where the mean value shows increasing or decreasing trends

Properties where the mean value has a rising trend	Properties where the mean value has a decreasing trend
Flash point batches near specification limit (increasing since 1991)	Distillation IBP (decreasing since 1991)
	Distillation 10 % recovery (decreasing since 1991)
	Distillation 50 % recovery (decreasing since 2010)
	Distillation 90 % recovery (decreasing since 1998)
	Flash point (decreasing since 1991)
	Freezing point and freezing point batches near specification limit (decreasing since 1988)
	Viscosity (decreasing since 1991)

4.2 SIGNIFICANT CHANGES IN 2015

Table 2: Significant changes in mean values

Property	Change
Distillation, IBP	Down 3,2 °C since 2010 (mean is at the lowest level since records began in 1986)
Distillation, 10 % recovered	Down 5,7 °C since 2010 (mean is at the lowest level since records began in 1986)
Distillation, 50 % recovered	Down 6,1 °C since 2010 (mean is at the lowest level since records began in 1986)
Flash point	Down 1,7 °C since 2010 (mean is at the lowest level since records began in 1986)
Viscosity	Down 0,35 mm^2/s since 2010 (mean is at the lowest level since records began in 1986)

5 ACKNOWLEDGEMENTS

The author would like to thank the following companies who provided the data used for this survey:

Essar Oil
ExxonMobil
INEOS
Shell
Total

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ANNEX A
RESULTS SUMMARIES

A.1 2015 – DATA FROM 1 087 BATCHES OF JET FUEL REPRESENTING 9 758 342 M^3

Table A.1: Minima and maxima for 2015 data and specification limits

Method	Def Stan 91-91 Specification limits		Results Summary 2015		
	Min	Max	Min	Max	Mean
Total acidity, mg KOH/g	–	0,015	0,000	0,015	0,0046
Aromatics, % volume	–	25,0[H]	11,3	24,7	17,5
Total sulfur, % mass	–	0,30	0,001	0,217	0,051
Mercaptan sulfur, % mass	–	0,0030	0,0000	0,0020	0,0006
Distillation IBP, °C	Report		122,7	159,3	147,9
10 % recovery, °C	–	205,0	153,7	182,7	165,4
50 % recovery, °C	Report		182,3	202,4	191,2
90 % recovery, °C	Report		211,5	250,5	233,3
FBP, °C	–	300,0	235,2	277,8	255,7
Flash point, °C	38,0	–	37,5	47,5	40,9
Density @ 15 °C, kg/m^3	775,0	840,0	780,8	811,5	799,2
Freezing point, °C	–	–47,0	–78	–48	–54,5
Viscosity @ –20 °C, mm^2/s	–	8,00	2,80	4,19	3,56
Specific energy, Net MJ/kg	42,80	–	43,06	43,57	43,24
Smoke point, mm	19,0	–	19,7	28,5	23,4
Naphthalenes, % volume	–	3,00	0,06	2,42	1,59
Existent gum, mg/100 ml	–	7	1	3	1,21
MSEP	85 (70 with SDA)	–	71	100	91,3
BOCLE, mm	–	0,85	N/A	N/A	N/A
Particulate, mg/l	–	1,0	0,00	1,00	0,26
Colour	Report		16	30	26,9
Particle count,					
≥4 μm	Report		10	22	16,4
≥6 μm	Report		9	21	14,5
≥14 μm	Report		7	17	10,9
≥21 μm	Report		7	16	9,2
≥25 μm	Report		7	14	8,2
≥30 μm	Report		7	12	7,2

H The limit is 26,5 if using IP 436. All results have been converted to IP 156 equivalent data.

ANNEX B
FIGURES

B.1 TOTAL ACIDITY

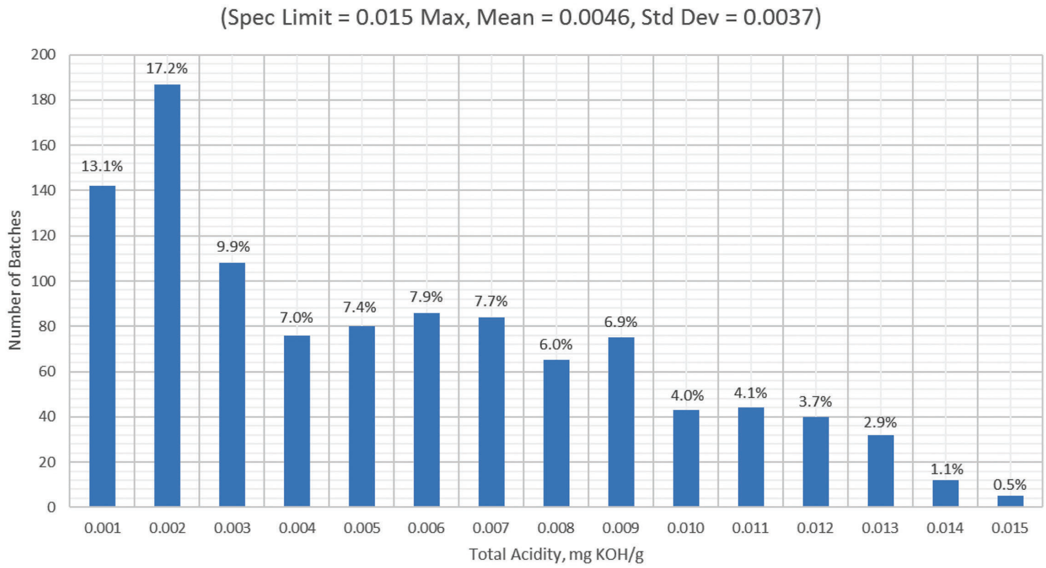

Figure B.1: Total acidity histogram

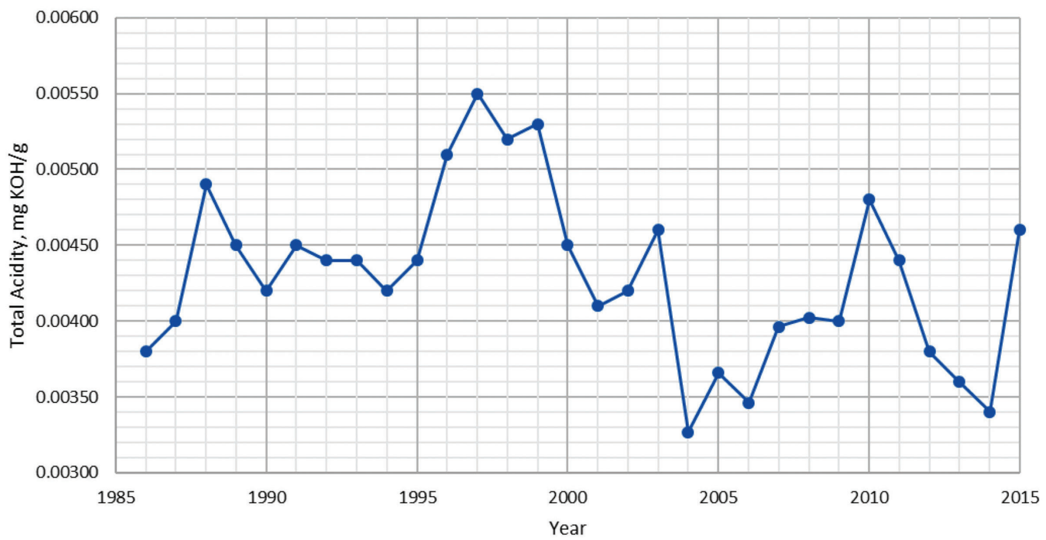

Figure B.2: Total acidity trend of the annual mean graph

B.2 AROMATICS

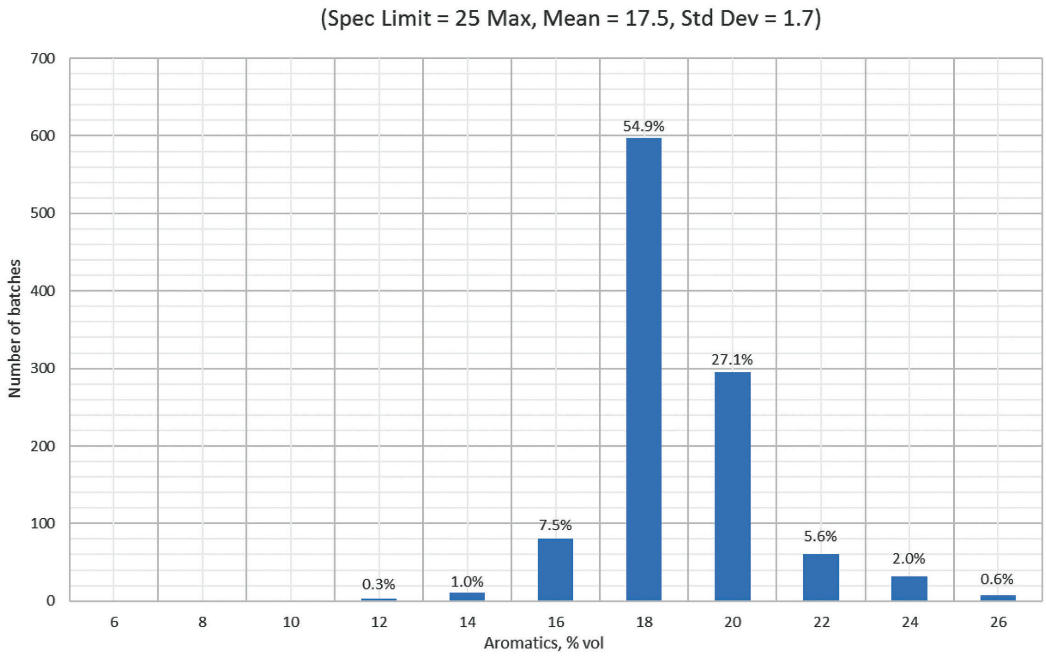

Figure B.3: Aromatics histogram

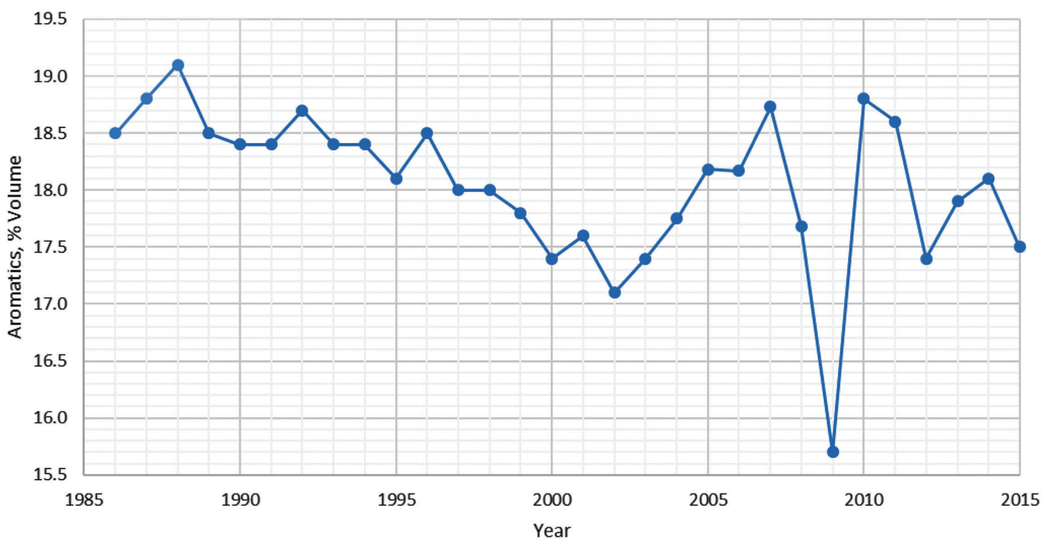

Figure B.4: Aromatics trend of the annual mean graph

B.3 TOTAL SULPHUR

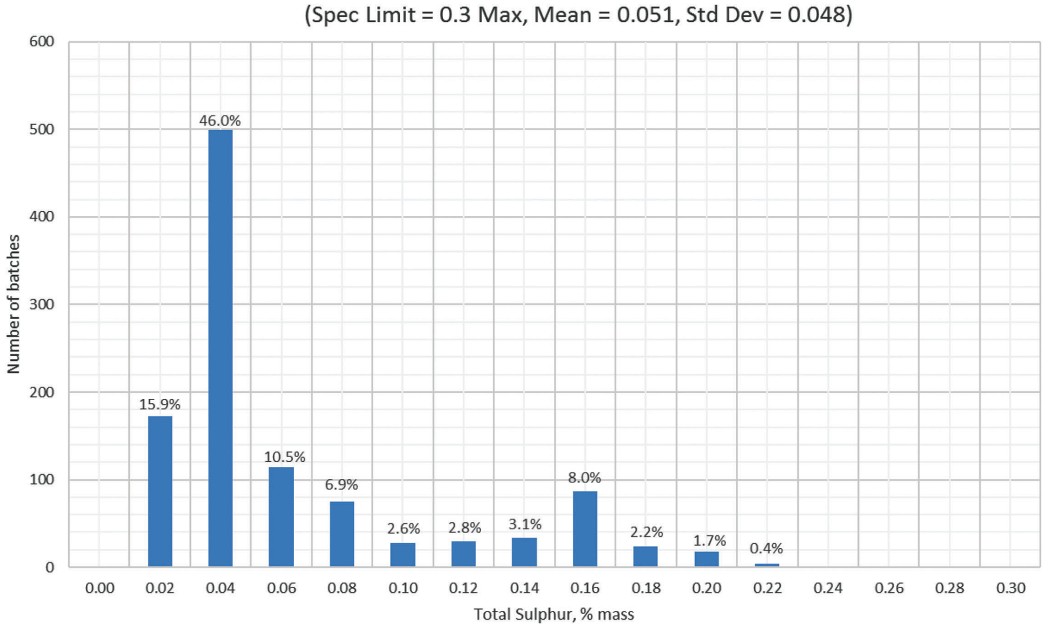

Figure B.5: Total sulphur histogram

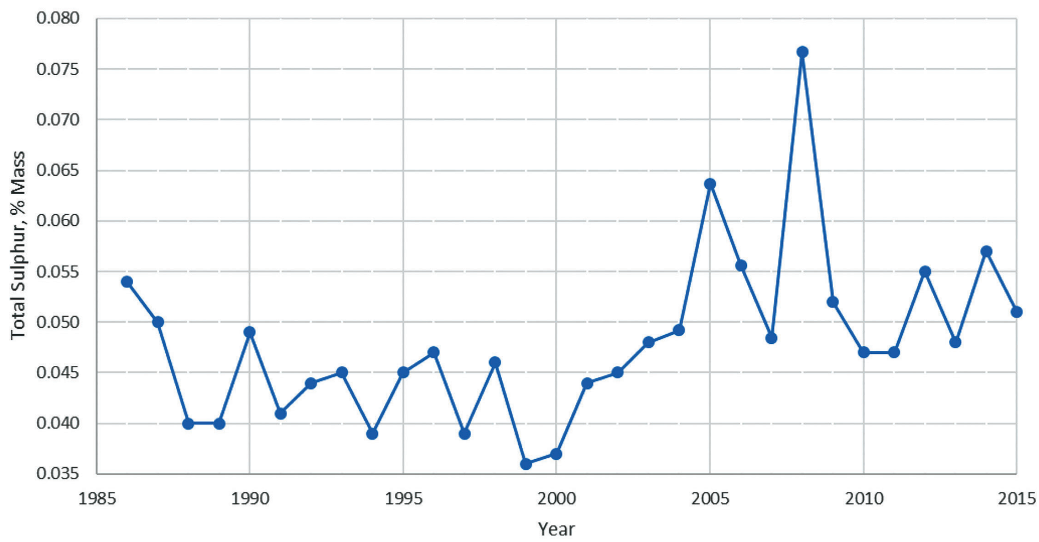

Figure B.6: Total sulphur trend of the annual mean graph

B.4 MERCAPTAN SULPHUR

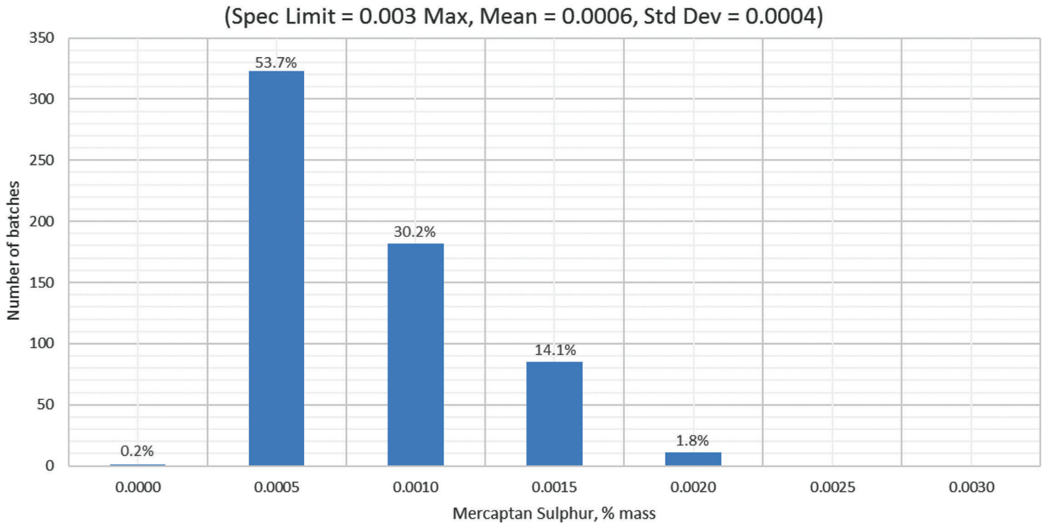

Figure B.7: Mercaptan sulphur histogram

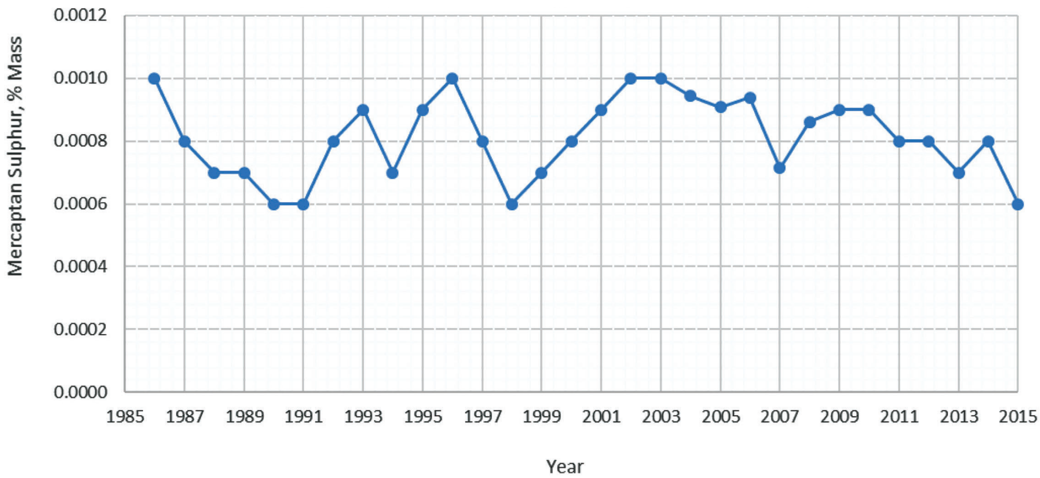

Figure B.8: Mercaptan trend of the annual mean graph

B.5 DISTILLATION IBP

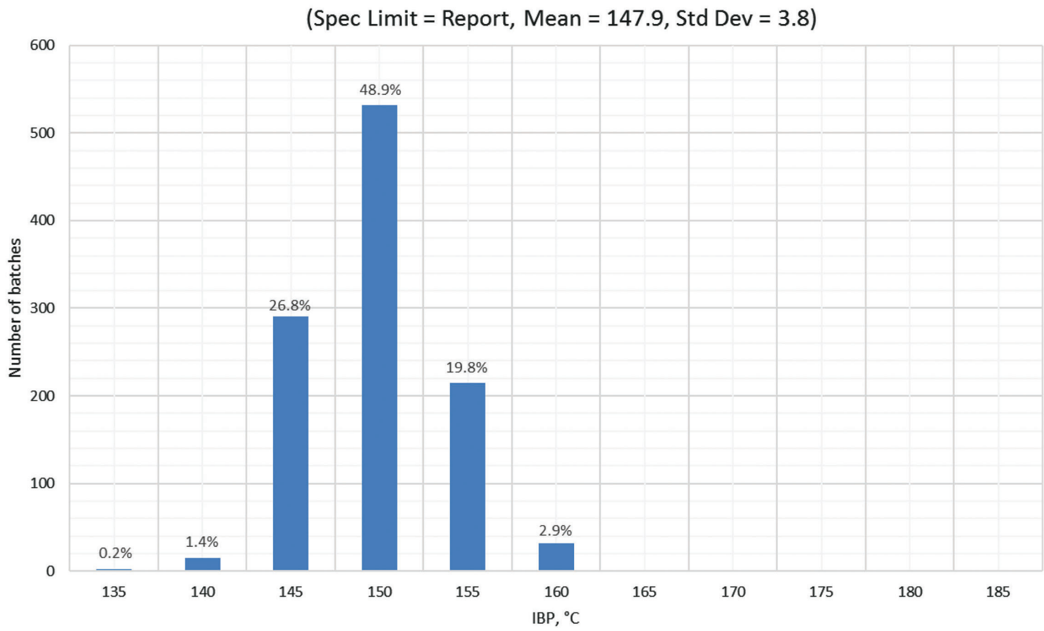

Figure B.9: Distillation IBP histogram

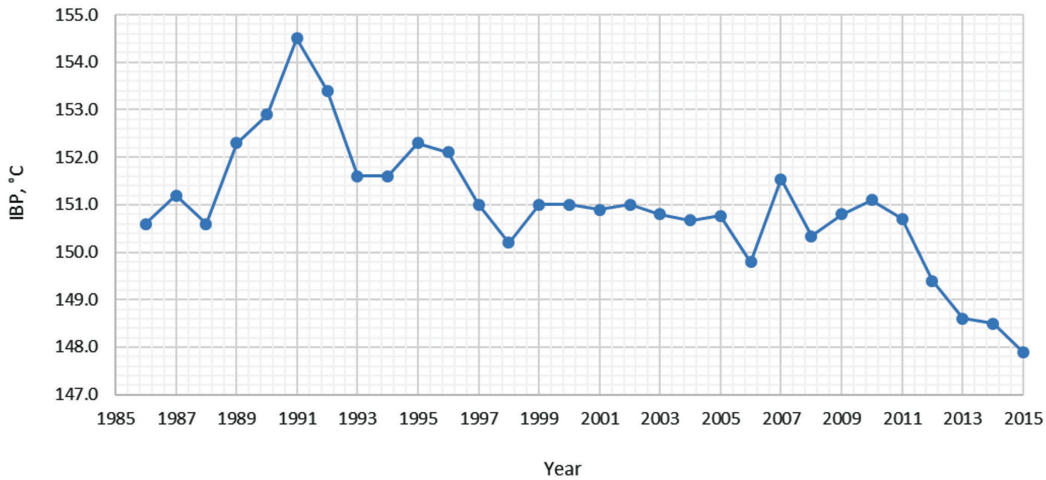

Figure B.10: Distillation IBP trend of the annual mean graph

B.6 DISTILLATION 10 % RECOVERY

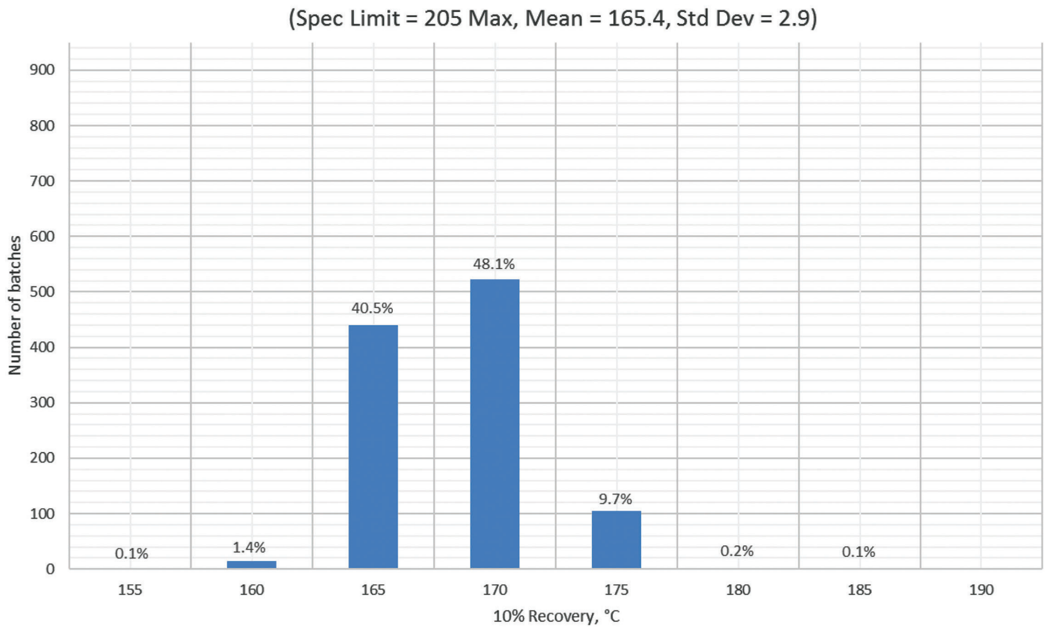

Figure B.11: Distillation 10 % recovery histogram

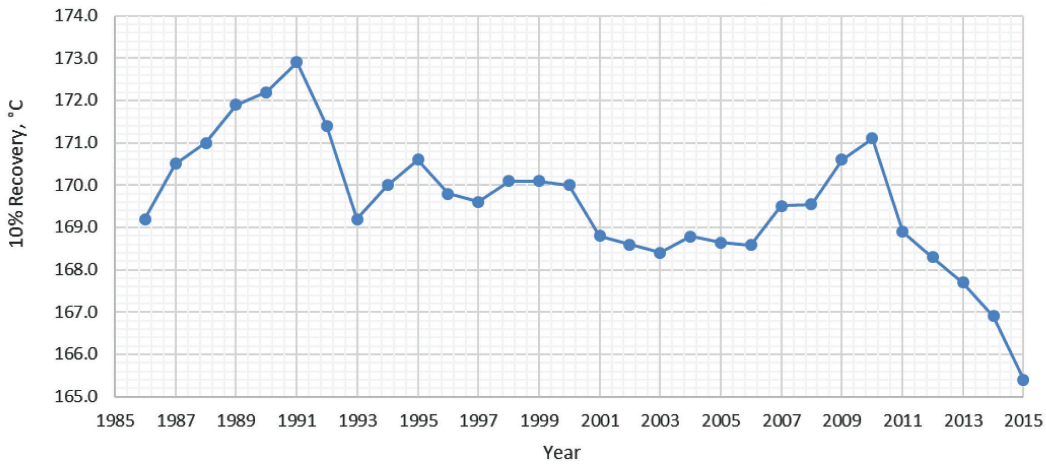

Figure B.12: Distillation 10 % recovery trend of the annual mean graph

B.7 DISTILLATION 50 % RECOVERY

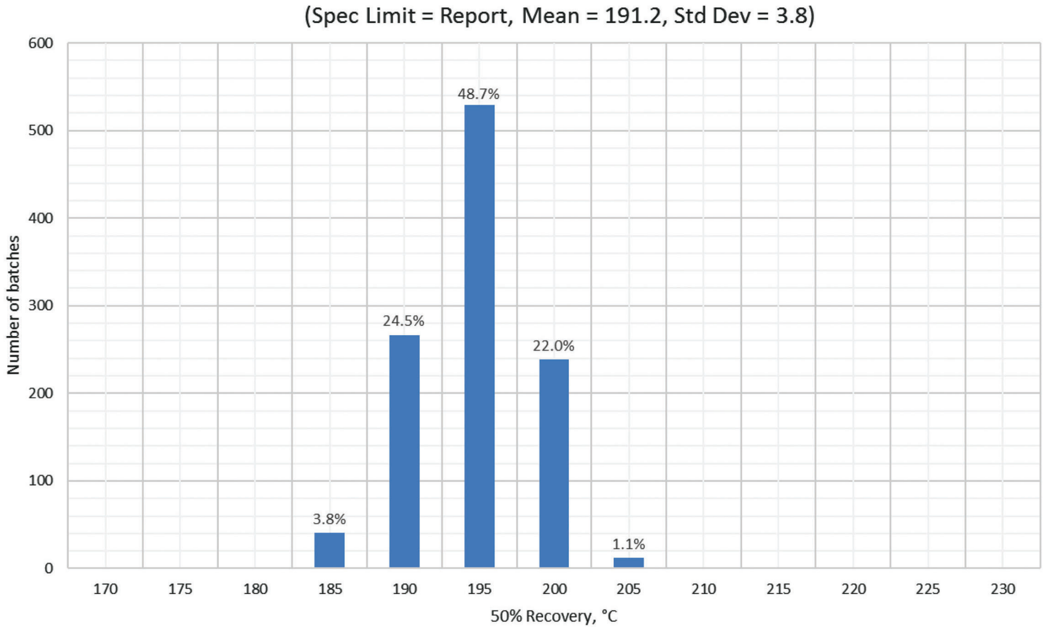

Figure B.13: Distillation 50 % recovery histogram

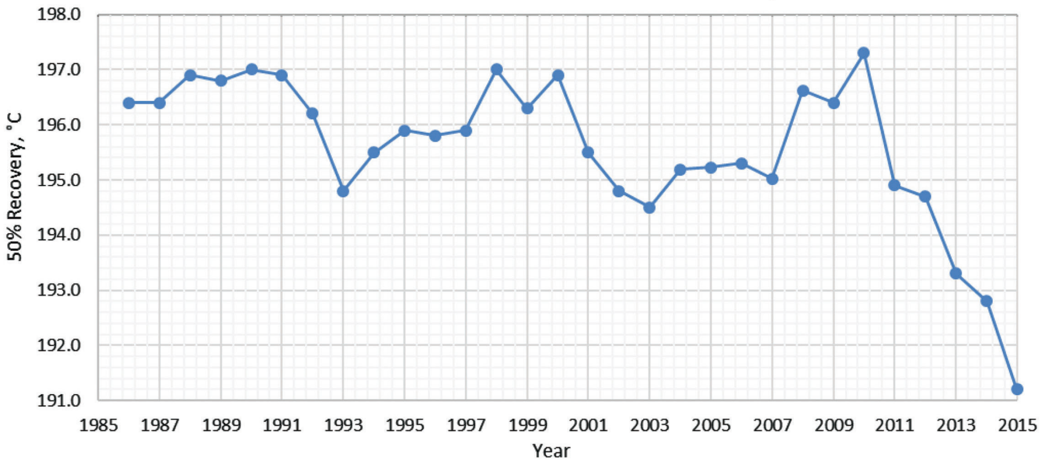

Figure B.14: Distillation 50 % recovery trend of the annual mean graph

B.8 DISTILLATION 90 % RECOVERY

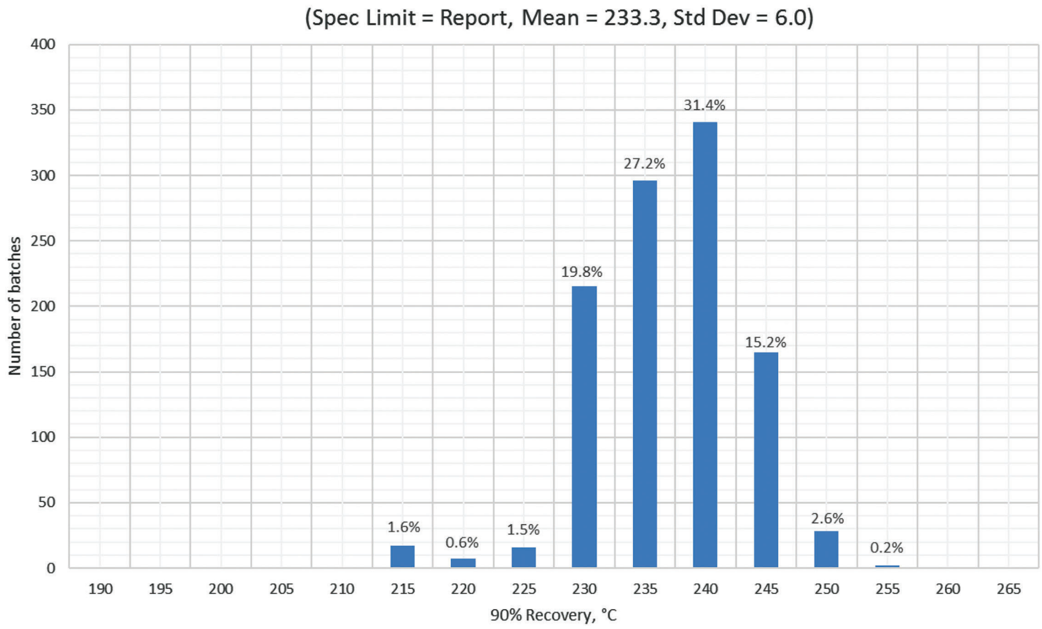

Figure B.15: Distillation 90 % recovery histogram

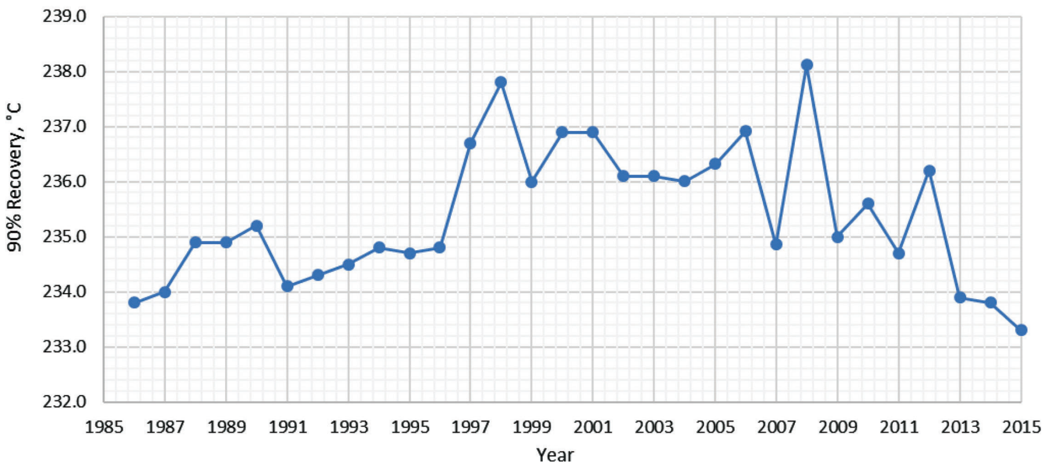

Figure B.16: Distillation 90 % recovery trend of the annual mean graph

B.9 DISTILLATION FBP

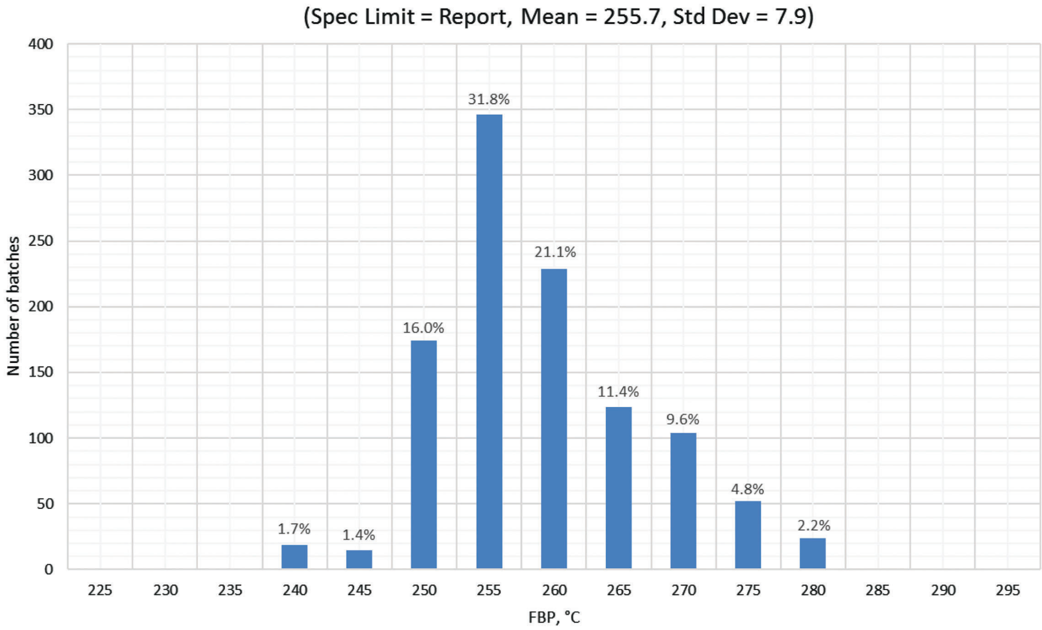

Figure B.17: Distillation FBP histogram

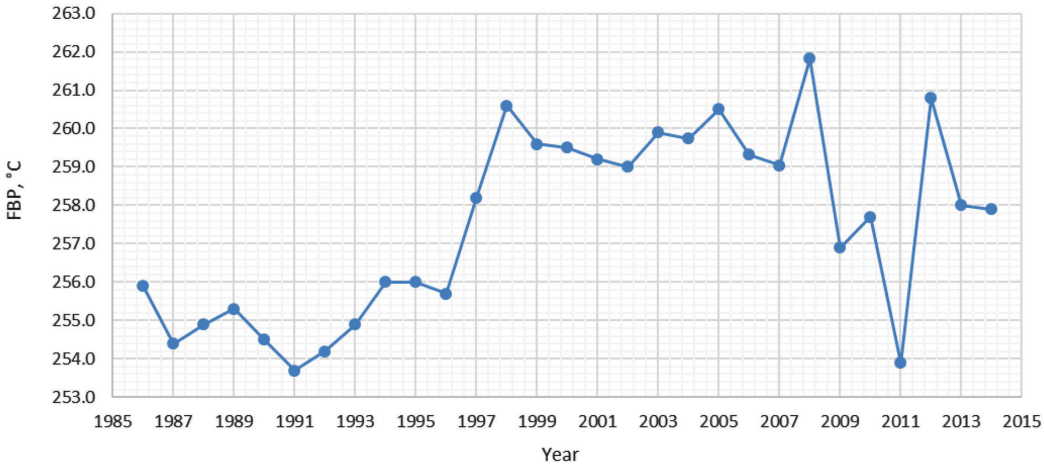

Figure B.18: Distillation FBP trend of the annual mean graph

B.10 DISTILLATION RANGE

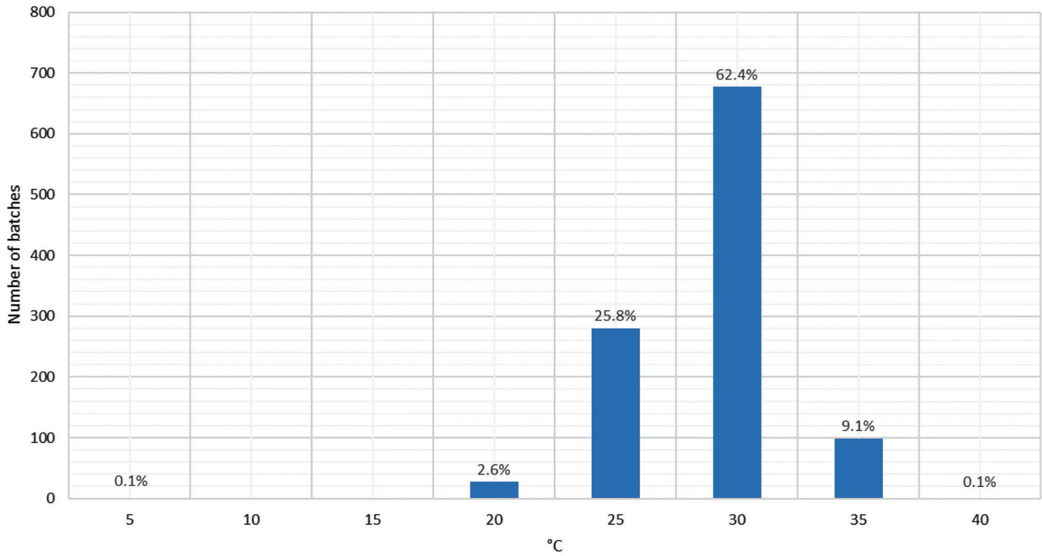

Figure B.19: Distillation T50-T10

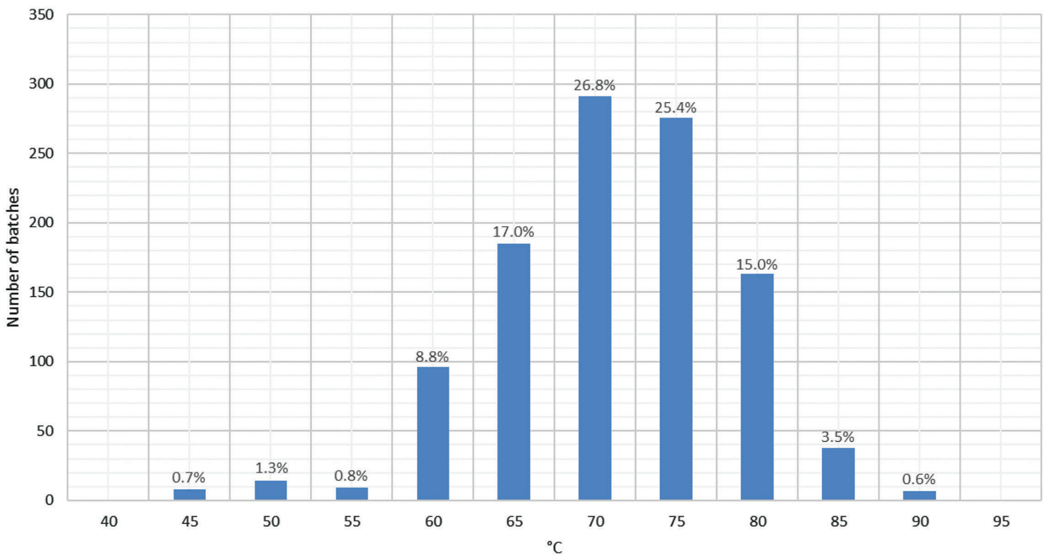

Figure B.20: Distillation T90-T10

B.11 FLASH POINT

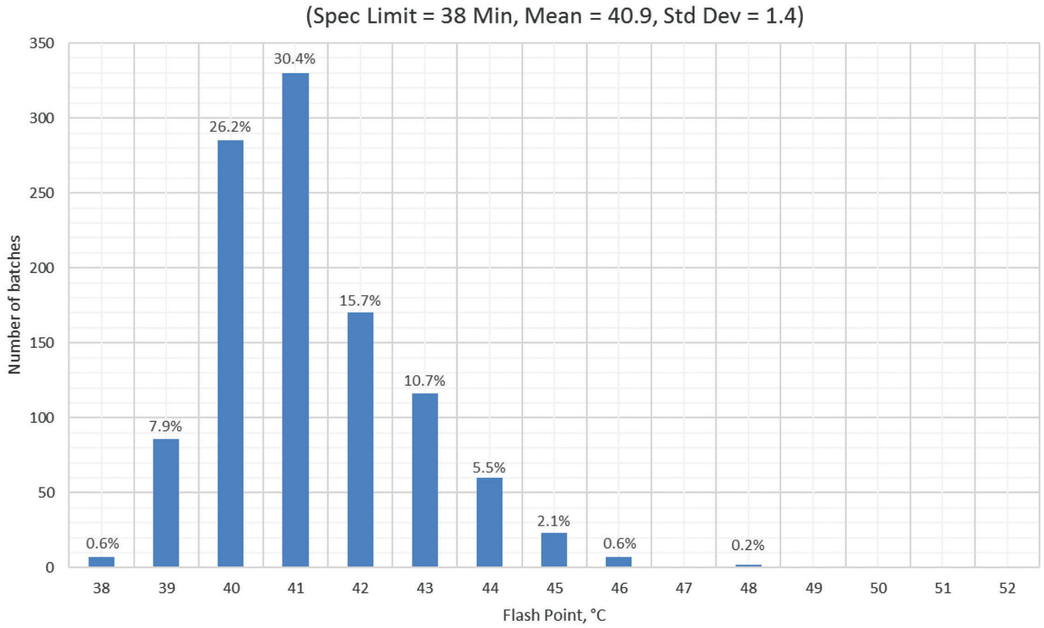

Figure B.21: Flash point histogram

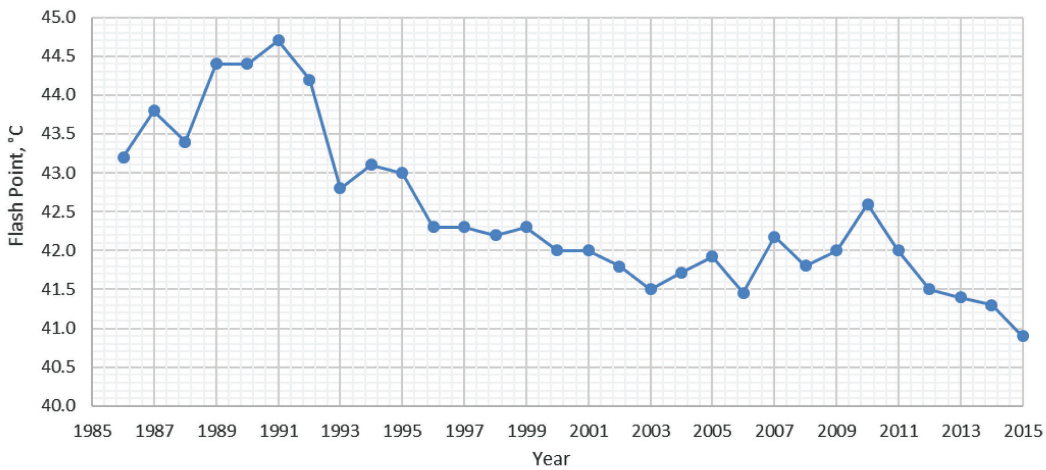

Figure B.22: Flash point trend of the annual mean graph

B.12 DENSITY AT 15 °C

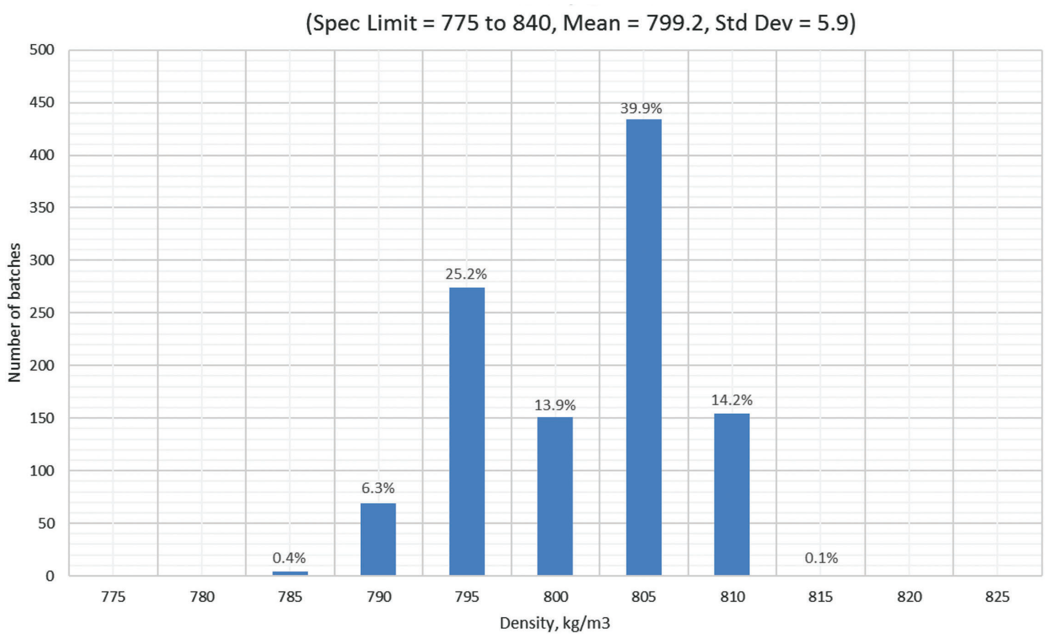

Figure B.23: Density histogram

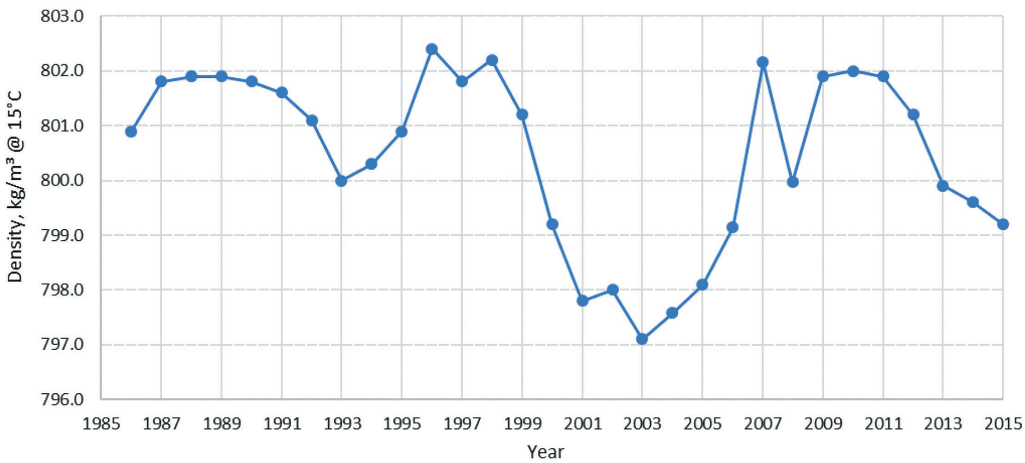

Figure B.24: Density trend of the annual mean graph

B.13 FREEZING POINT

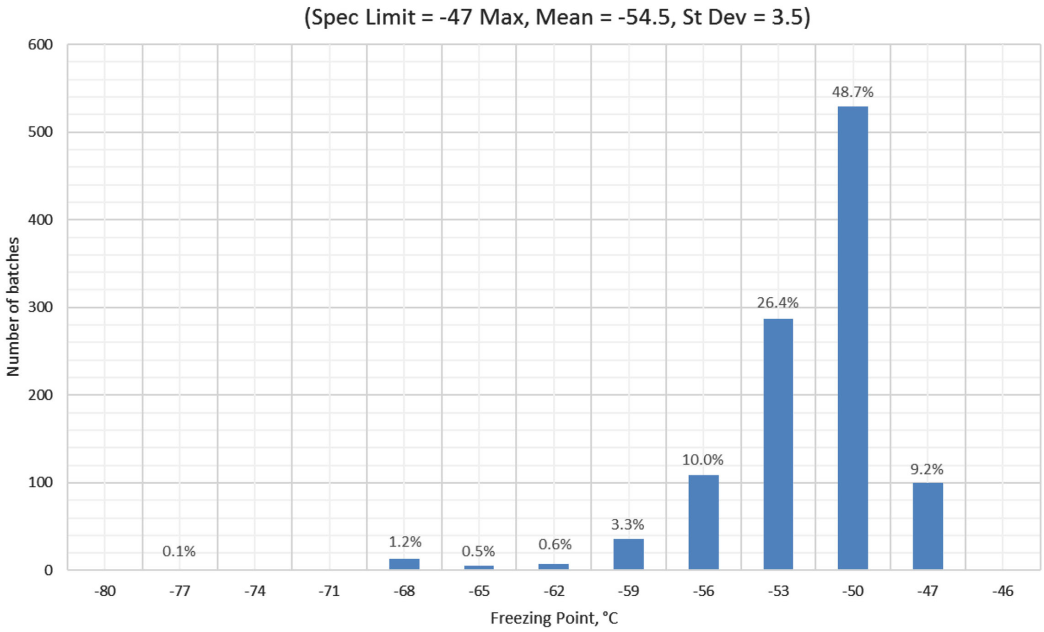

Figure B.25: Freezing point histogram

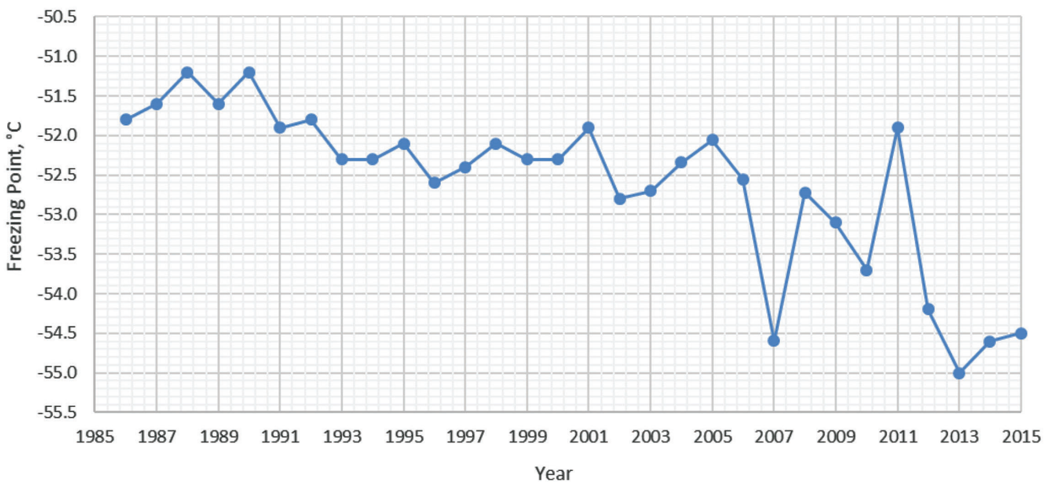

Figure B.26: Freezing point trend of the annual mean graph

B.14 KINEMATIC VISCOSITY AT –20 °C

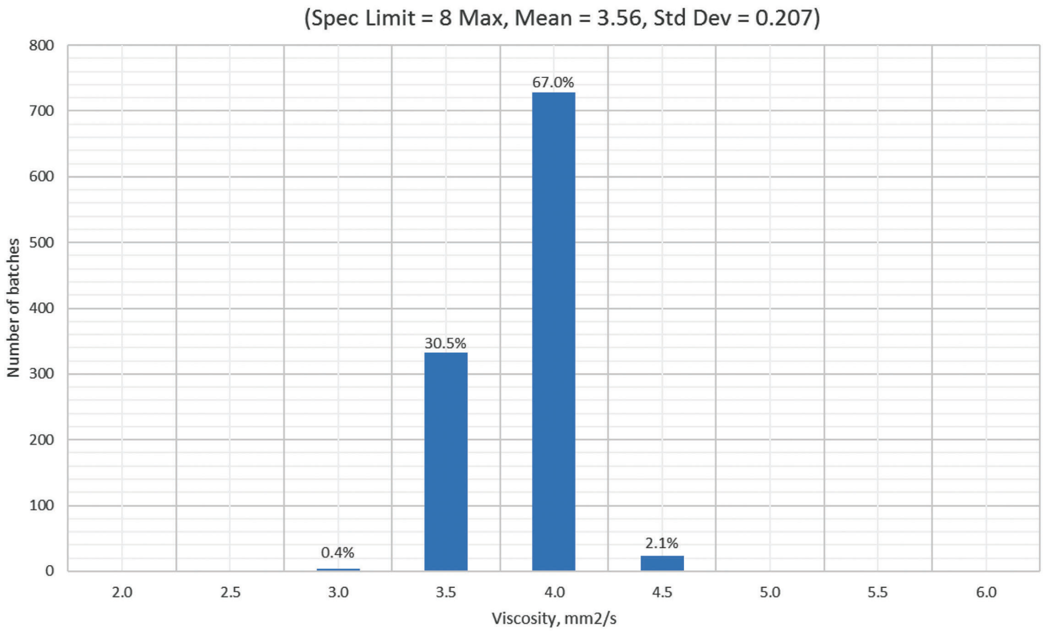

Figure B.27: Kinematic viscosity histogram

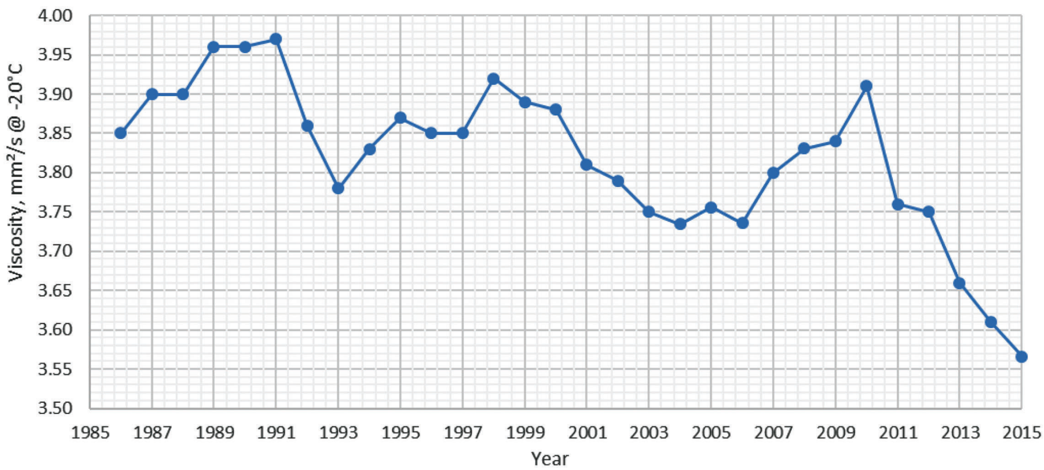

Figure B.28: Kinematic viscosity trend of the annual mean graph

B.15 SPECIFIC ENERGY

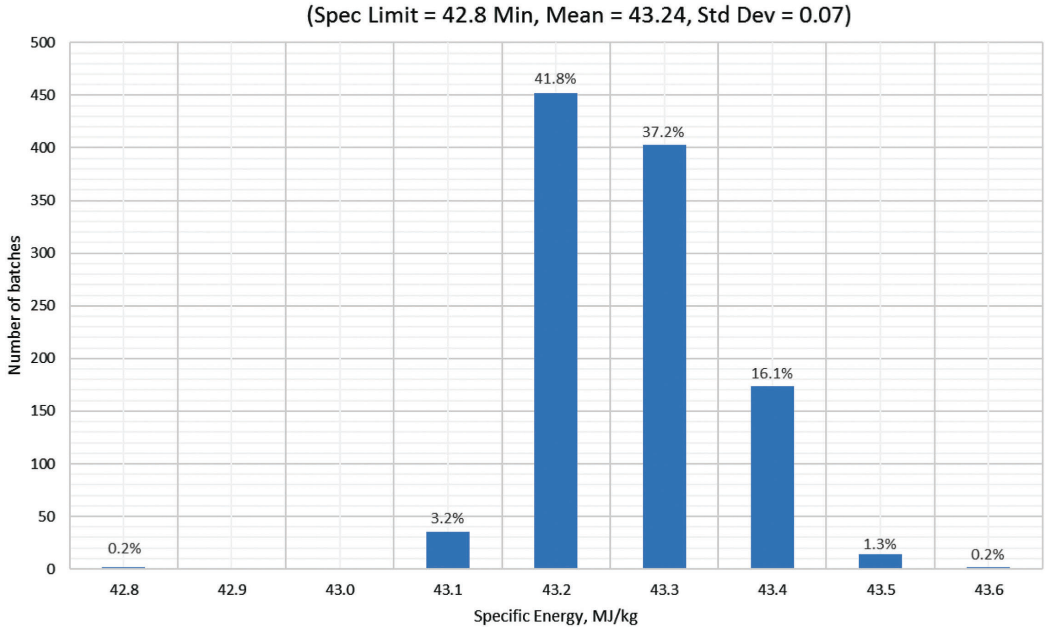

Figure B.29: Specific energy histogram

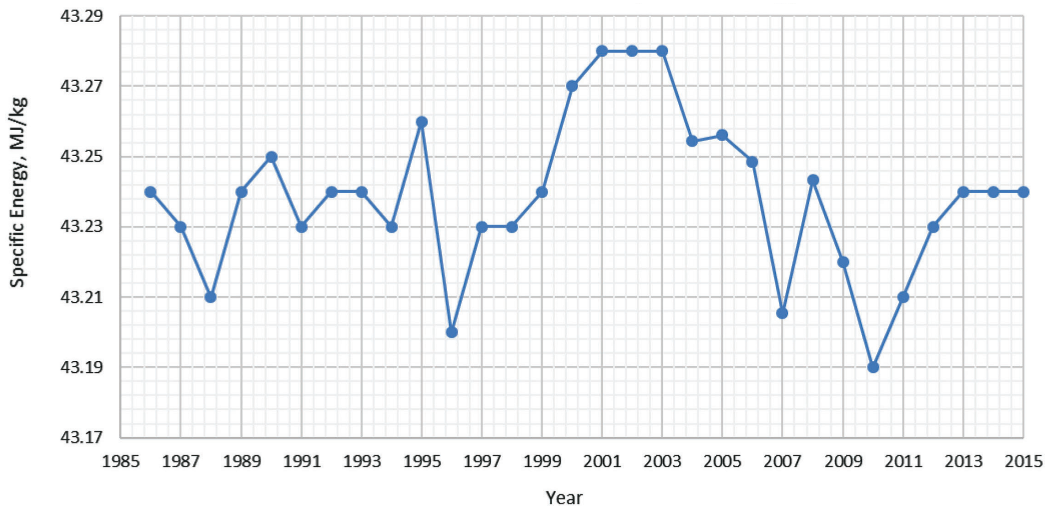

Figure B.30: Specific energy trend of the annual mean graph

B.16 SMOKE POINT

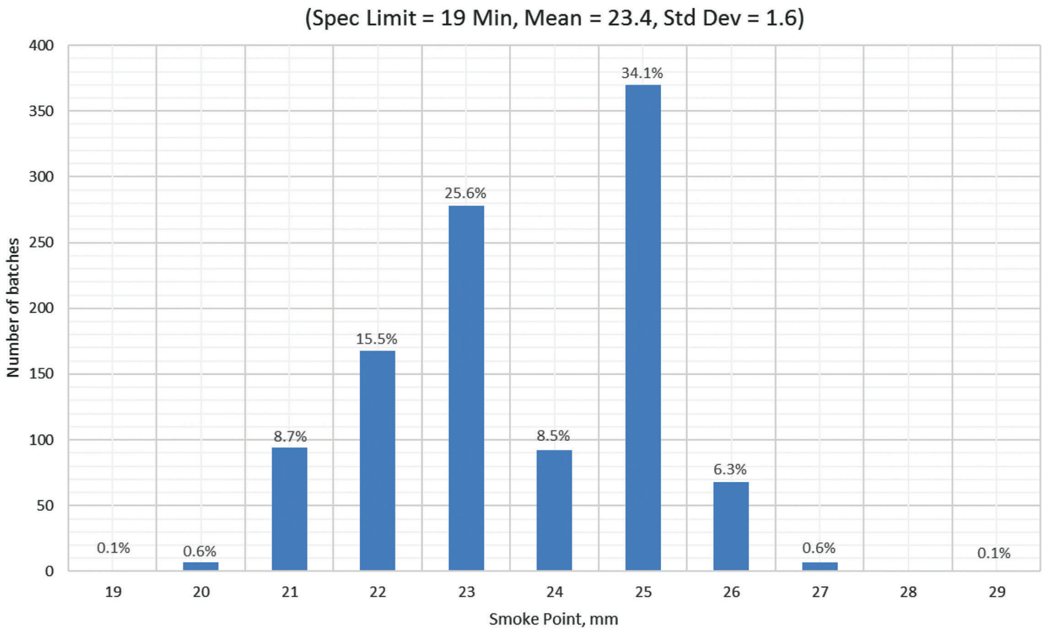

Figure B.31: Smoke point histogram

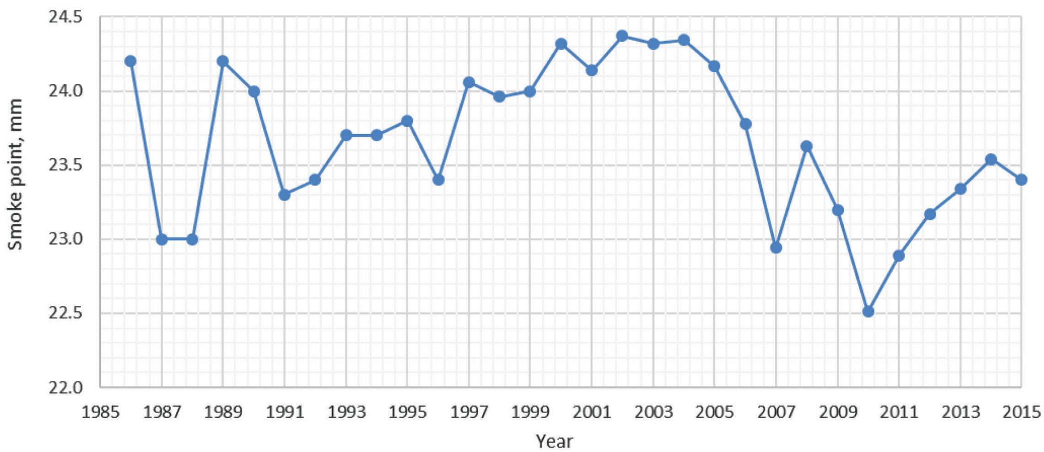

Figure B.32: Smoke point trend of the annual mean graph

B.17 NAPHTHALENES

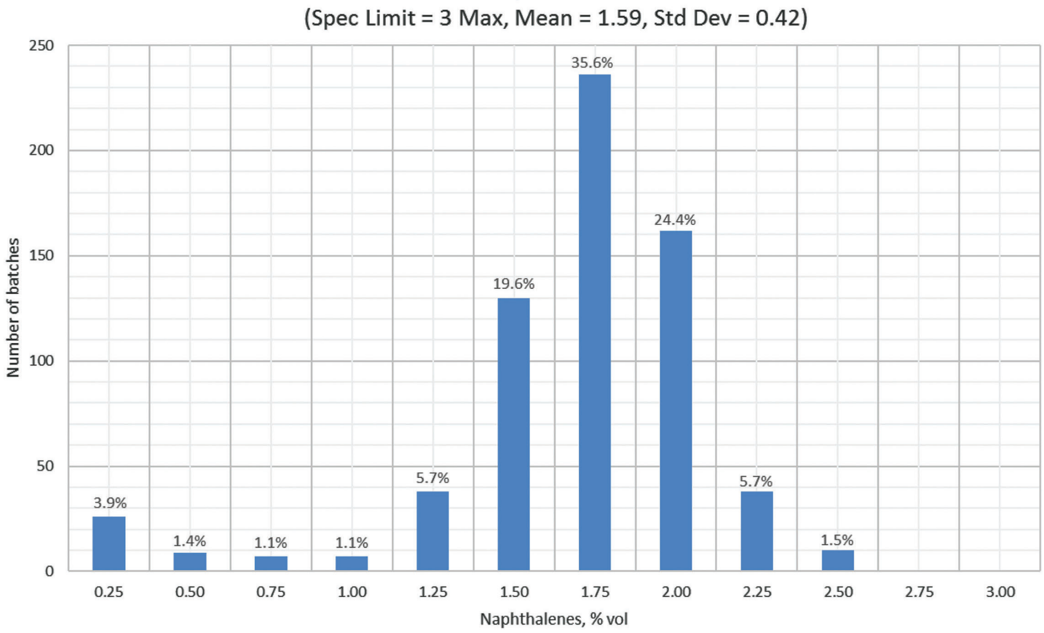

Figure B.33: Naphthalenes histogram

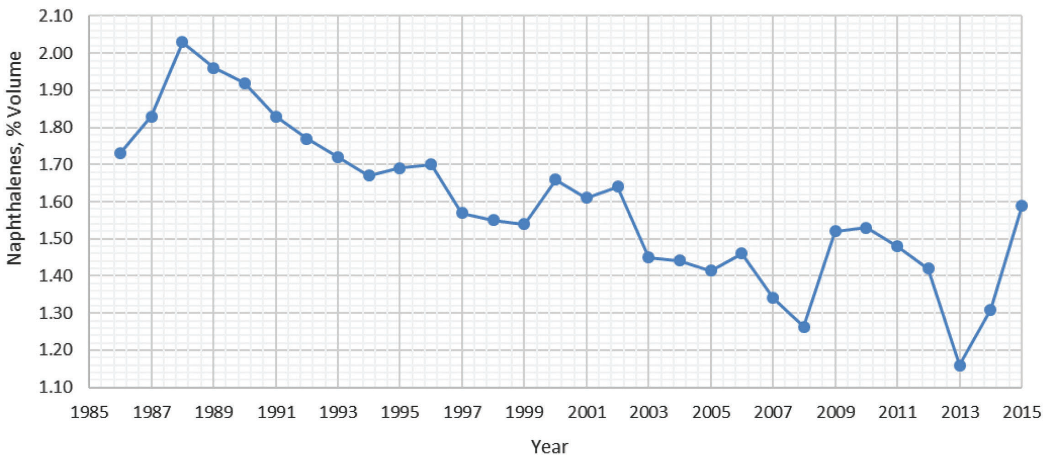

Figure B.34: Naphthalenes trend of the annual mean graph

B.18 EXISTENT GUM

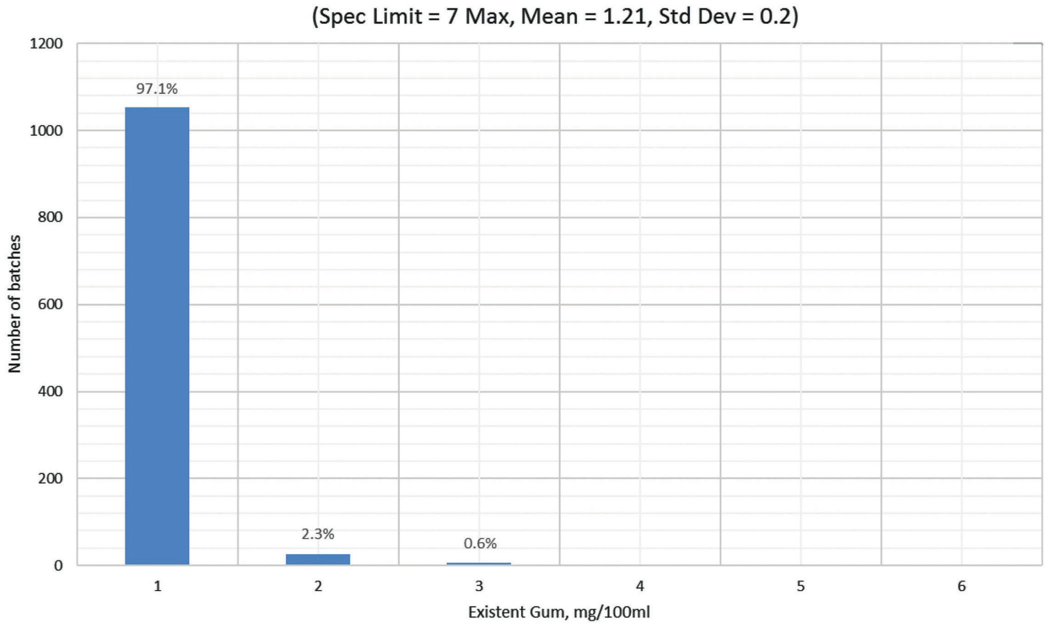

Figure B.35: Existent gum histogram

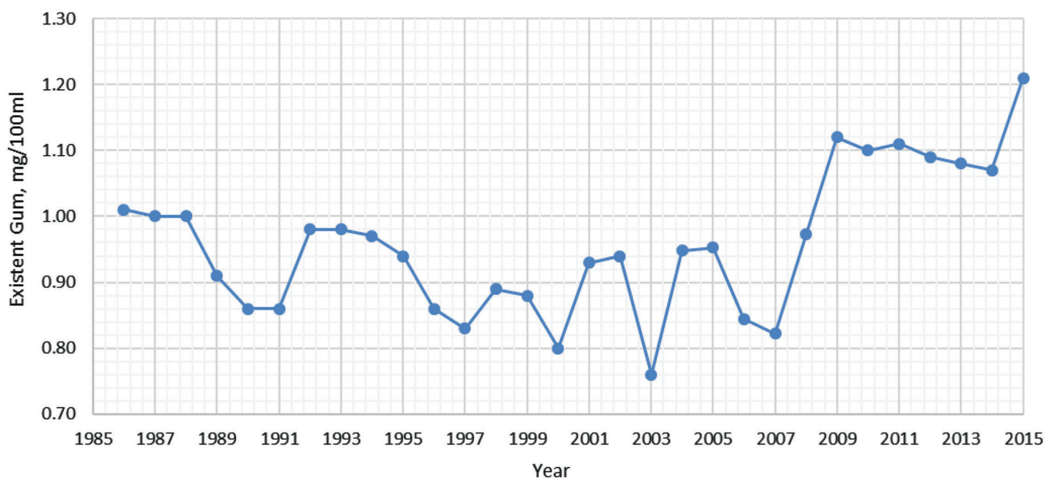

Figure B.36: Existent gum trend of the annual mean graph

B.19 MSEP®

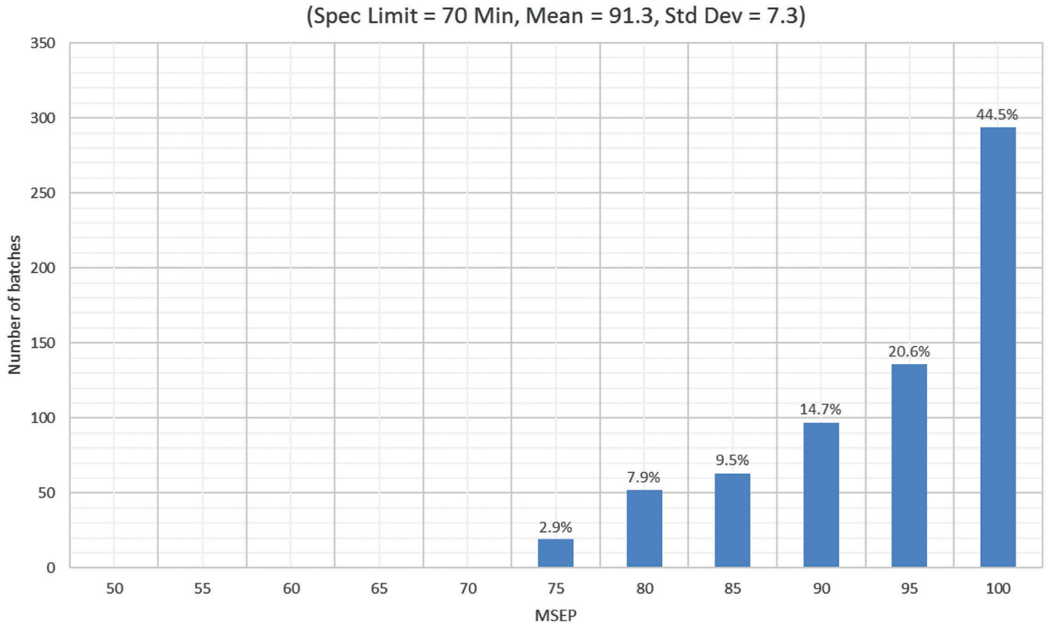

Figure B.37: MSEP® histogram

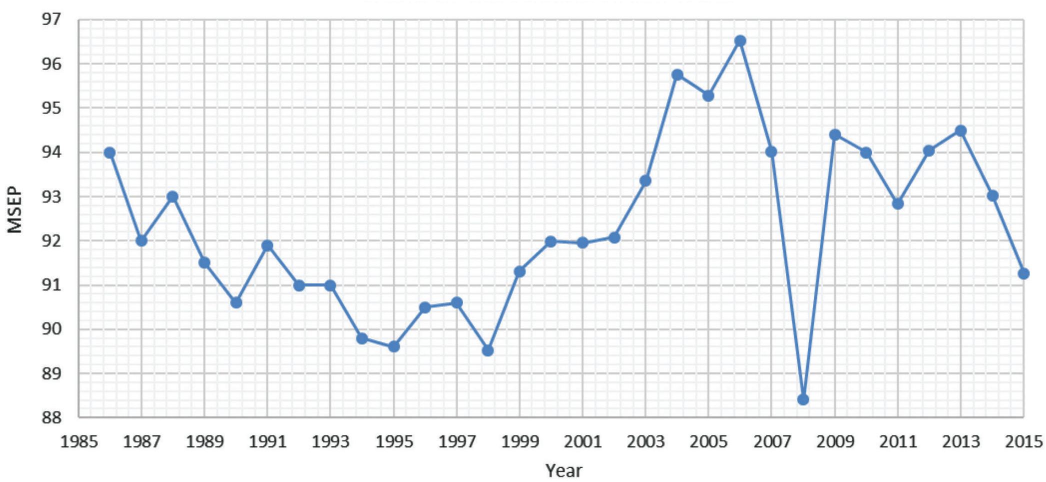

Figure B.38: MSEP® trend of the annual mean graph

B.20 PARTICULATE (GRAVIMETRIC)

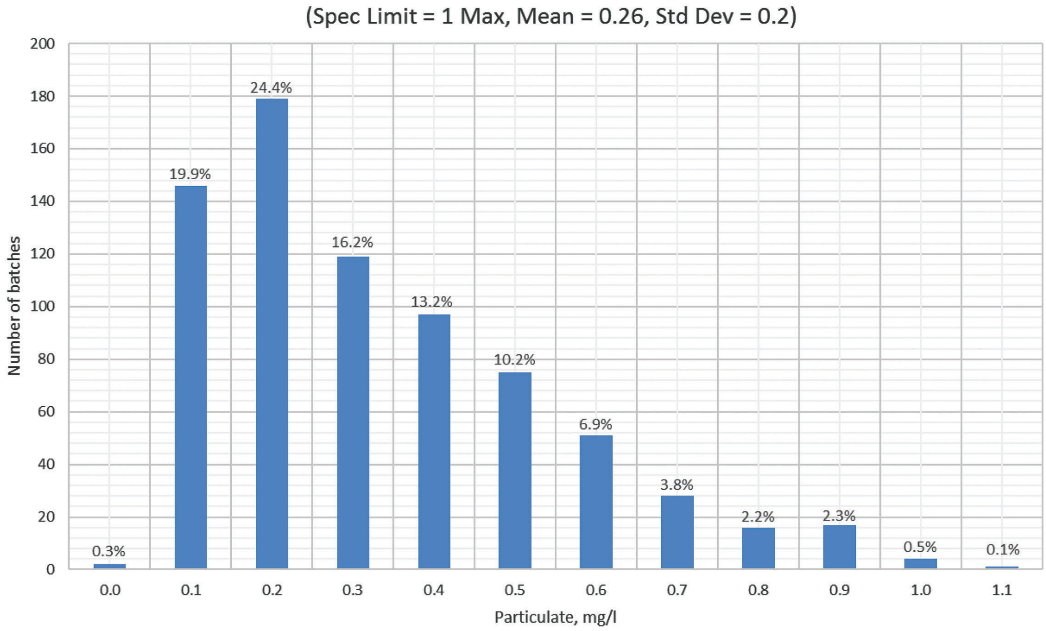

Figure B.39: Particulate histogram

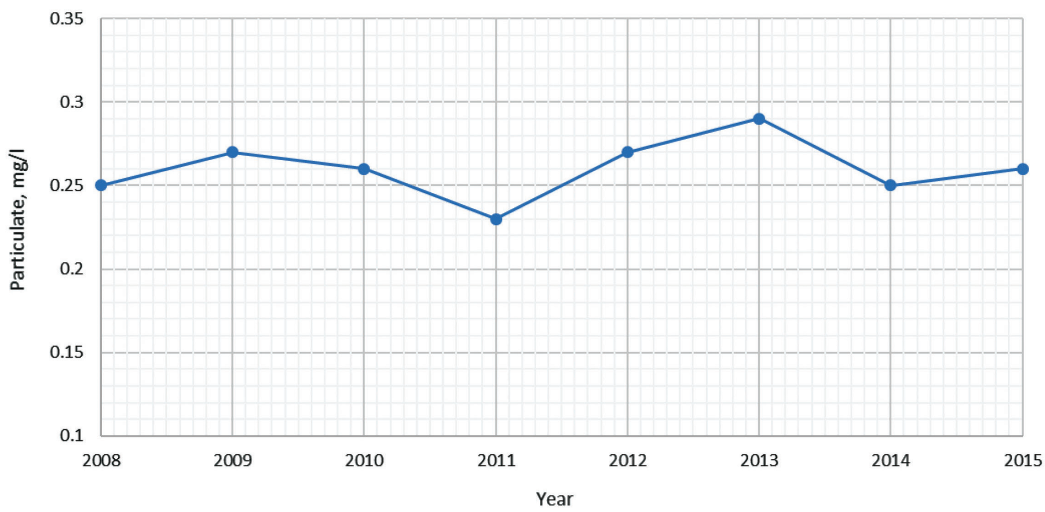

Figure B.40: Particulate trend of the annual mean graph

B.21 SAYBOLT COLOUR

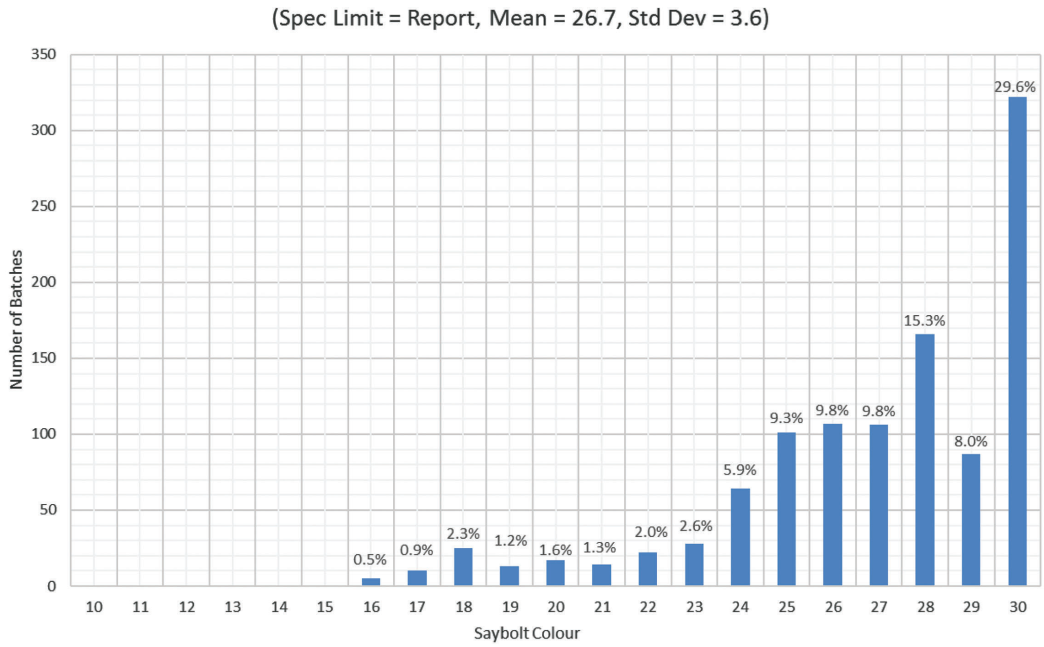

Figure B.41: Saybolt colour histogram

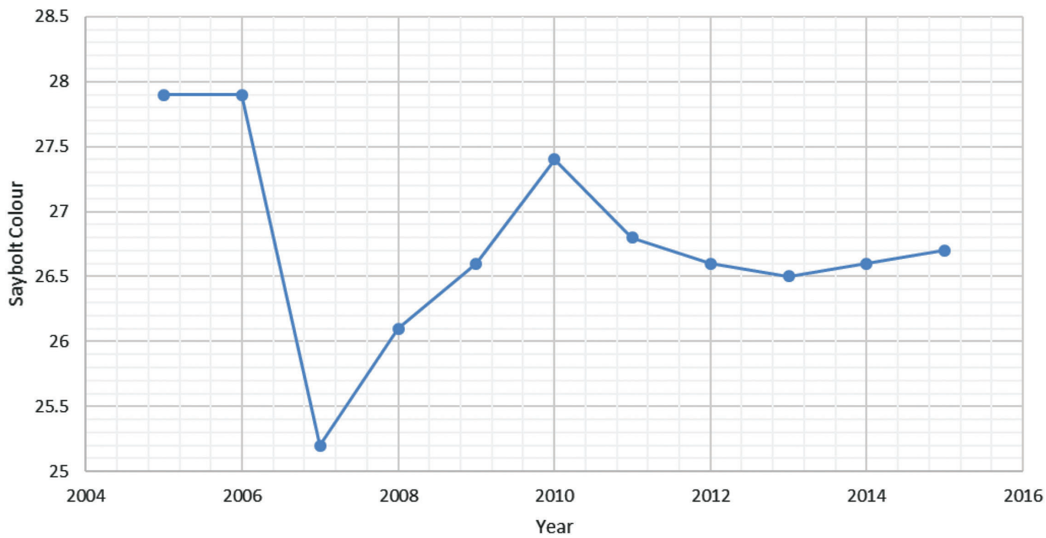

Figure B.42: Saybolt colour trend of the annual mean graph

B.22 PARTICLE COUNTS

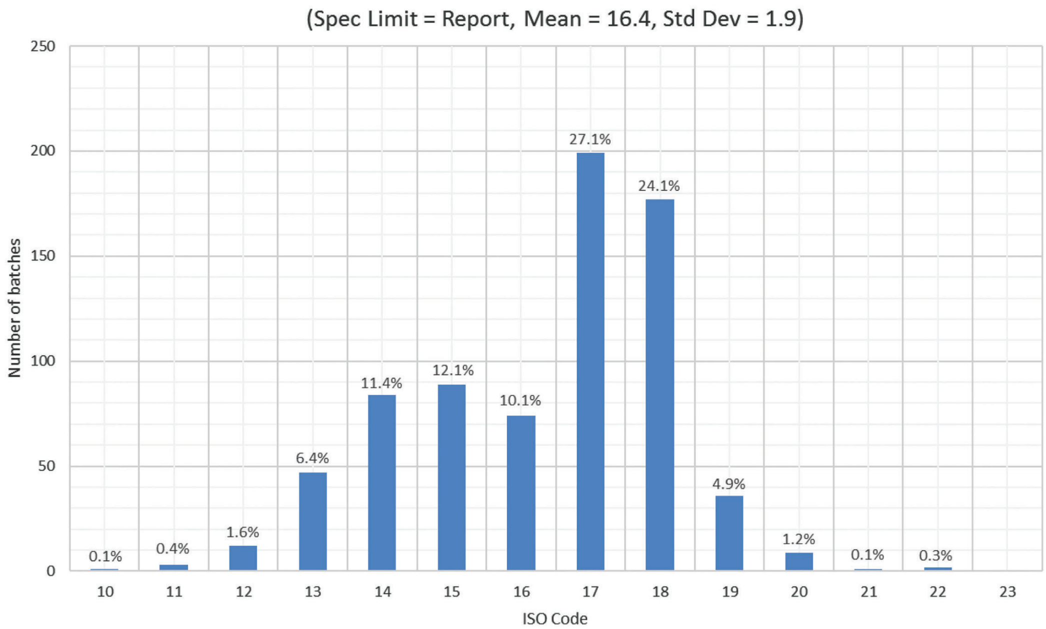

Figure B.43: Particle counts ≥4 µm ISO code

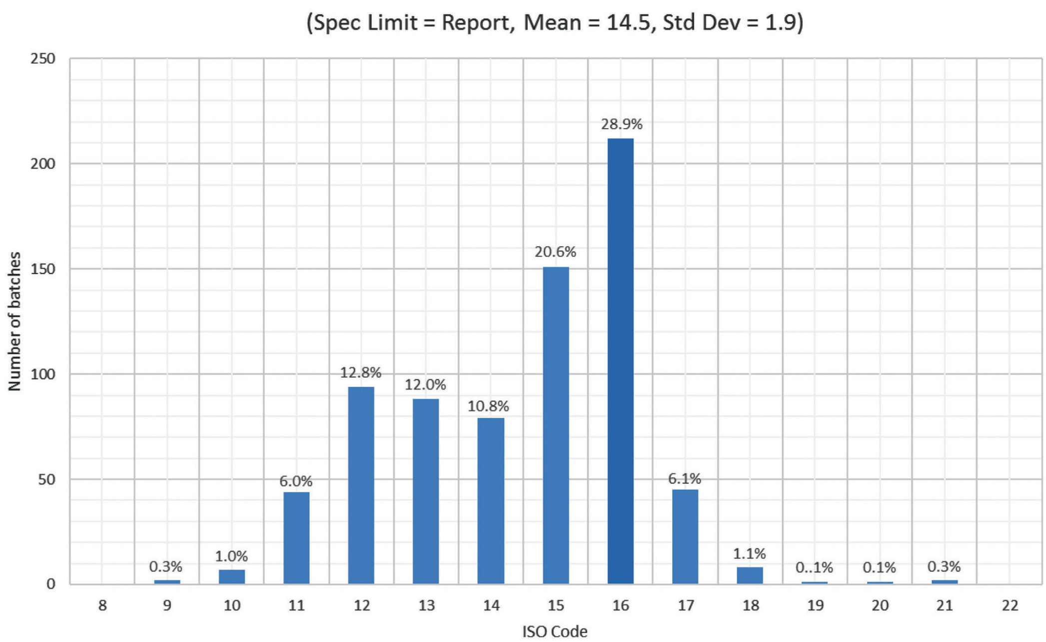

Figure B.44: Particle counts ≥6 µm (ISO code)

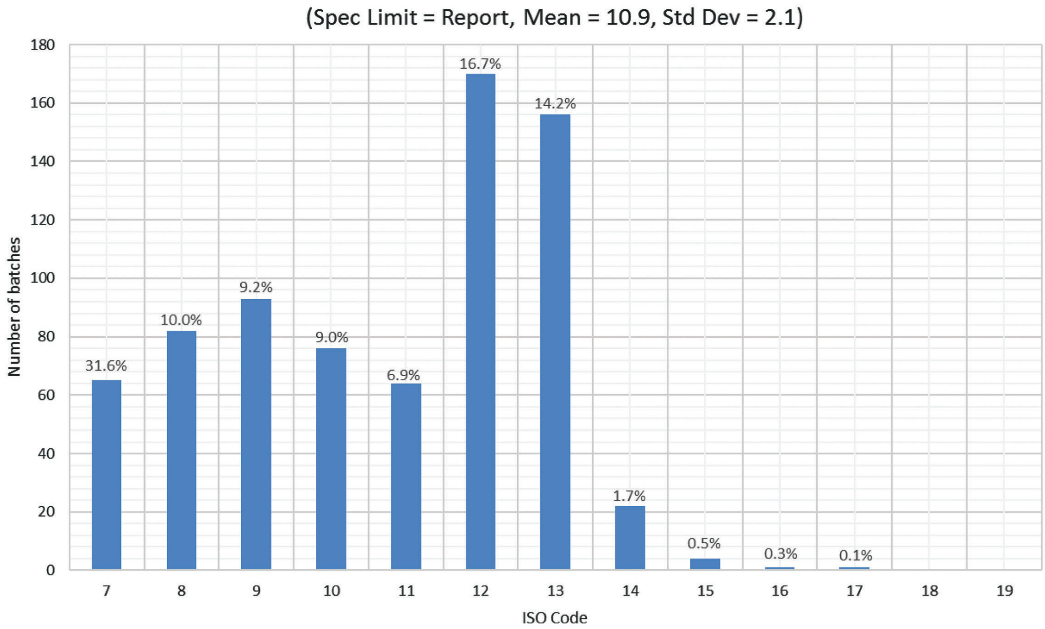

Figure B.45: Particle counts ≥14 µm (ISO code)

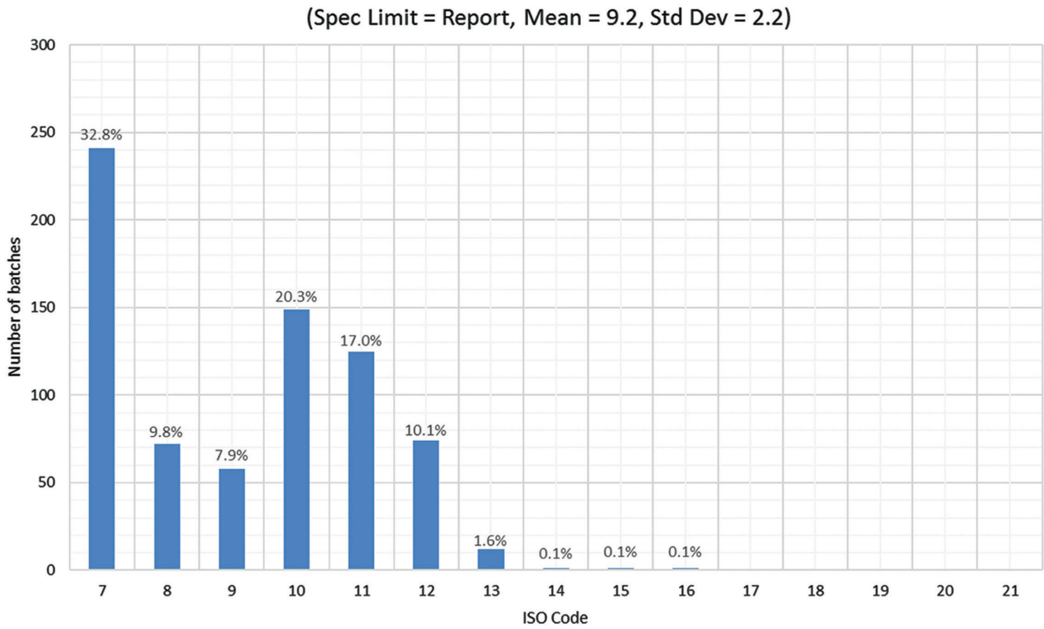

Figure B.46: Particle counts ≥21 µm (ISO code)

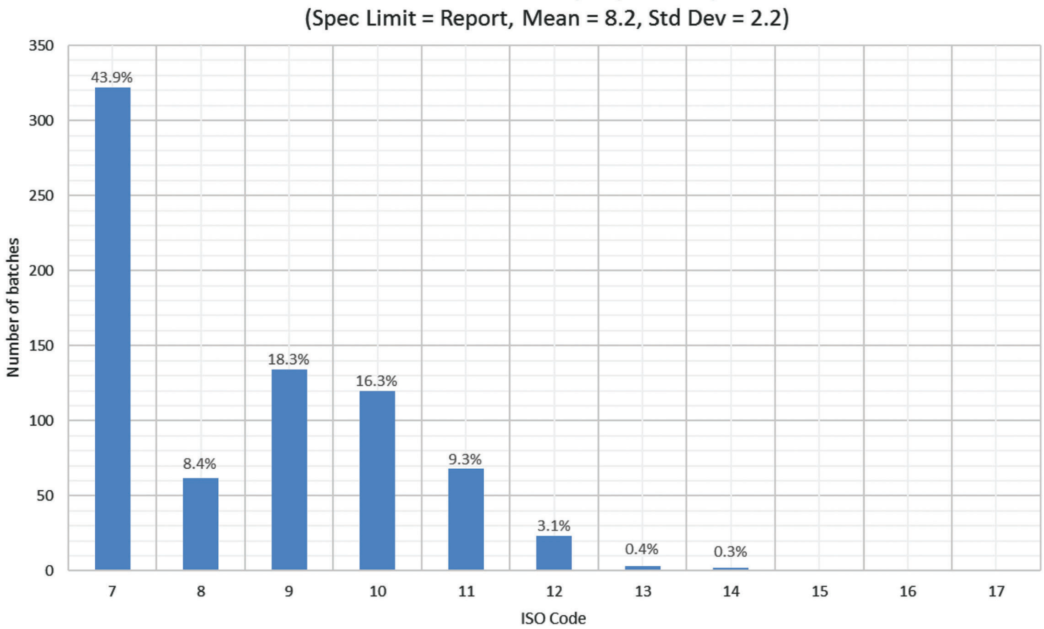

Figure B.47: Particle counts ≥25 μm (ISO code)

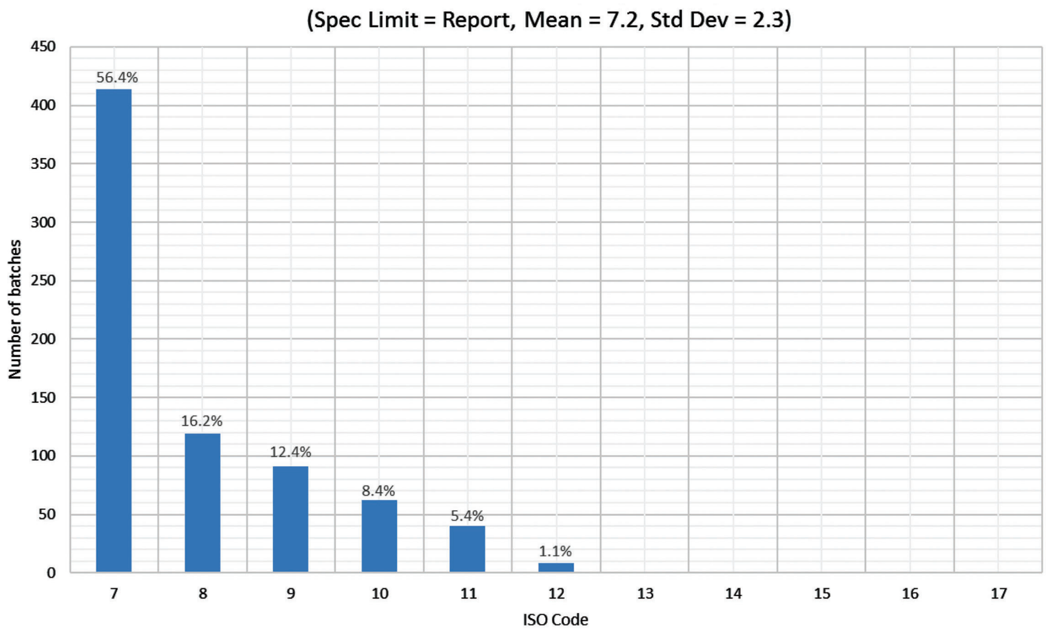

Figure B.48: Particle counts ≥30 μm (ISO code)

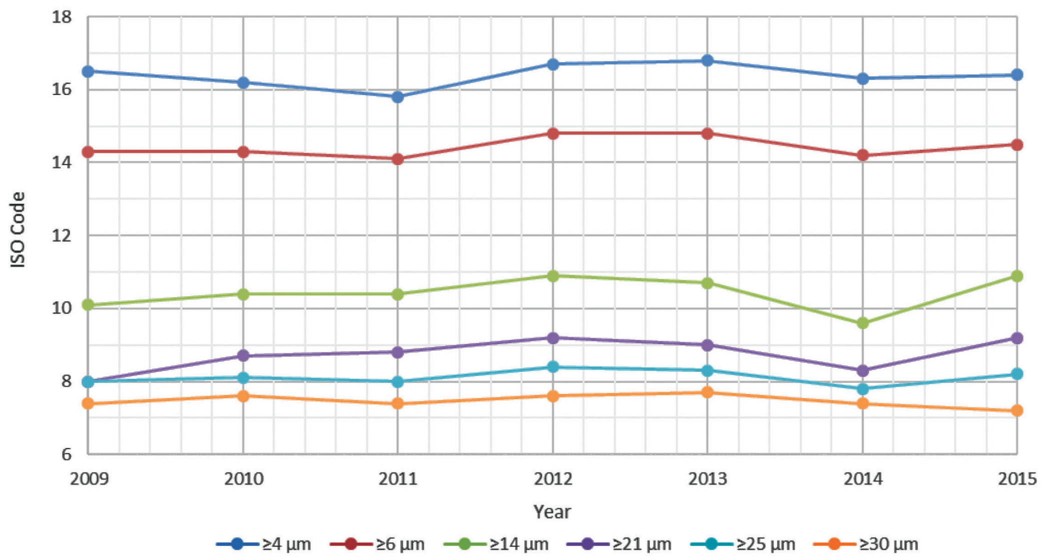

Figure B.49: Particle count trend of the annual mean graph

B.23 NEAR SPECIFICATION LIMIT TREND ANALYSIS

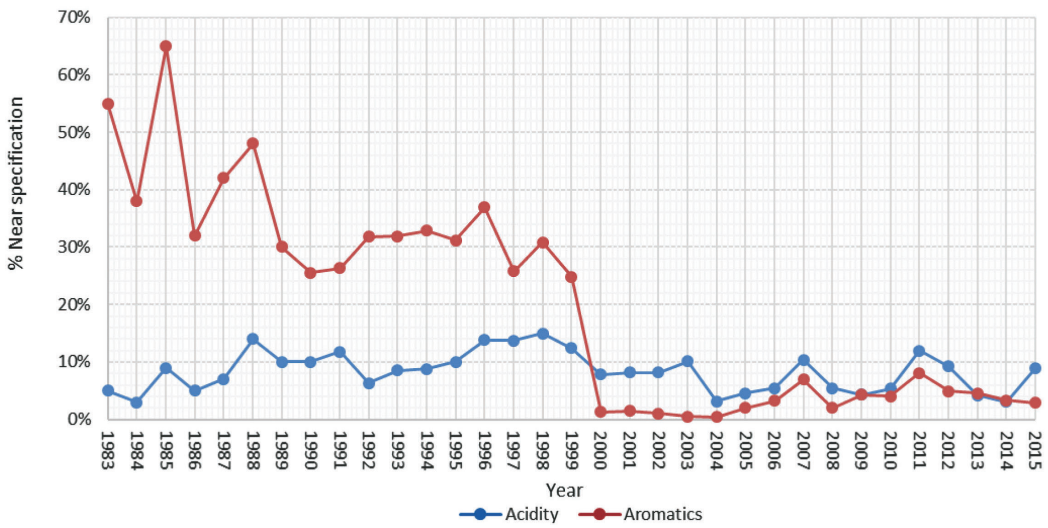

Figure B.50: Near specification trend, acidity and aromatics

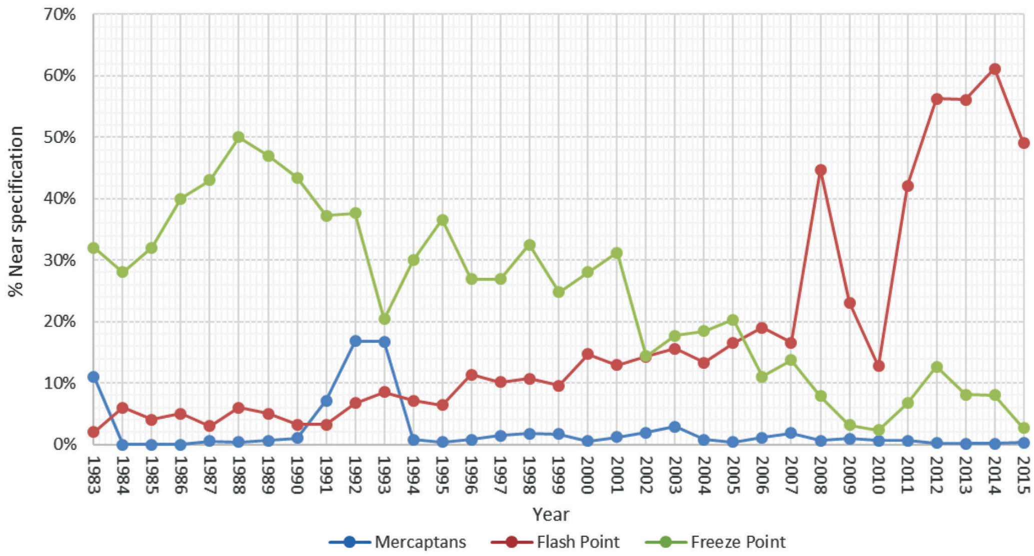

Figure B.51: Near specification trend, mercaptans, flash point and freezing point

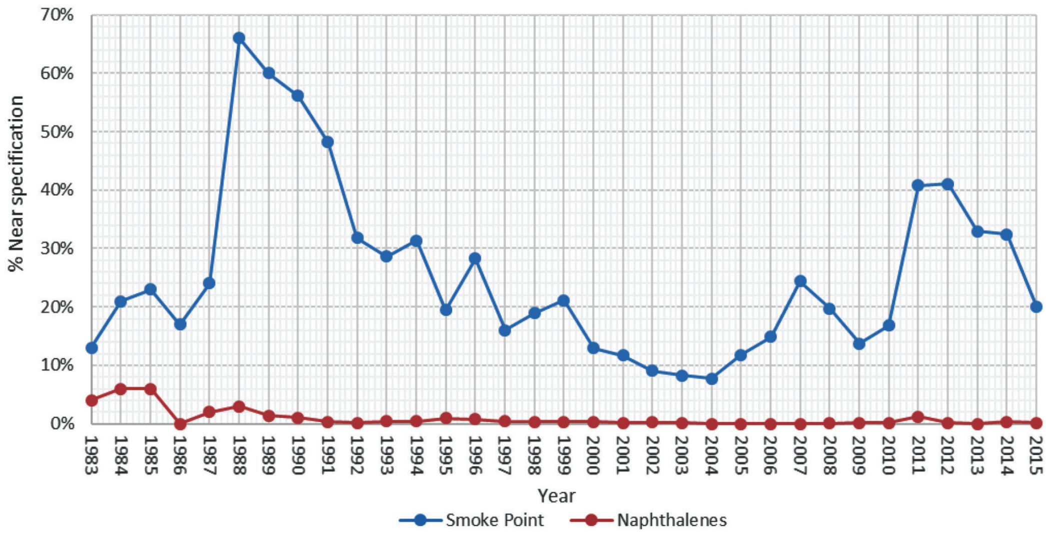

Figure B.52: Near specification trend, smoke point and naphthalenes

This publication has been produced as a result of work carried out within the Technical Team of the Energy Institute (EI), funded by the EI's Technical Partners and other stakeholders. The EI's Technical Work Programme provides industry with cost effective, value adding knowledge on key current and future issues affecting those operating in the energy industry.

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9781787253452

ISBN 978 1 78725 345 2
Registered Charity Number: 1097899