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The quality of aviation fuel available in the United Kingdom

Annual survey 2018-2019

CRC project AV-18-18/19

CRC/EI RESEARCH REPORT

THE QUALITY OF AVIATION FUEL AVAILABLE IN THE UNITED KINGDOM ANNUAL SURVEY 2018-2019

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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 2018 and 2019. The data for each year is expressed separately, in the form of histograms and mean values, which are graphically compared over the period 1986-2019. This report is the 40th 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[1])[1-26]. This report covers a similar survey for aviation fuel (Jet A-1) supplied during the years 2018 and 2019, including 1 144 and 1 185 batches respectively complying with Defence Standard 91-091[27]. 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 main batches of aviation fuel released during 2018 and 2019. The data have been expressed in the form of histograms and mean values, which are graphically compared over the period of 1986 to 2019. 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 do not give exact details on the number of imports, it is expected that a large proportion of the data contained in this survey are from imported batches. Therefore, the data presented are likely to be 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, original equipment manufacturers (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.

1 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 have 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 2018 and 2019. The data for all but four of the properties detailed in Defence Standard 91-091 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, where provided, were typically 1A with a number of 1B results, and thermal stability results were typically a <1 tube rating with no pressure drop. No deposit thickness data were reported. All thermal stability results were reported at 260 °C. The data for electrical conductivity were 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.[27]

2.1 TABULATED DATA

Tables A1 and A2 detail the specification limits for each property from Defence Standard 91-091 compared to the maxima and minima of the AVTUR data collected for the respective years.

2.2 HISTOGRAMS AND TREND GRAPHS FOR ANNUAL MEAN RESULTS

Figure B1 to Figure B80 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, where available, for each property plotted against year for the period 1986 to 2019.

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 B4) includes a range of results from >9 to ≤11.

2.3 GRAPHS OF NEAR SPECIFICATION TRENDS FOR AVTUR PRODUCED FROM 1986 TO 2019

For seven specification properties, Figure B78 to Figure B80 show the percentage of batches that have results near the specification limits, plotted against year for the period 1986 to 2019. The properties the figures relate to are listed below:

– Figure B78: acidity, aromatics
– Figure B79: mercaptan sulfur, flash point, freeze point
– Figure B80: 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, ball-on-cylinder lubricity evaluator (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.[2]

No BOCLE results were reported for the batches used in this survey.

3.1 SAMPLE SIZE

In 2018, results for 1 144 batches were recorded. In 2019 results for 1 185 batches were recorded. These batches represent 11 991 760 m^3 and 13 613 865 m^3 respectively. In total, this report includes data from over 70 000 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 allowing waivers, for various reasons, or due to the data provided having some results unavailable.

3.2 TOTAL ACIDITY

The volume-weighted mean value in 2018 and 2019 was 0,0052 and 0,0044 mg KOH/g respectively. The results do not indicate increasing or decreasing trends (Figure B3). The percentage of batches 'near specification limit' has showed some fluctuation in recent years but there is no obvious trend.

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 17,8 % v/v in 2018 (Figure B4) and 17,1 % v/v in 2019 (Figure B5). There appears to be no obvious trend in mean values; however, the value for 2019 is historically low.

Aircraft operators may be concerned about the problems caused by different batches of fuel having large variations in aromatics. In 2018 and 2019, aromatic content ranged from 9,0 % v/v to 25,0 % v/v with more than 99 % of batches in the range 13 % v/v to 25 % v/v.

2 It should be noted that some of the data supplied for this survey were not in the form of test certificates, but supplied in spreadsheet format. While electronic data do not provide all of the data found on main batch test certificates, this 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 91-091.

The small 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 % in 2019 and remains low compared to historical values.

3.4 TOTAL SULFUR

The volume-weighted mean value was 0,039 % m/m (Figure B7) in 2018, and 0,052 % m/m (Figure B8) in 2019. There appears to be no apparent trend in recent years. The total sulfur content also appears to show a multimodal distribution.

Defence Standard 91-091 allows several different methods for determining the sulfur content. Some laboratories use methods that can determine the sulfur 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)[28]. Consequently, results for many batches are reported to two decimal places and those with low sulfur 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 means that accurate data for the sulfur content in batches with low levels of sulfur is not possible, and this – alongside how the results are reported – may have an effect on the apparent weighted mean value.

3.5 MERCAPTAN SULFUR

Mercaptan sulfur was reported for approximately 60 % of batches. Mercaptan sulfur is not required to be reported if the 'doctor' test is negative. Nevertheless, some batches had mercaptan sulfur reported even though the doctor test was negative and these data have been recorded. The volume weighted mean was 0,0009 % m/m and 0,0010 % m/m in 2018 and 2019 respectively (Figures B10 and B11). The weighted mean values have increased over the last three years (Figure B12).

Results for a number of batches showed the mercaptan sulfur 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. Furthermore, because many batches are not tested for mercaptan sulfur (where the doctor test is negative), the true mean value of mercaptan sulfur in jet fuel is likely to be lower than reported here.

3.6 DISTILLATION

The volume-weighted mean value for initial boiling point (IBP) was 147,1 °C in 2018 and 147,8 °C in 2019 (Figures B13 and B14). The mean values in 2018 and 2019 for 10 % recovered were 165,4 °C and 166,5 °C respectively (Figures B16 and B17). Fifty per cent recovered results in 2018 and 2019 were 192,7 °C and 193,5 °C respectively (Figures B19 and B20).

IBP, 10 % and 50 % recovered mean values have shown decreasing trends for a number of years but now appear to be levelling out. The mean results remain historically low.

Distillation, along with other properties, such as flash point, density and viscosity have shown trends in the previous decade indicating jet fuel containing more volatile components. The latest survey suggests this trend may be levelling off, perhaps as some properties approach specification limits.

The 2018 and 2019 weighted mean values for 90 % recovered were 237,3 °C and 235,0 °C respectively (Figure B22 and B23). The final boiling point (FBP) weighted means of 259,1 °C and 257,4 °C recorded in 2018 and 2019 (Figure B25 and B26) show no consistent trend (Figure B27).

Aviation turbine fuels containing synthesized hydrocarbons, in accordance with ASTM D7566[29], have extended requirements (over ASTM D1655 and Defence Standard 91-091) to ensure a sufficient distillation range[3]. The requirements for T50-T10 are a minimum of 15 °C, and for T90-T10 is a minimum of 40 °C[4].

All of the 2 329 batches in 2018 and 2019 would have met both the T50-T10 and the T90-T10 requirements (Figures B28–B31).

3.7 FLASH POINT

The volume-weighted mean value for flash point was 40,5 °C in 2018 and 40,7 °C in 2019 (Figures B32 and B34). This property has shown a decreasing mean value for many years and the mean values in this report are the lowest recorded.

The 'near specification limit' analysis for flash point is shown in Figure B79. In 2018 and 2019, the proportion of batches that were 'near specification limit' was 82 % and 74 % respectively. 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 B79 are partially due to the change in reproducibility. Flash point appears to be a major restraining factor in jet fuel production for some refineries.

3.8 DENSITY

The volume-weighted mean for density was 799,7 kg/m^3 in 2018 and 798,5 kg/m^3 in 2019 (Figures B35 and B36). These values indicate the decreasing trend observed since 2010 (Figure B37) as stopped. The specification limits are 775 kg/m^3 to 840 kg/m^3.

3.9 FREEZING POINT

The volume-weighted mean value for 2018 was –52,9 °C and in 2019 was –54,1 °C (Figures B38 and B39).

3 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.

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

The percentage of batches 'near specification limit' during 2018 and 2019 was 4,4 % and 8,4 % respectively (Figure B40). Although the number of batches near specification have increased, freezing point no longer appears to be the major restraining factor in jet fuel production that it once was for some refineries.

3.10 KINEMATIC VISCOSITY

The volume-weighted mean value in 2018 was 3,65 cSt and was 3,66 cSt 2019 (Figures B41 and B42). The reducing trend in mean viscosity from 2010 to 2015 has stopped but the mean remains historically low (Figure B43).

The specification limit is 8 cSt maximum at –20 °C. However, it should be noted that most aircraft engines are certified with a maximum viscosity of 12 cSt at –40 °C[5], which is approximately equivalent to 5,5 cSt at –20 °C. For 2018 and 2019 there were no batches that exceeded 5,5 cSt, with the maximum result being 4,920 cSt.

3.11 SPECIFIC ENERGY

The volume-weighted mean was 43,24 MJ/kg and 43,26 MJ/kg in 2018 and 2019 respectively. There is no obvious trend in the mean value (Figure B46). 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 2018 and 2019 was 24,0 mm and 23,4 mm (Figures B47 and B48). The smoke point specification limit changed from 19 mm to 18 mm minimum at the start of 2017. Previous surveys showed an unusual distribution with regard to the high percentage of results at 25 mm, which may have been linked to the specification requirement for the measurement of naphthalenes when the smoke point is less than 25 mm. This is less apparent in this survey and may be linked to increased use of the automated smoke point methodology.

From 2010 to 2017 there was an increasing trend in the volume-weighted mean values. However, the results in 2018 and 2019 stop this trend (Figure B49). The change in near specification results from 2016 onwards is largely due to changes in method reproducibility and specification limit rather than a change in smoke point distribution.

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. Some naphthalenes results were reported even though not required due to the smoke point result.

5 The requirement for 12 cSt is particularly relevant for auxiliary power units (APUs) which may need to be started at altitude after cold soak conditions. Some APUs are flight critical.

The mean for 2018 and 2019 was 1,40 % vol and 1,51 % vol (Figures B50 and B51). There appears to be no obvious trend in the last few years (Figure B52). 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 of all the batches.

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 2018 and 2019 mean values were both 0,96 mg/100 ml as shown in Figures B53 and B54. The precision for existent gum is very poor; it is likely that all batches contain virtually no gum and the range of results 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 2018 mean microseparometer (MSEP®) value was 91,2, which is similar to the previous few years (Figure B56). The 2019 mean MSEP® has a similar value of 91,0 (Figure B57).

The Defence Standard 91-091 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. Less than 1 % of batches had results below 70. Where there were batches that reported MSEP® failures, it is likely that these were downstream from the manufacture of the fuel.

3.16 PARTICULATE CONTAMINATION

This requirement for Defence Standard 91-091 has a maximum limit of 1 mg/l, and no batches in 2018 and 2019 had a result above this limit (Figures B59 and B60).

As many batches used for this survey were imported fuel, not all batches had associated particulate contamination results.

Since the start of recording this property there has been minimal variation in the mean values; however, the 2018 and 2019 values are lower than previously recorded (Figure B61).

3.17 SAYBOLT COLOUR

Saybolt colour is a relatively new requirement for Defence Standard 91-091. The 2018 volume-weighted mean value was 28,2 (Figure B62) and is the highest value recorded (Figure B64). The 2018 volume-weighted mean value decreased to 27,5 (Figure B63). 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[6,30]. Histograms show the distribution of ISO codes for ≥4 µm, ≥6 µm, ≥14 µm, ≥21 µm, ≥25 µm, and ≥30 µm channels (Figures B65–B76). 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.

The mean values are shown in Figure B77 over the period of 2009 to 2019. The mean values show no particular trends. No specification limits for this property were set at the time of these analyses.

3.19 BOCLE

There were no BOCLE results reported in 2018 or 2019.

3.20 NEAR SPECIFICATION TRENDS

Figure B78 to Figure B80 are graphs showing the percentage of batches with test results near the specification limit, against each year, for seven specification properties.

The property with the highest percentage of batches with results near the specification limit in 2018 and 2019 was flash point (82 % and 74 %). Smoke point batches near specification limit reduce dramatically due to test method and specification limit changes.

6 According to ISO 4406, codes are applicable to the ≥4 µm, ≥6 µm, and ≥14 µm channels. However, for the purposes of Defence Standard 91-091, codes are reported using the same ISO 4406 coding table for all six channels.

4 SUMMARY OF CHANGES AND TRENDS

4.1 TREND DATA

Table 1: Properties showing increasing or decreasing trends

Properties where there is a rising trend	Properties where there is a decreasing trend
Flash point batches near specification limit (increasing since 1991)	Distillation mean value IBP (decreasing since 1991)
Mercaptan sulfur mean value (increasing since 2016)	Flash point mean value (decreasing since 1991)

4.2 SIGNIFICANT CHANGES

Table 2: Significant changes in mean values for 2018 and 2019

Property	Change
Mercaptan sulfur	2019 showed the joint highest value since records began in 1986
Distillation IBP	2018 and 2019 show lowest means ever recorded
Aromatics	2019 value is a drop of 0,7 % v/v and is a historically low value
Flash point	Highest value near to specification limit since records began. Lowest ever mean values

5 ACKNOWLEDGEMENTS

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6 REFERENCES

[1] Various MQAD and Harefield Annual Fuel Surveys 1974-1986

[2] DQA/TS Materials Centre Report No. 361, March 1987

[3] DQA/TS Technical Report No. 88/2, May 1988

[4] DQA/TS Technical Report No. 89/8, November 1989

[5] DQA/TS Technical Report No. 91/4, March 1991

[6] DQA/TS Technical Report No. 91/10, November 1991

[7] QATS FL Division Technical Paper FLT/1/93, March 1993

[8] QATS FL Division Technical Paper FLT/3/93, June 1993

[9] FVS FL Division Technical paper DRA/FVS/FL/TR94002/1, September 1994

[10] LS FL Division Technical paper DRA/LS/LSF4/TR95004, June 1995

[11] LS FL Division Technical paper DRA/LS4/TR96/044/1, July 1996

[12] SMC FL Division Technical paper DERA/SMC/SM1/TR970039, May 1997

[13] MSS Technical Report DERA/MSS1/TR980069/1.0, May 1998

[14] MSS Technical Report DERA/MSS/MSMA1/TR990400/1.0, August 1999

[15] MSS Technical Report DERA/MSS/MSMA3/CR001238, June 2000

[16] FST Technical Report DERA/FST/CET/TR010603, June 2001

[17] FST Technical Report QinetiQ/FST/CR023267, May 2002

[18] FST Technical Report QinetiQ/FST/CR032630, June 2003

[19] FST Technical Report QinetiQ/FST/TR042832, June 2004

[20] FST Technical Report QinetiQ/FST/ TR050276, June 2005

[21] FST Technical Report QinetiQ/FST/ TR0601360, June 2006

[22] Technical report QINETIQ/S&DU/T&P/E&M/TR0701148, June 2007

[23] Technical report QINETIQ/08/01656, June 2008

[24] Technical report QINETIQ/09/01120, December 2009

[25] The quality of aviation fuel available in the United Kingdom Annual surveys 2009 to 2015. CRC project no. AV-18-14. October 2019.

[26] The quality of aviation fuel available in the United Kingdom Annual surveys 2016 to 2017. CRC project no. AV-18-19. December 2022.

[27] Specification Defence Standard 91-91. Turbine Fuel, Aviation Kerosine Type, Jet A-1, NATO code: F-35, JSD: AVTUR. Issued by UK Defence Standardisation, Kentigern House, 65 Brown Street, Glasgow G2 8EX (www.dstan.mod.uk).

[28] IP 336: Petroleum products – Determination of sulfur content – Energy-dispersive-X-ray fluorescence method. www.energypublishing.org.

[29] ASTM D7566, Standard Specification for Aviation Turbine Fuel Containing Synthesized Hydrocarbons. www.ASTM.org.

[30] BS ISO 4406, Hydraulic fluid power – fluids – Method for coding the level of contamination by solid particles.

APPENDIX A
RESULTS SUMMARIES

A.1 2018 DATA FROM 1 144 BATCHES OF JET FUEL REPRESENTING 11 991 760 m³

Table A1: Minima and maxima for 2018, data and specification limits

Method	Def Stan 91-091 specification limits		Results summary 2018		
	Min.	Max.	Min.	Max.	Mean
Total acidity, mg KOH/g	–	0,015	0,000	0,015	0,005
Aromatics, % volume	–	25,0[7]	9,4	25,0	17,8
Total sulfur, % mass	–	0,30	0,001	0,250	0,039
Mercaptan sulfur, % mass	–	0,0030	0,0001	0,0029	0,0009
Distillation IBP, °C	Report		137,8	158,1	147,1
10 % recovery, °C	–	205,0	148,5	178,9	165,4
50 % recovery, °C	Report		169,0	208,6	192,7
90 % recovery, °C	Report		219,9	249,1	237,3
FBP, °C	–	300,0	238,1	280,0	259,1
Flash point, °C	38,0	–	38,0	47,0	40,5
Density @ 15 °C, kg/m³	775,0	840,0	785,8	818,5	799,7
Freezing point, °C	–	–47,0	–80,3	–47,9	–52,9
Viscosity @ –20 °C, mm²/s	–	8,00	3,01	4,92	3,65
Specific energy, net MJ/kg	42,80	–	43,00	43,44	43,24
Smoke point, mm	19,0	–	19,1	27,7	23,4
Naphthalenes, % volume	–	3,00	0,03	2,87	1,40
Existent gum, mg/100 ml	–	7	0	5	0,96
MSEP®	85 (70 with SDA)	–	54	100	91
BOCLE, mm	–	0,85	N/A	N/A	N/A
Particulate, mg/l	–	1,0	0,01	0,97	0,22

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

Table A1: Minima and maxima for 2018, data and specification limits (continued)

Method	Def Stan 91-091 specification limits		Results summary 2018		
	Min.	Max.	Min.	Max.	Mean
Colour	Report		13	30	28,2
Particle count,					
≥4 µm	Report		12	21	15,8
≥6 µm	Report		10	19	14,0
≥14 µm	Report		7	16	10,3
≥21 µm	Report		7	15	8,9
≥25 µm	Report		7	14	8,4
≥30 µm	Report		7	13	7,9

A.2 2019 DATA FROM 1 185 BATCHES OF JET FUEL REPRESENTING 13 613 865 m³

Table A2: Minima and maxima for 2019, data and specification limits

Method	Def Stan 91-091 specification limits		Results summary 2019		
	Min.	Max.	Min.	Max.	Mean
Total acidity, mg KOH/g	–	0,015	0,000	0,015	0,004
Aromatics, % volume	–	25,0[8]	9,0	24,2	17,2
Total sulfur, % mass	–	0,30	0,000	0,220	0,052
Mercaptan sulfur, % mass	–	0,0030	0,0003	0,0030	0,0010
Distillation IBP, °C	Report		137,7	161,0	147,8
10 % recovery, °C	–	205,0	160,3	177,6	166,6
50 % recovery, °C	Report		177,5	205,6	193,6
90 % recovery, °C	Report		210,6	251,5	235,0
FBP, °C	–	300,0	227,6	291,7	257,4
Flash point, °C	38,0	–	38,0	49,0	40,7
Density @ 15 °C, kg/m³	775,0	840,0	786,0	819,1	798,5
Freezing point, °C	–	–47,0	–67,8	–47,0	–54,1
Viscosity @ –20 °C, mm²/s	–	8,00	2,85	4,72	3,66

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

Table A2: minima and maxima for 2019 data and specification limits (continued)

Method	Def Stan 91-091 specification limits		Results summary 2019		
	Min.	Max.	Min.	Max.	Mean
Specific energy, Net MJ/kg	42,80	–	43,06	43,51	43,26
Smoke point, mm	18,0	–	19,0	28,4	23,7
Naphthalenes, % volume	–	3,00	0,05	2,99	1,51
Existent gum, mg/100 ml	–	7	0	6	0,96
MSEP®	85 (70 with SDA)	–	60	100	91
BOCLE, mm	–	0,85	N/A	N/A	N/A
Particulate, mg/l	–	1,0	0,00	1,00	0,23
Colour	Report		14	30	27,5
Particle count,					
≥4 μm	Report		11	22	16,1
≥6 μm	Report		8	20	14,3
≥14 μm	Report		7	18	10,7
≥21 μm	Report		7	16	8,9
≥25 μm	Report		7	16	8,3
≥30 μm	Report		7	15	7,9

APPENDIX B
FIGURES

B.1 TOTAL ACIDITY

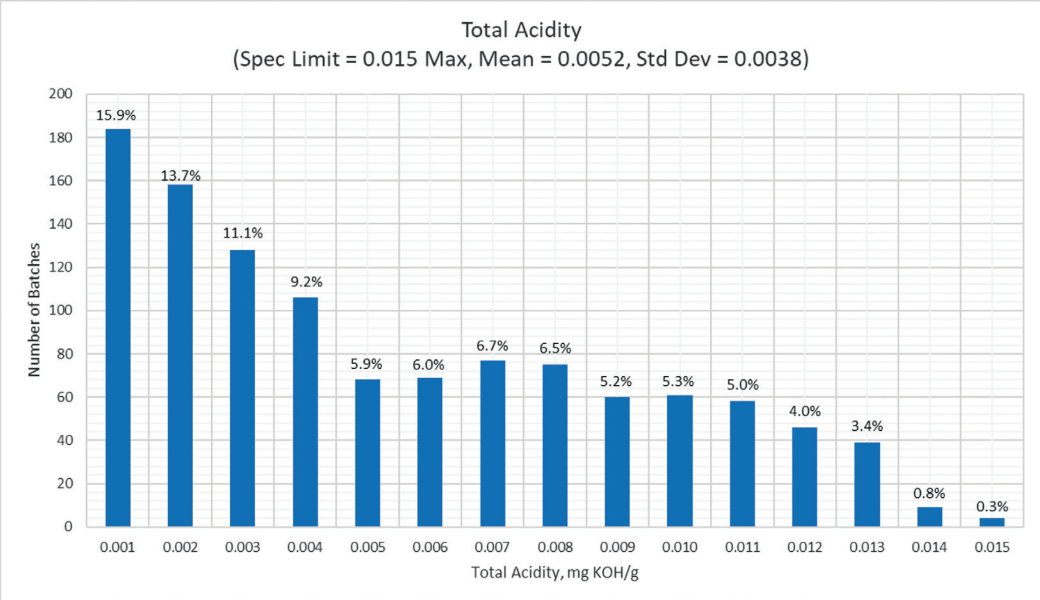

Figure B1: Total acidity histogram (2018)

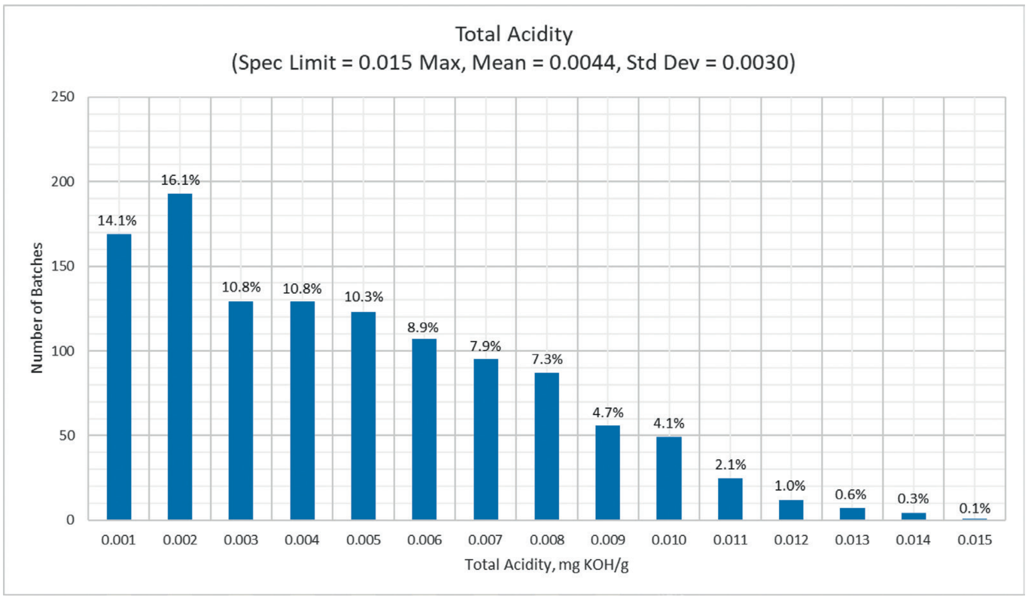

Figure B2: Total acidity histogram (2019)

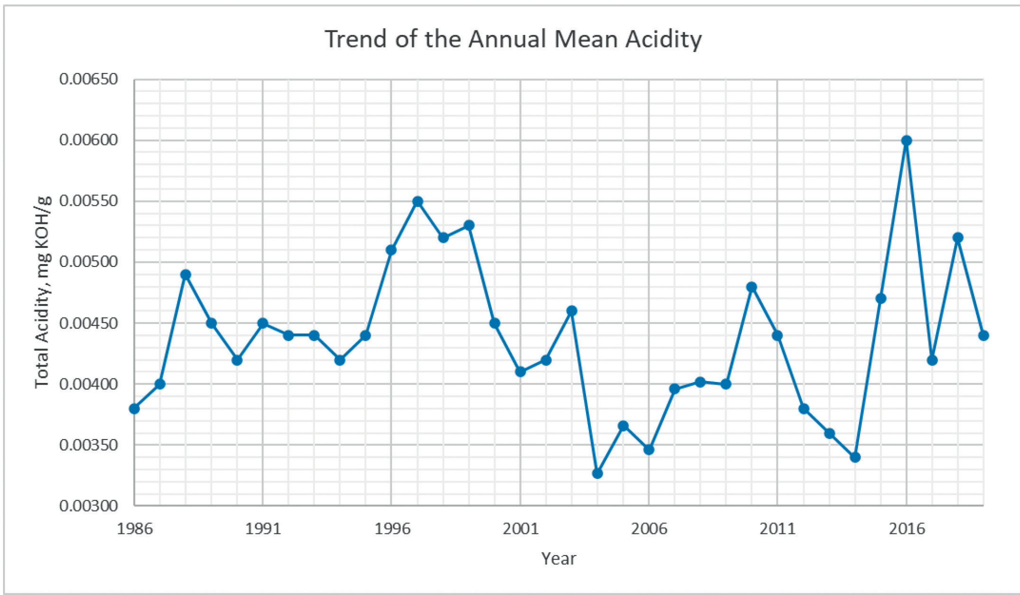

Figure B3: Total acidity trend graph

B.2 AROMATICS

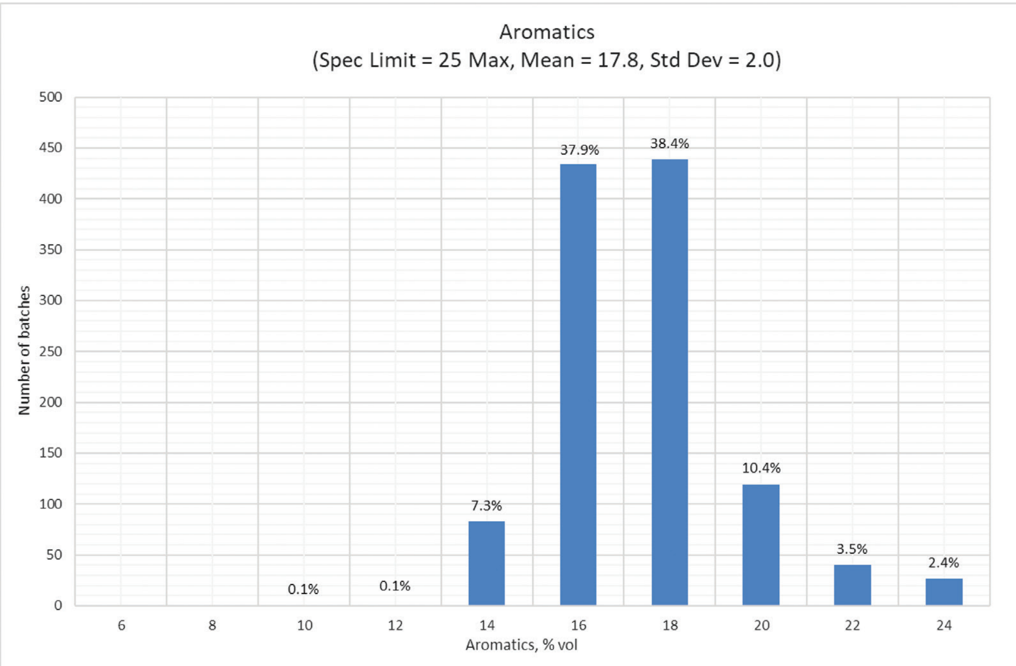

Figure B4: Aromatics histogram (2018)

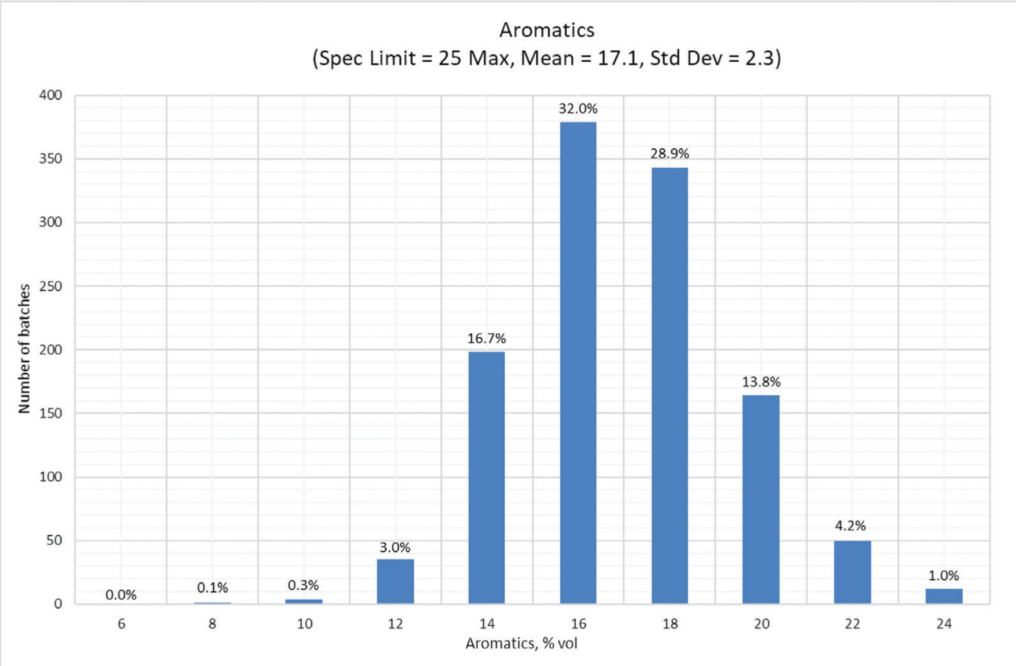

Figure B5: Aromatics histogram (2019)

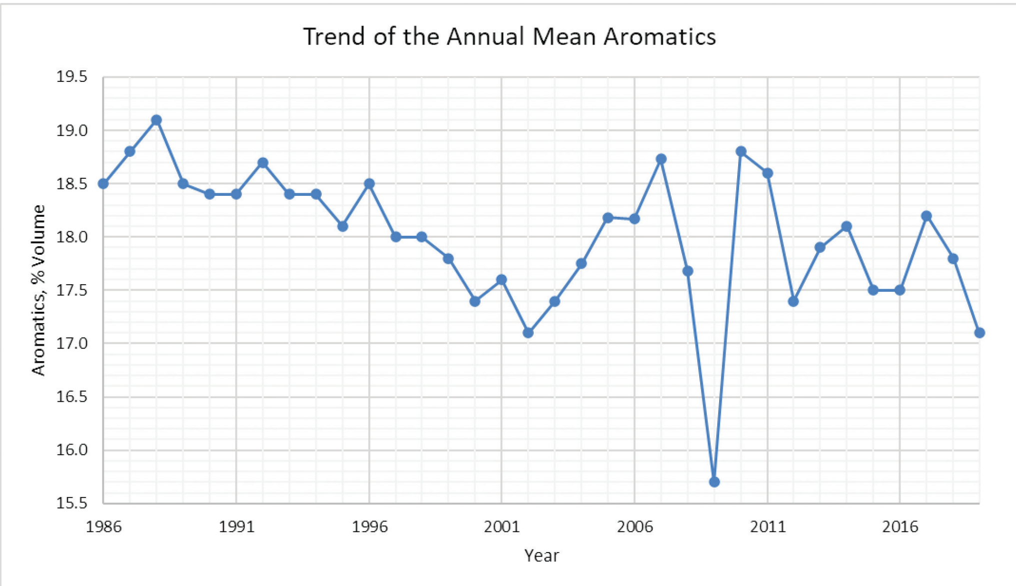

Figure B6: Aromatics trend graph

B.3 TOTAL SULFUR

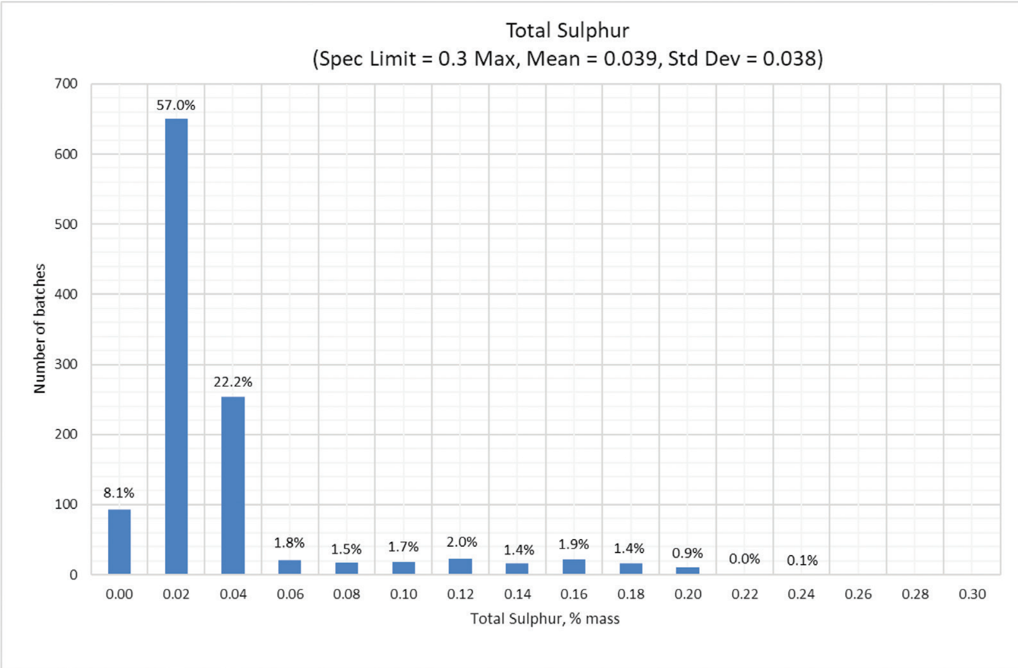

Figure B7: Total sulfur histogram (2018)

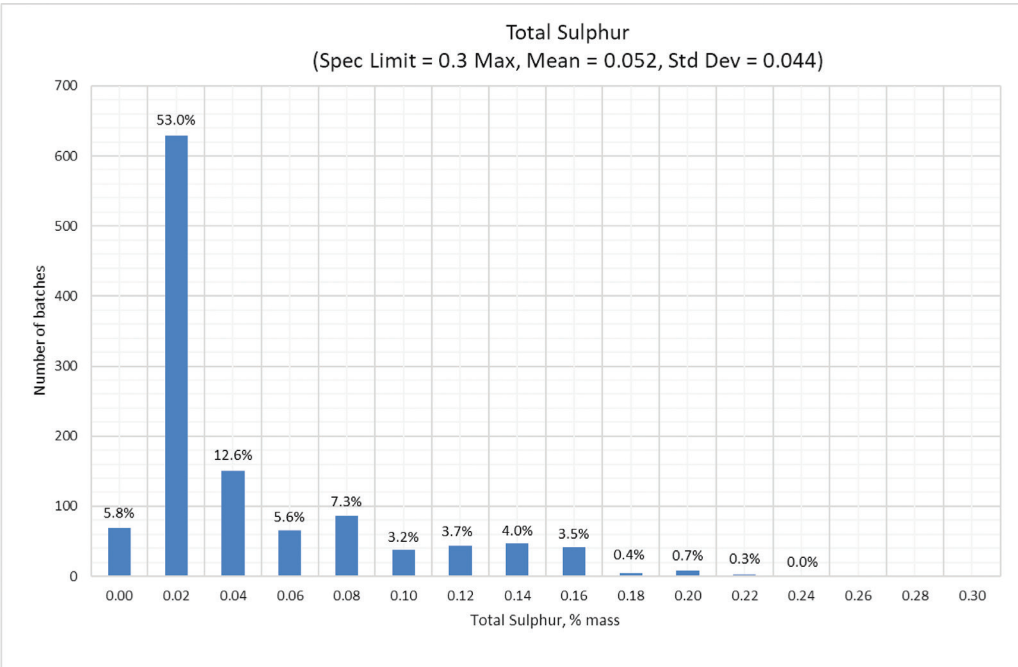

Figure B8: Total sulfur histogram (2019)

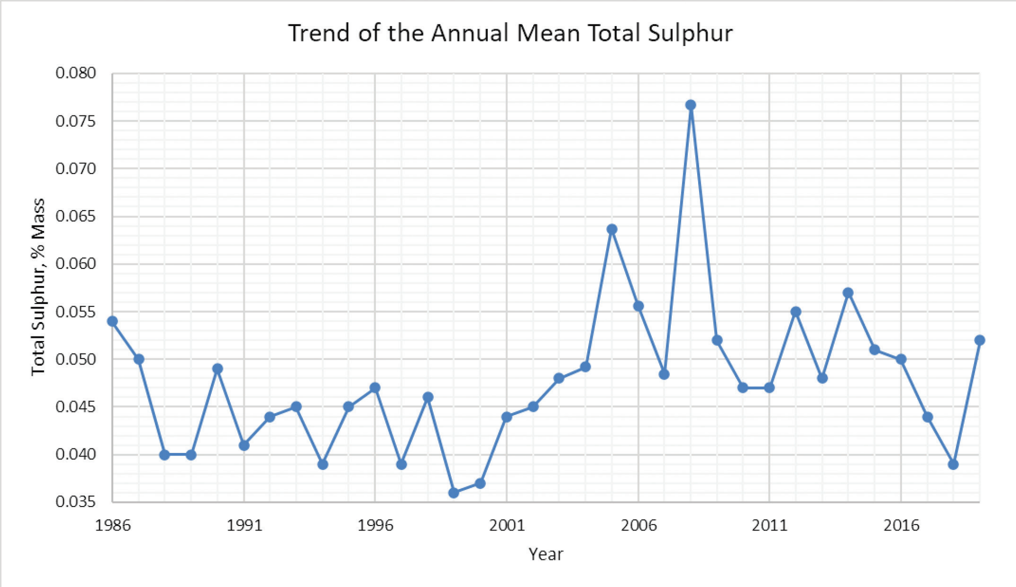

Figure B9: Total sulfur trend graph

B.4 MERCAPTAN SULFUR

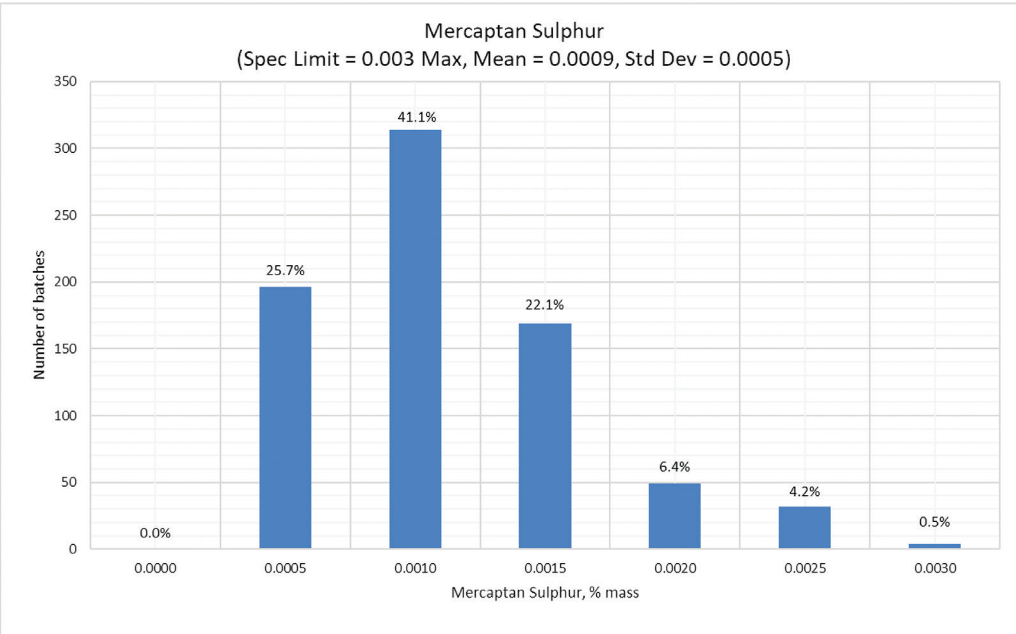

Figure B10: Mercaptan sulfur histogram (2018)

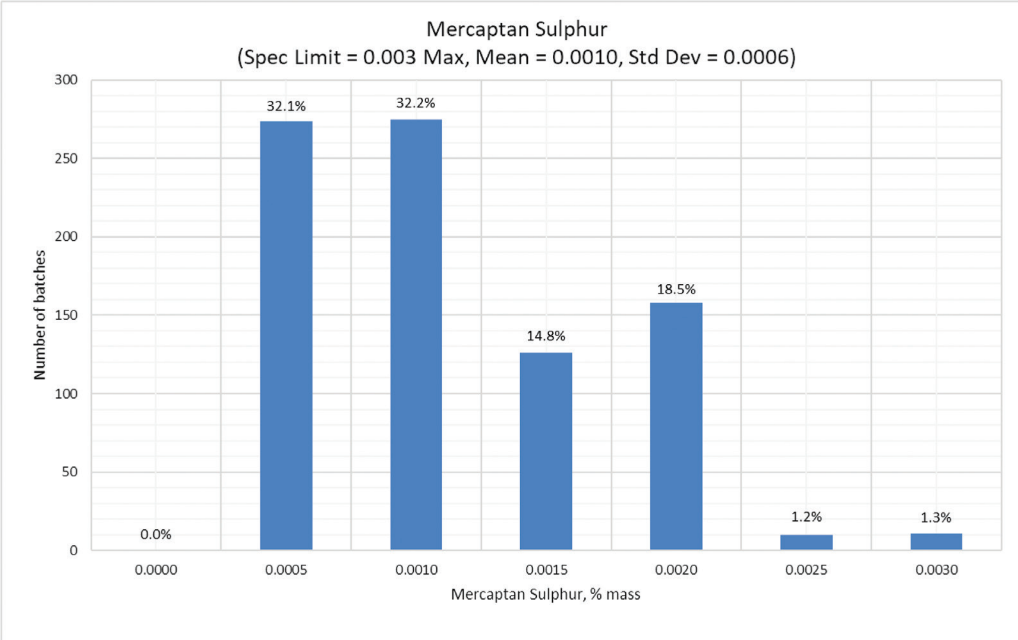

Figure B11: Mercaptan sulfur histogram (2019)

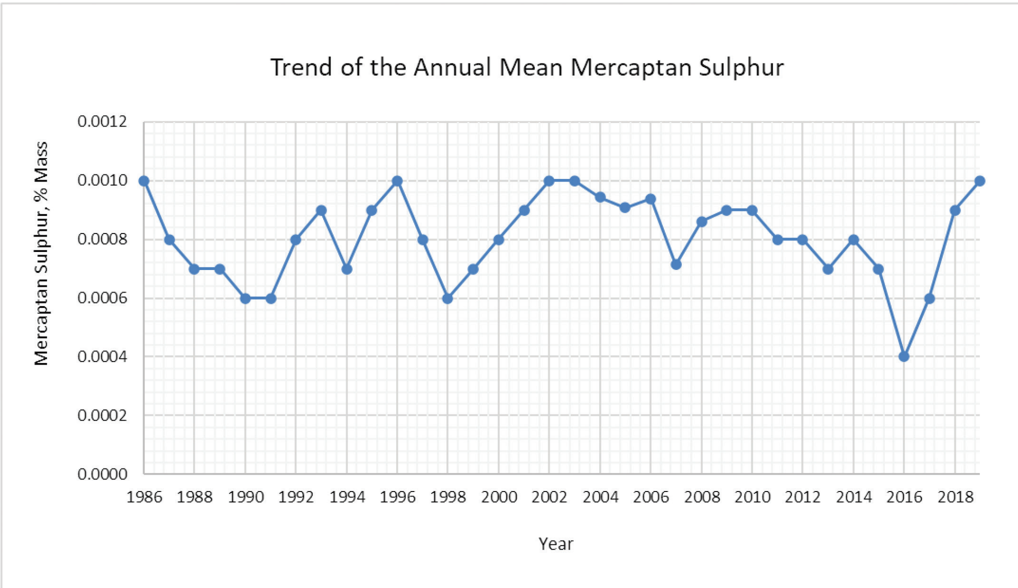

Figure B12: Mercaptan trend graph

B.5 DISTILLATION IBP

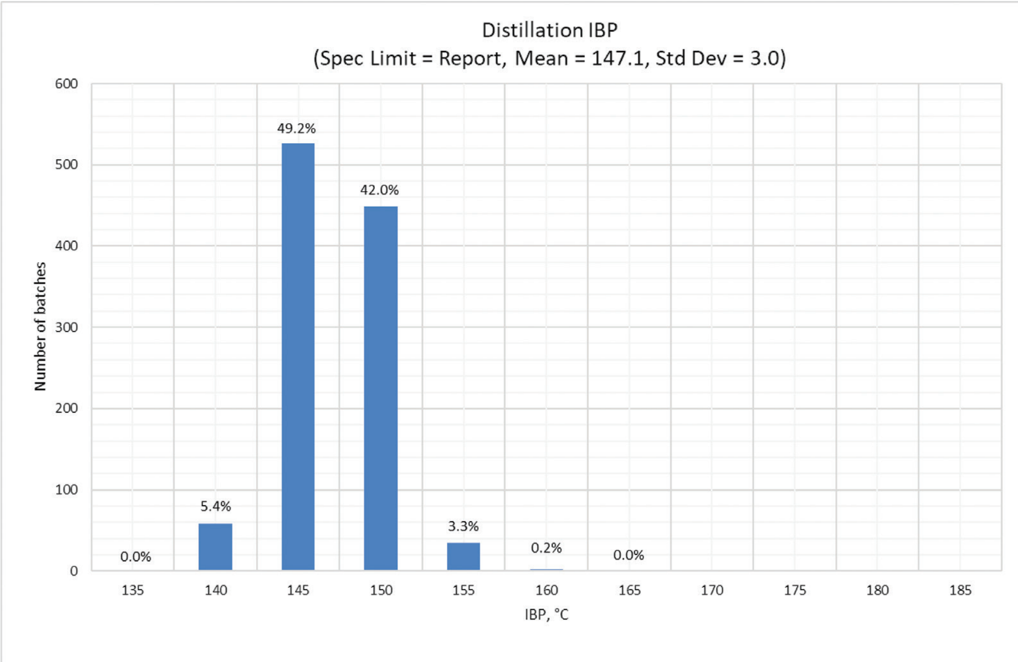

Figure B13: Distillation IBP histogram (2018)

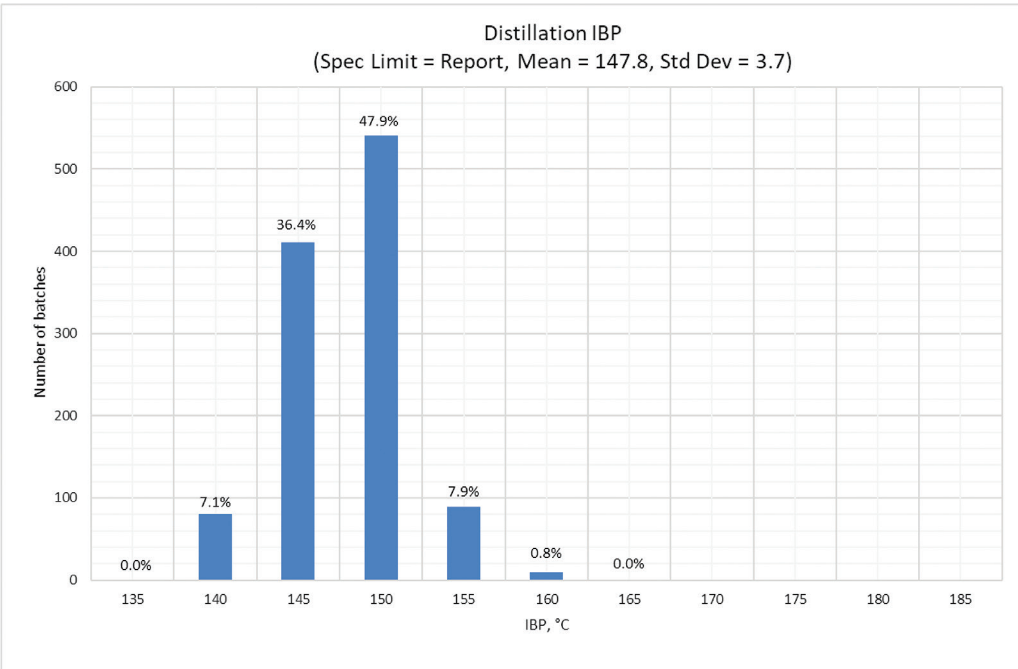

Figure B14: Distillation IBP histogram (2019)

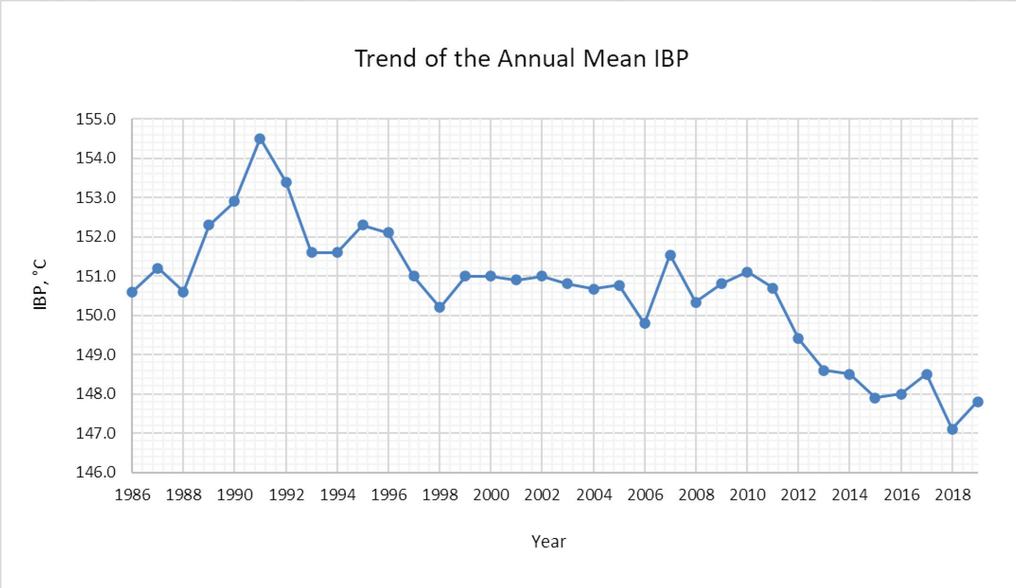

Figure B15: Distillation IBP trend graph

B.6 DISTILLATION 10 % RECOVERY

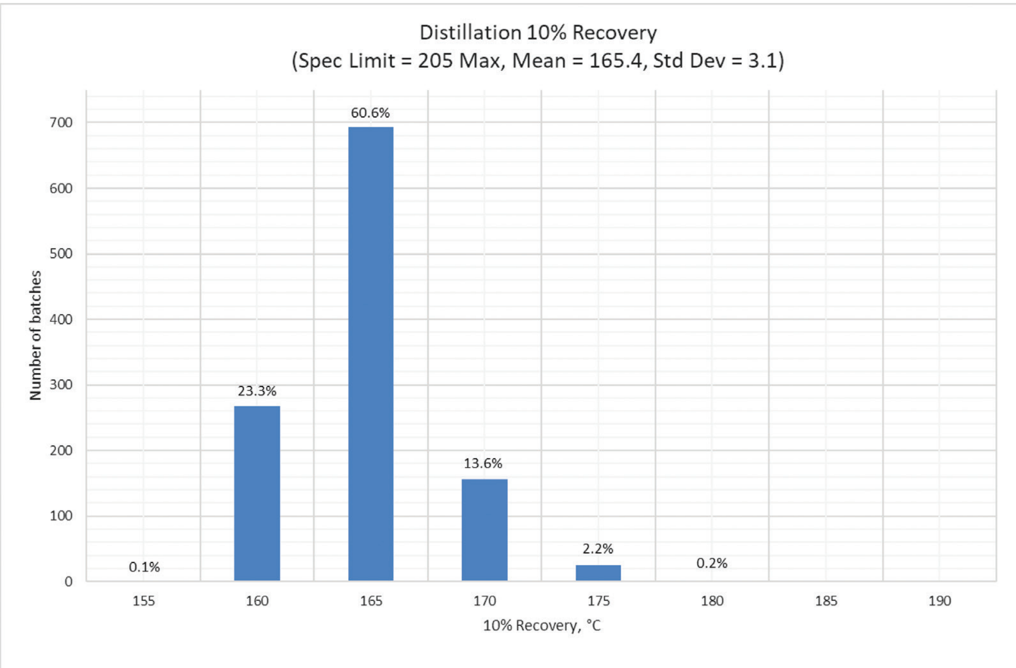

Figure B16: Distillation 10 % recovery histogram (2018)

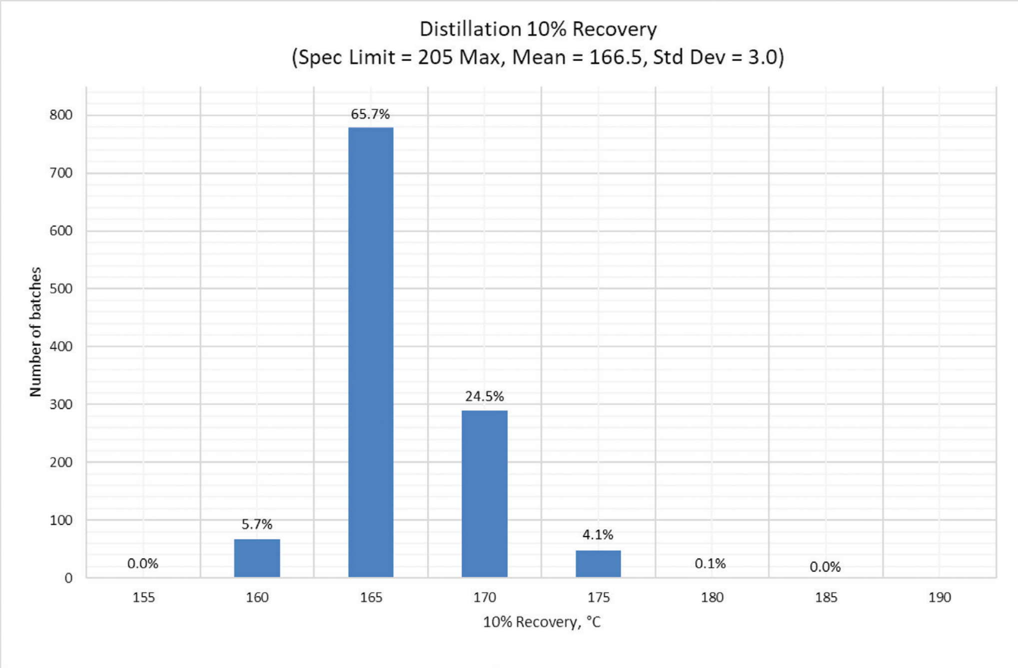

Figure B17: Distillation 10 % recovery histogram (2019)

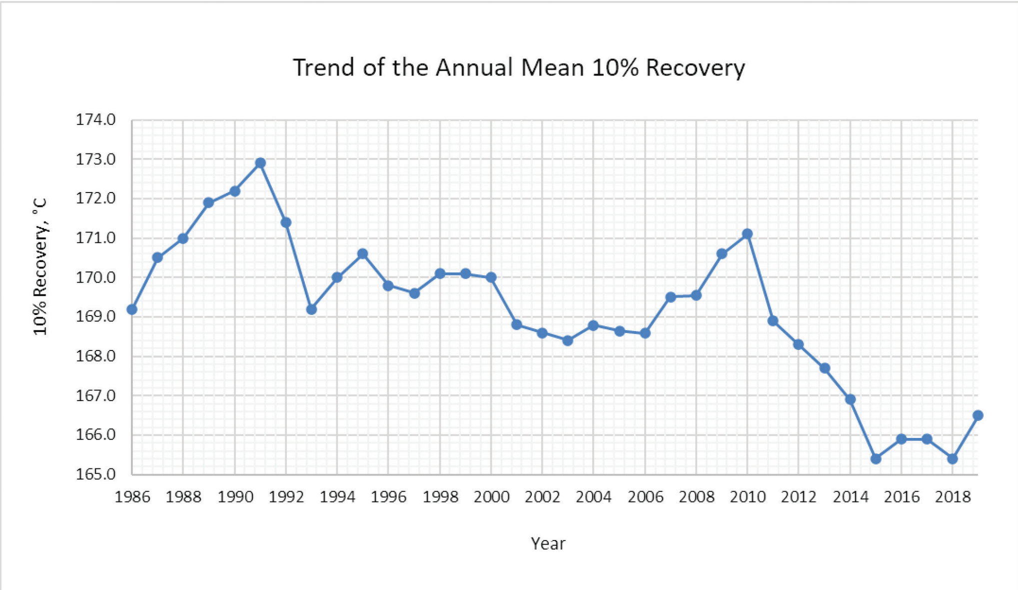

Figure B18: Distillation 10 % recovery trend graph

B.7 DISTILLATION 50 % RECOVERY

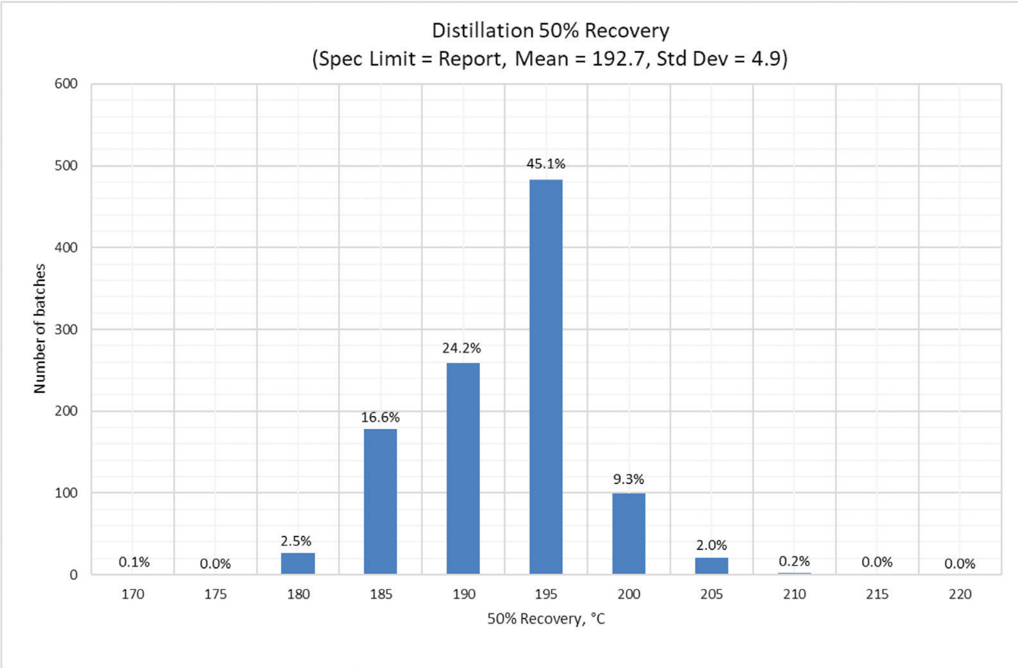

Figure B19: Distillation 50 % recovery histogram (2018)

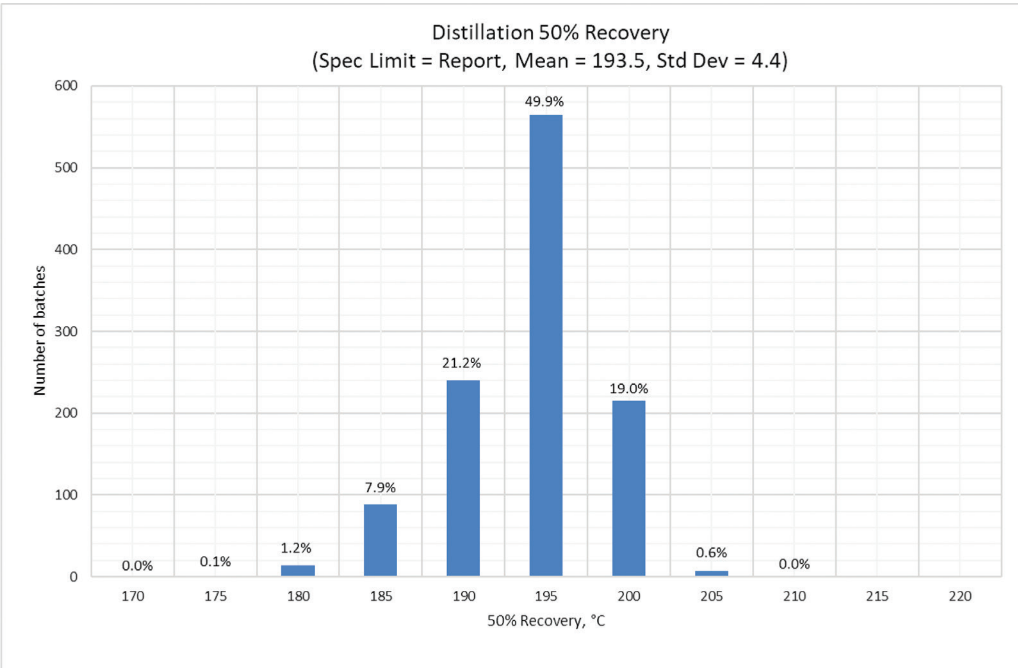

Figure B20: Distillation 50 % recovery histogram (2019)

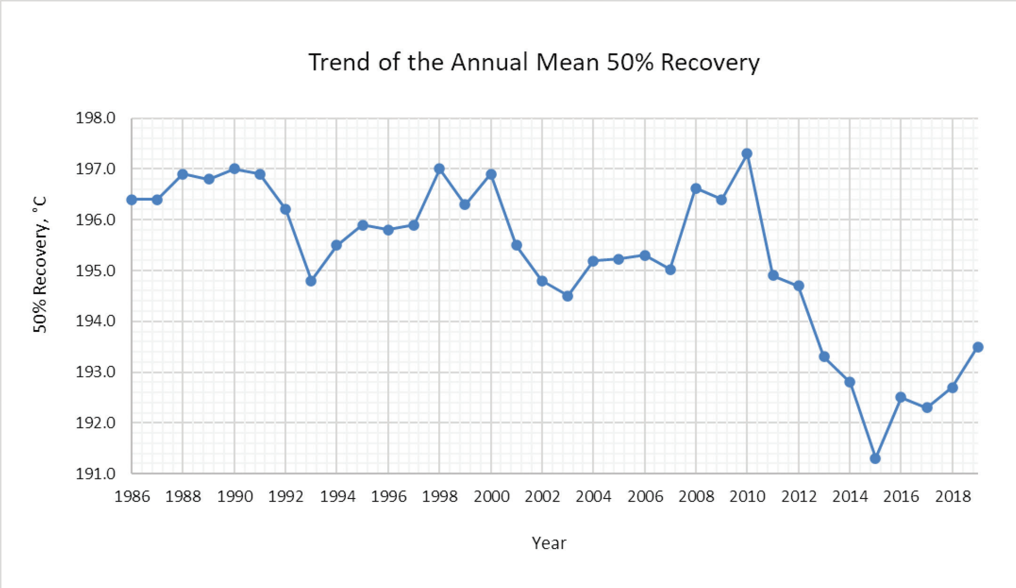

Figure B21: Distillation 50 % recovery trend graph

B.8 DISTILLATION 90 % RECOVERY

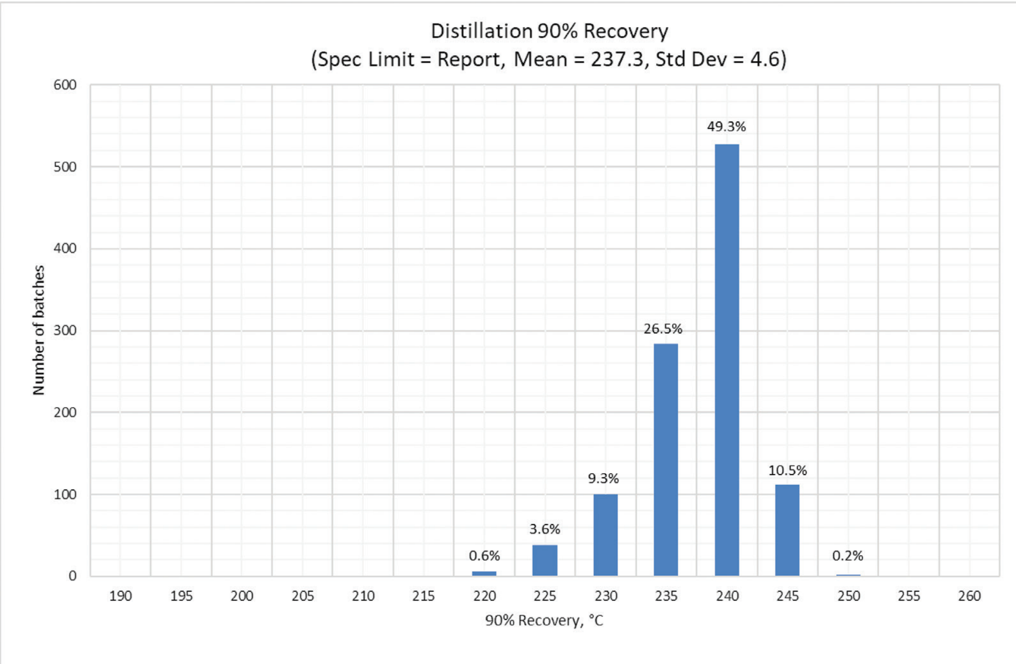

Figure B22: Distillation 90 % recovery histogram (2018)

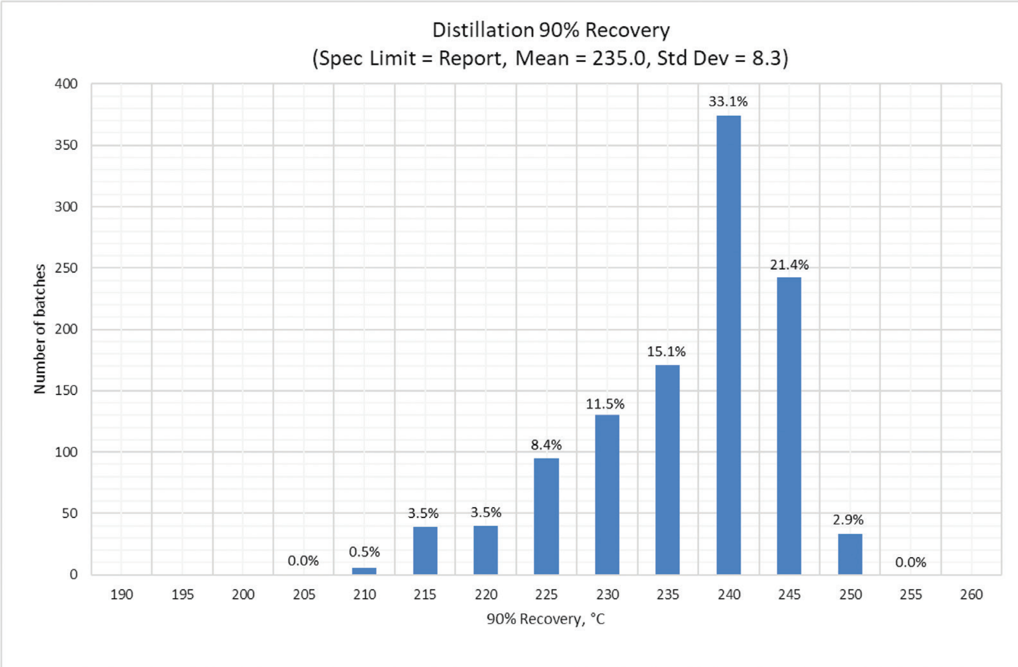

Figure B23: Distillation 90 % recovery histogram (2019)

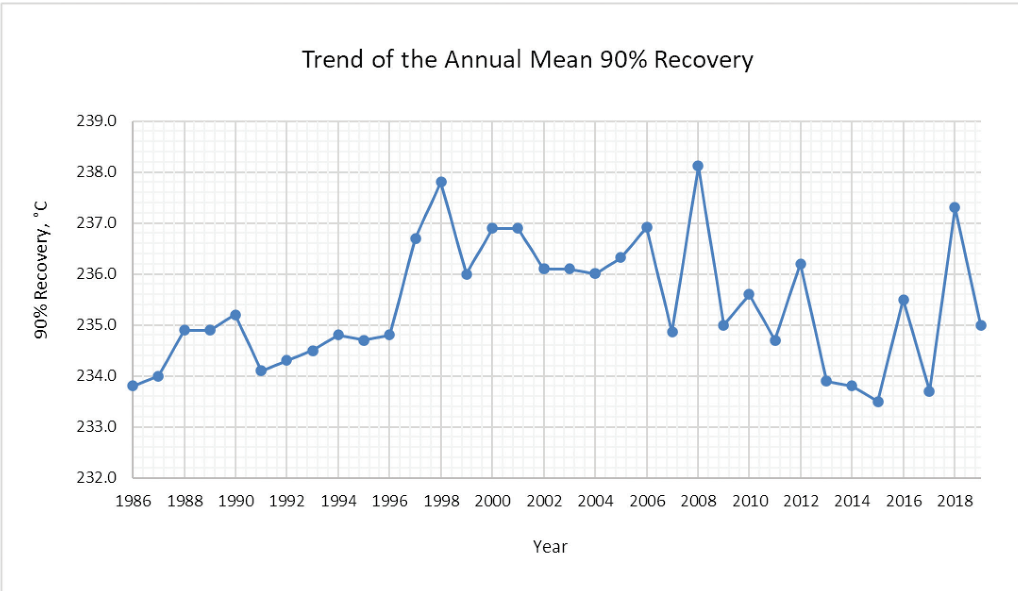

Figure B24: Distillation 90 % recovery trend graph

B.9 DISTILLATION FBP

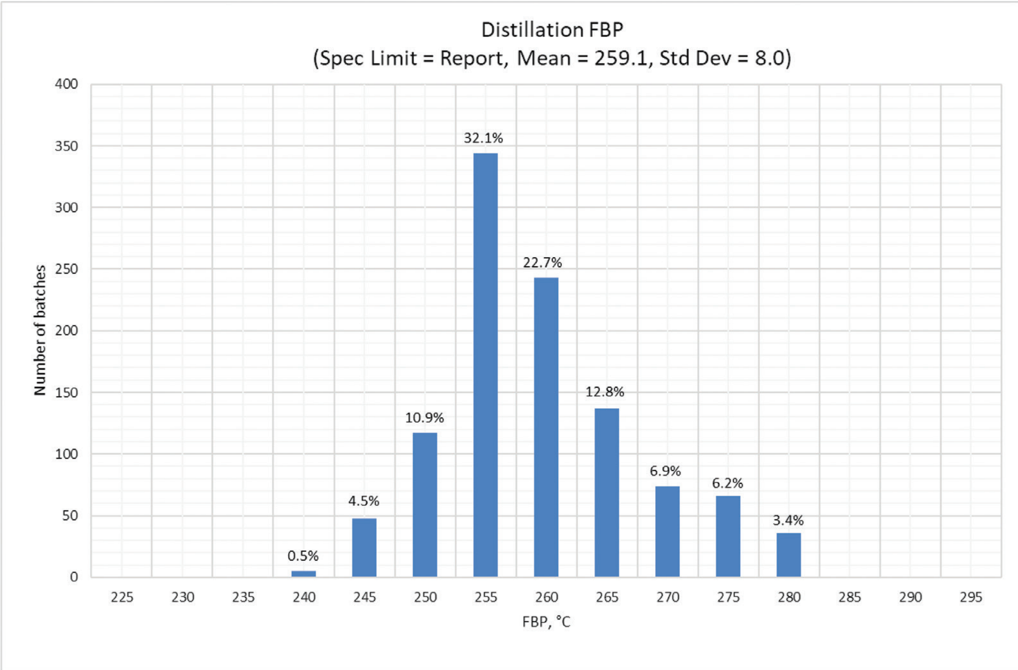

Figure B25: Distillation FBP histogram (2018)

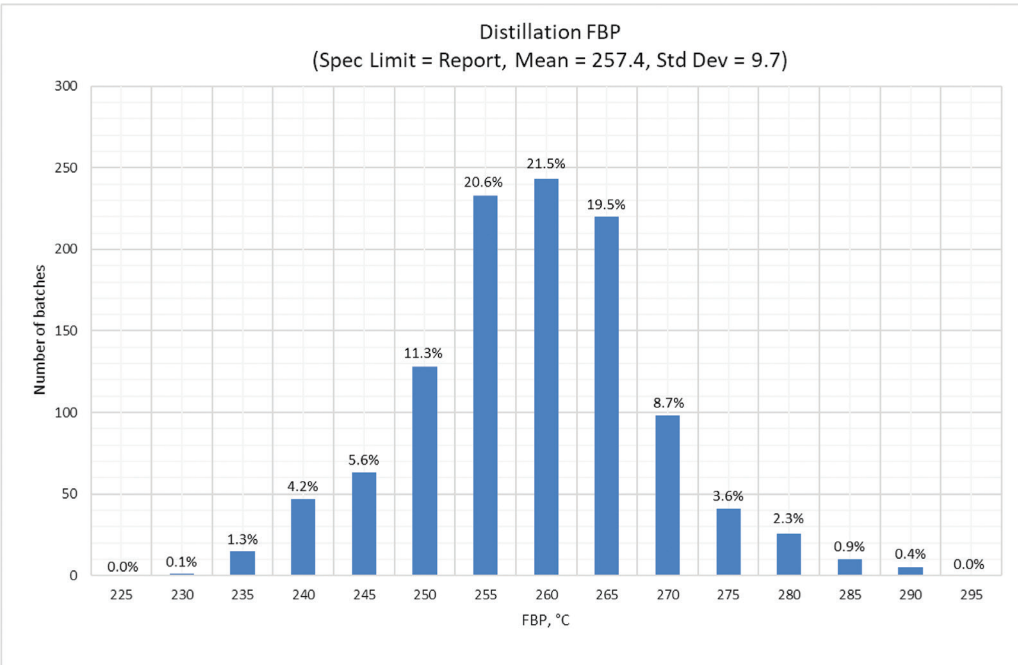

Figure B26: Distillation FBP histogram (2019)

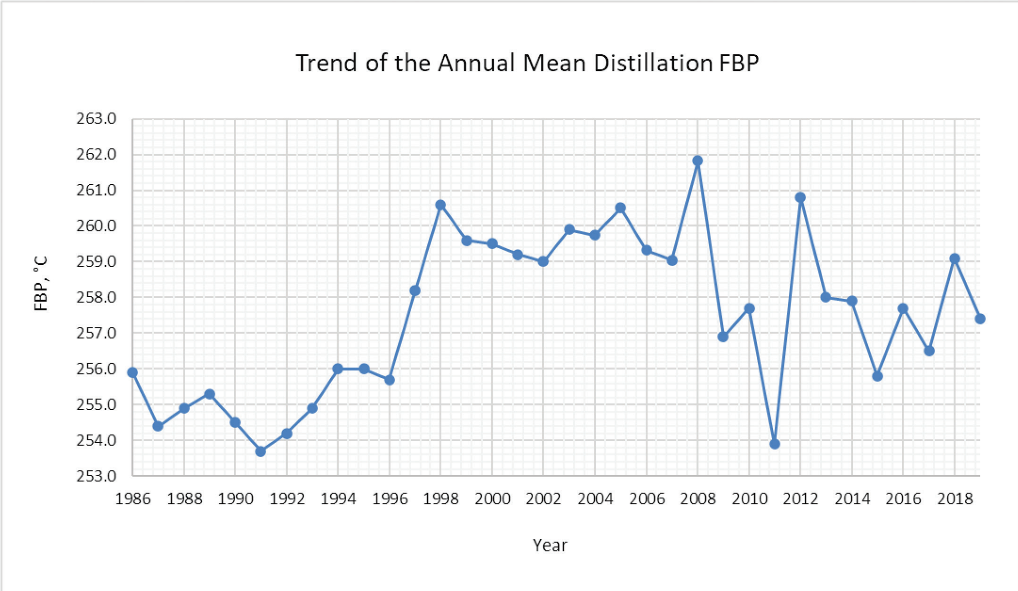

Figure B27: Distillation FBP trend graph

B.10 DISTILLATION RANGE

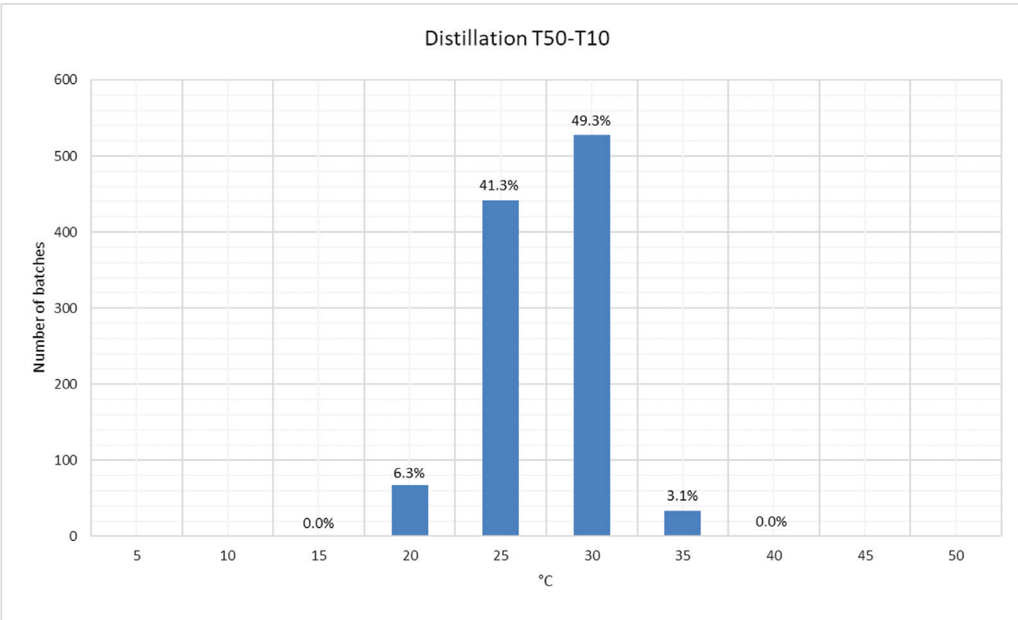

Figure B28: Distillation T50–T10 (2018)

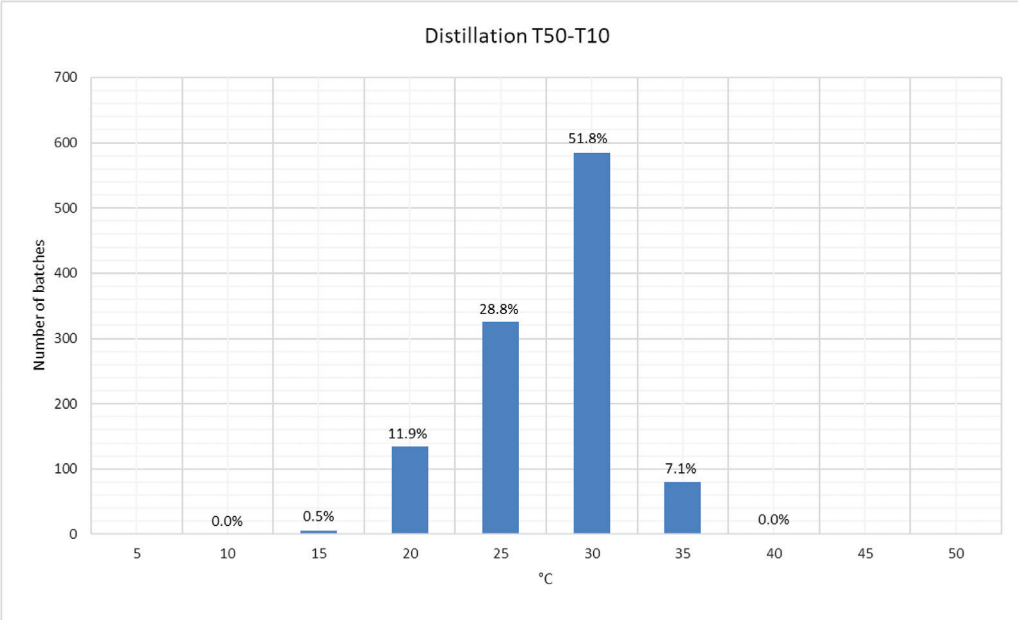

Figure B29: Distillation T50–T10 (2019)

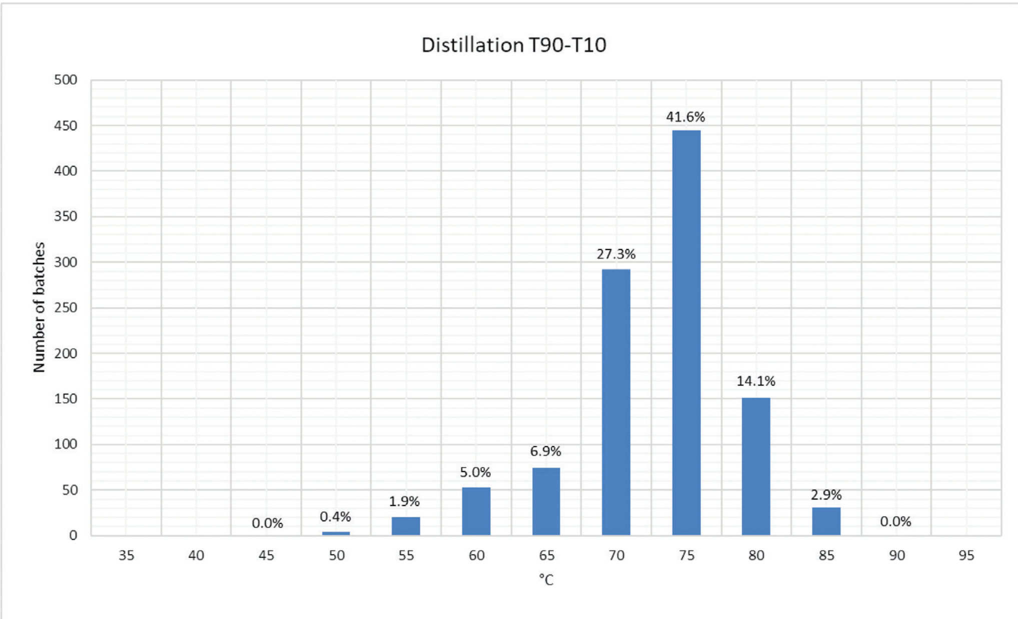

Figure B30: Distillation T90–T10 (2018)

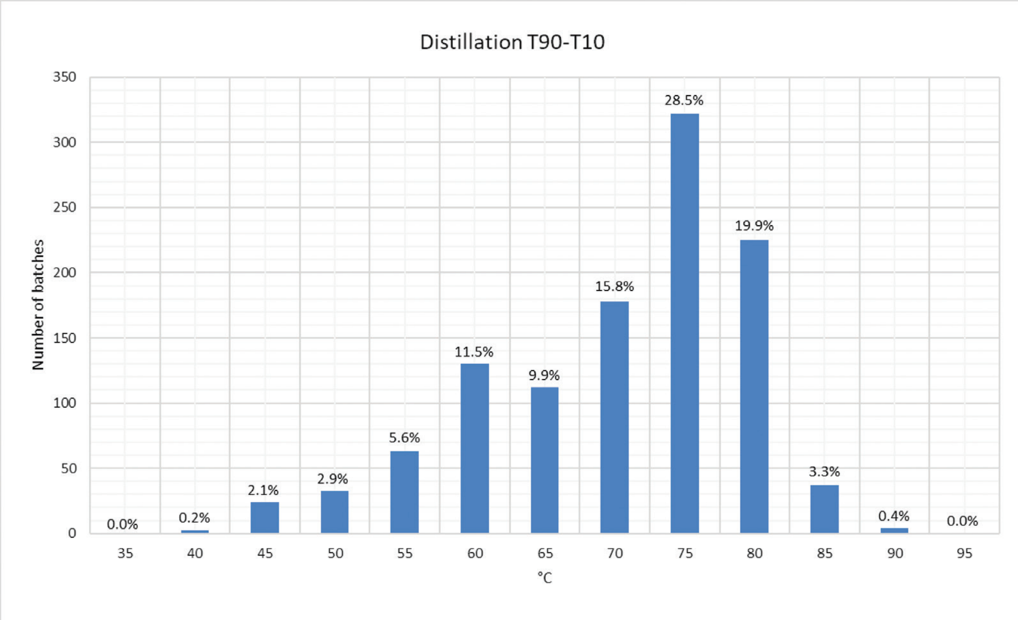

Figure B31: Distillation T90–T10 (2019)

B.11 FLASH POINT

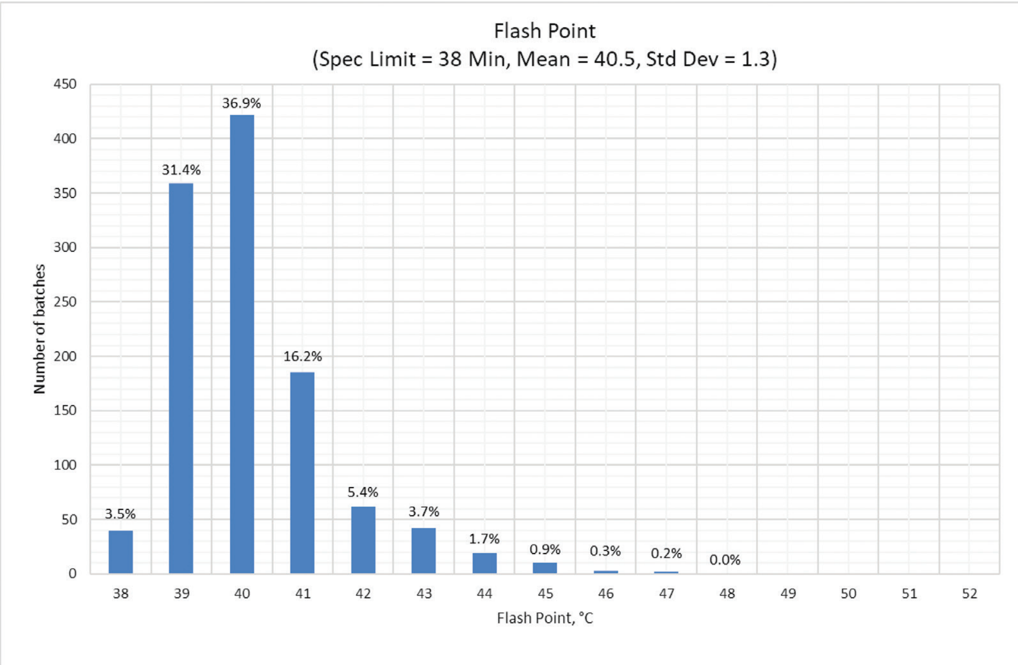

Figure B32: Flash point histogram (2018)

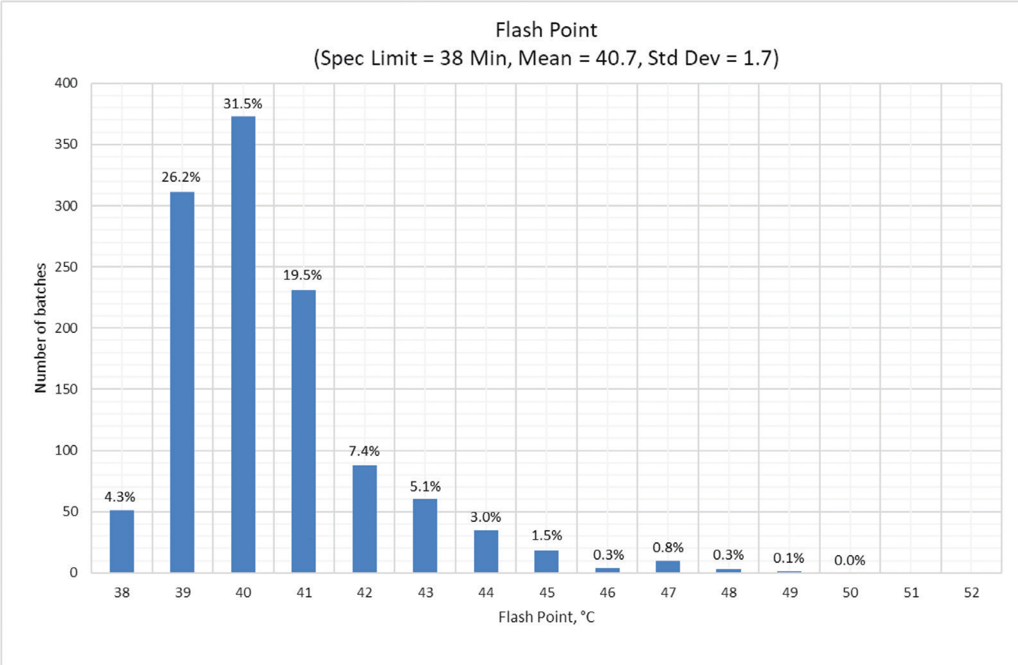

Figure B33: Flash point histogram (2019)

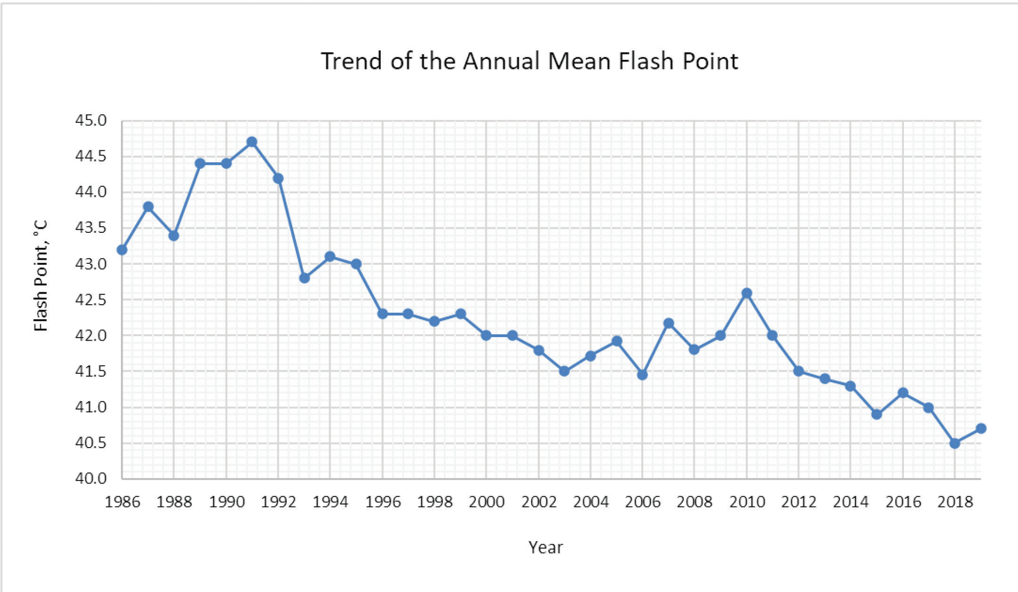

Figure B34: Flash point trend graph

B.12 DENSITY AT 15 °C

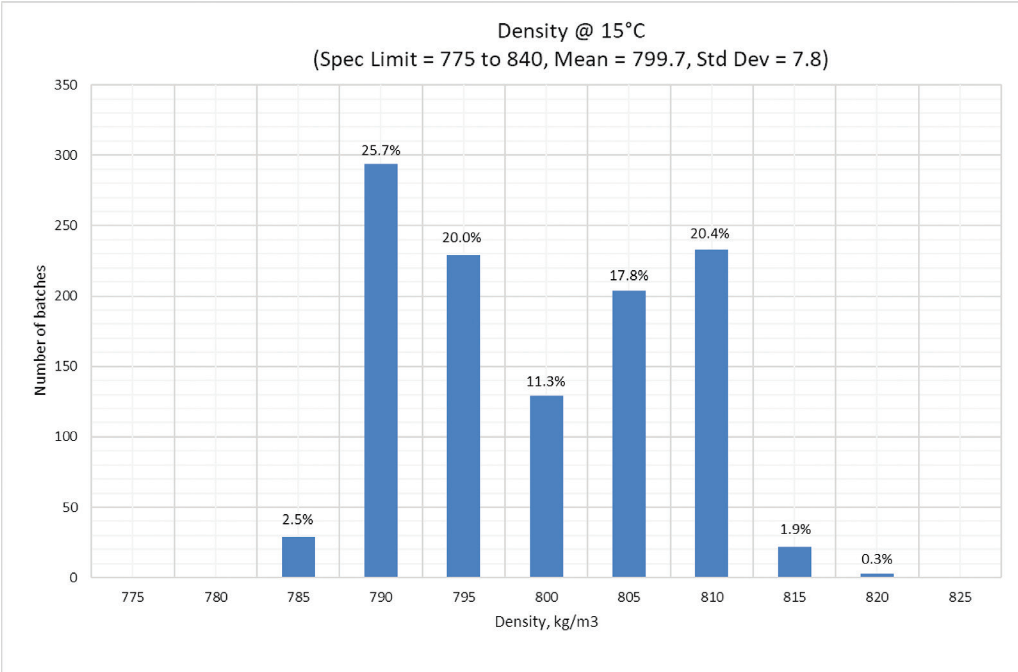

Figure B35: Density histogram (2018)

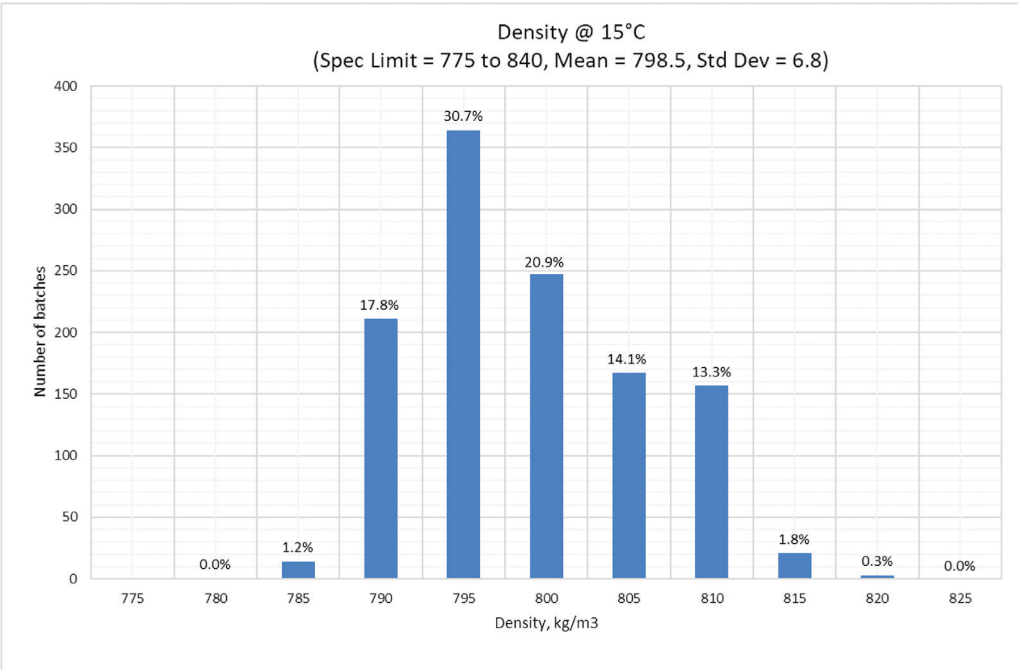

Figure B36: Density histogram (2019)

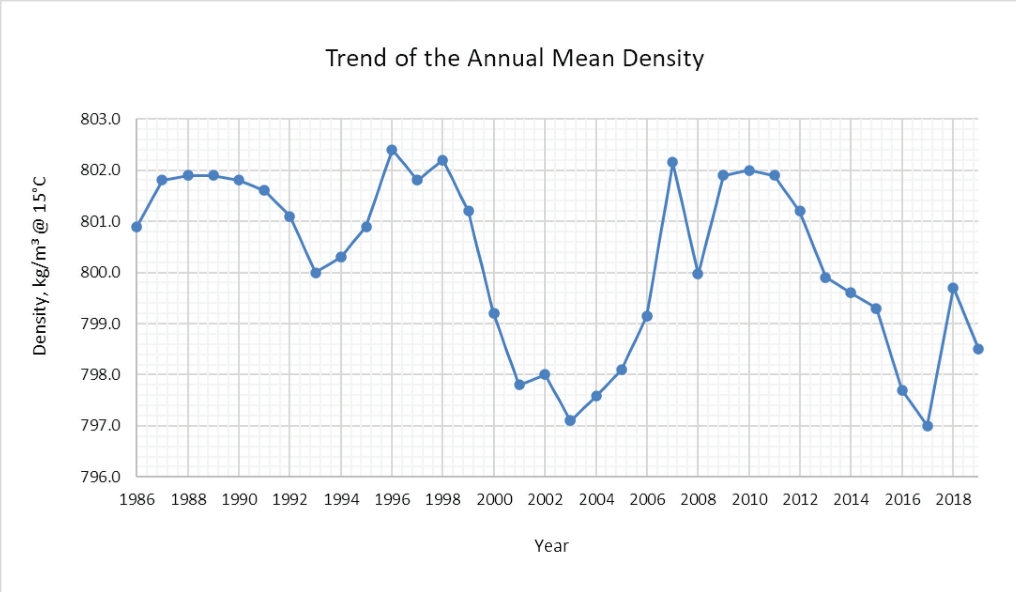

Figure B37: Density trend graph

B.13 FREEZING POINT

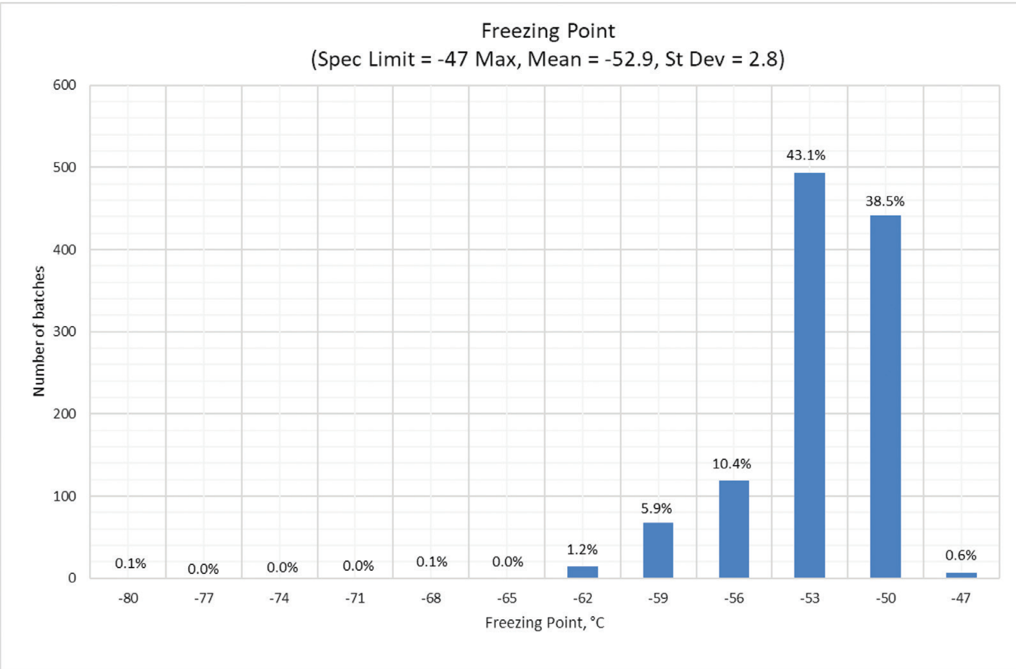

Figure B38: Freezing point histogram (2018)

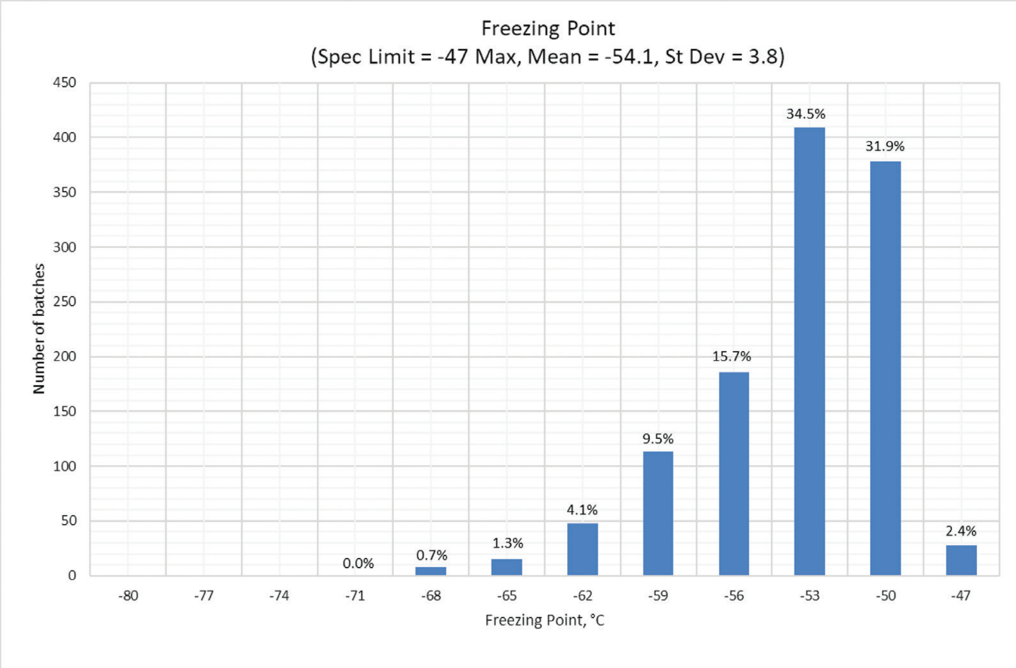

Figure B39: Freezing point histogram (2019)

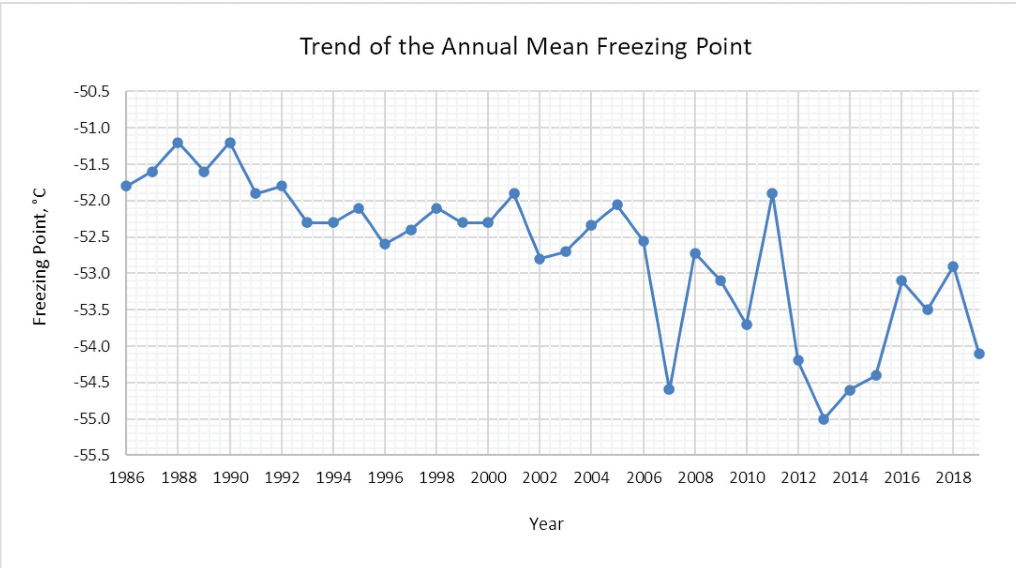

Figure B40: Freezing point trend graph

B.14 KINEMATIC VISCOSITY AT –20 °C

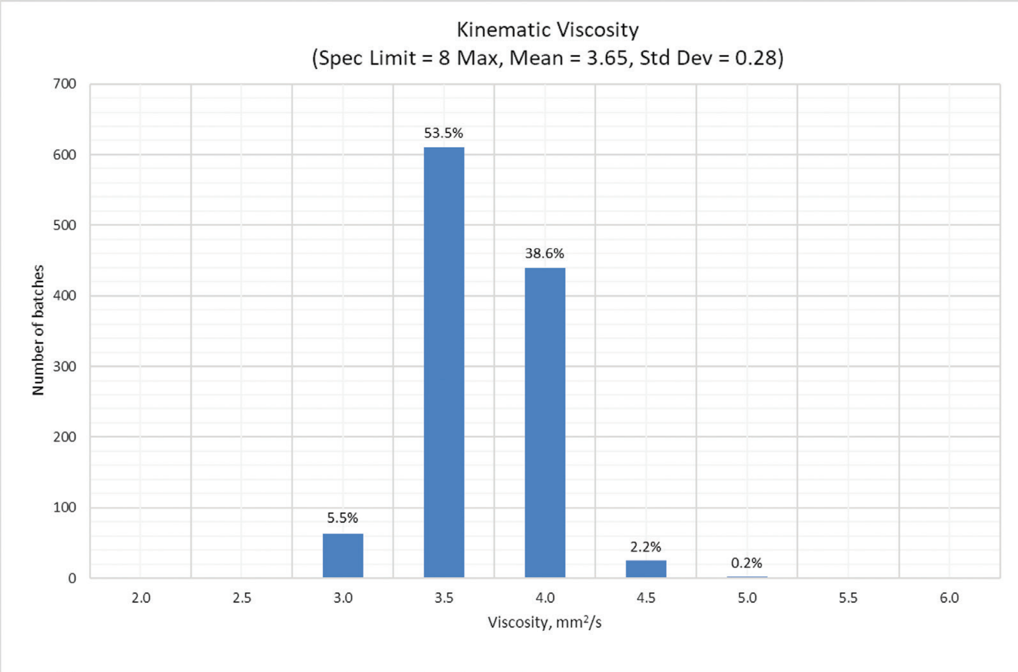

Figure B41: Kinematic viscosity histogram (2018)

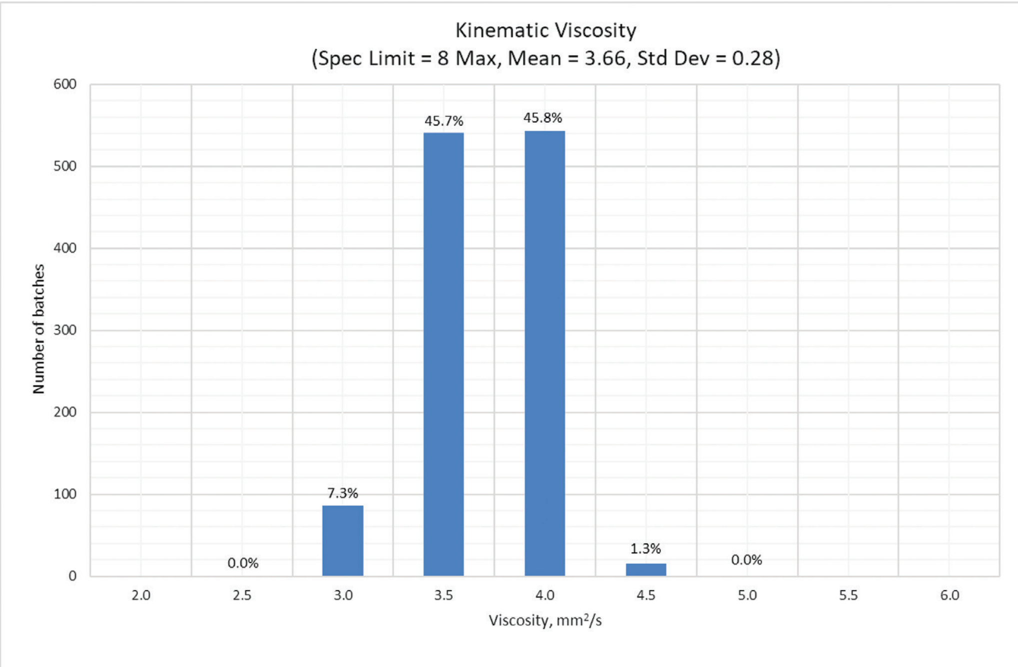

Figure B42: Kinematic viscosity histogram (2019)

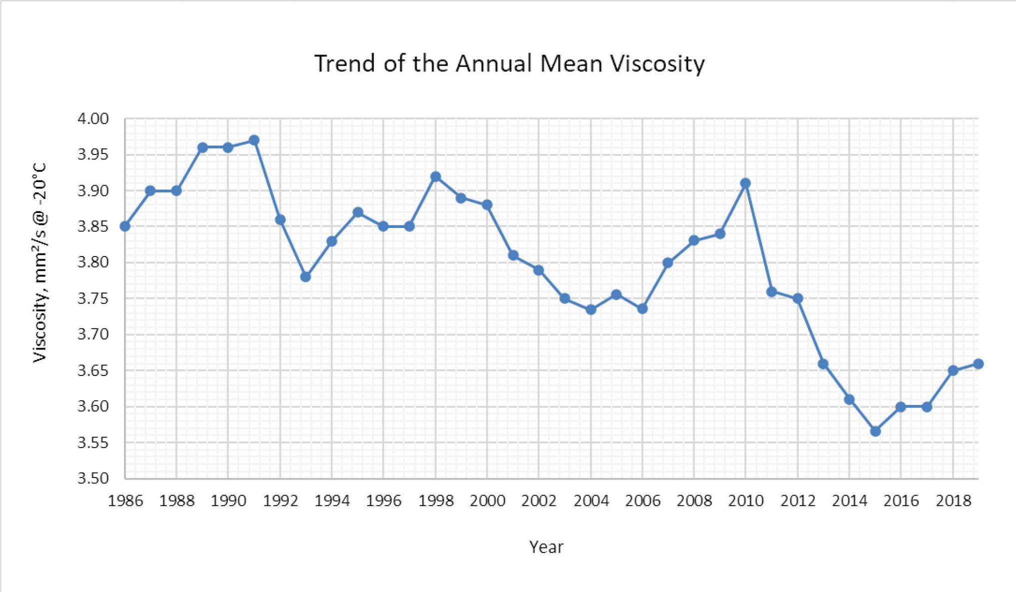

Figure B43: Kinematic viscosity trend graph

B.15 SPECIFIC ENERGY

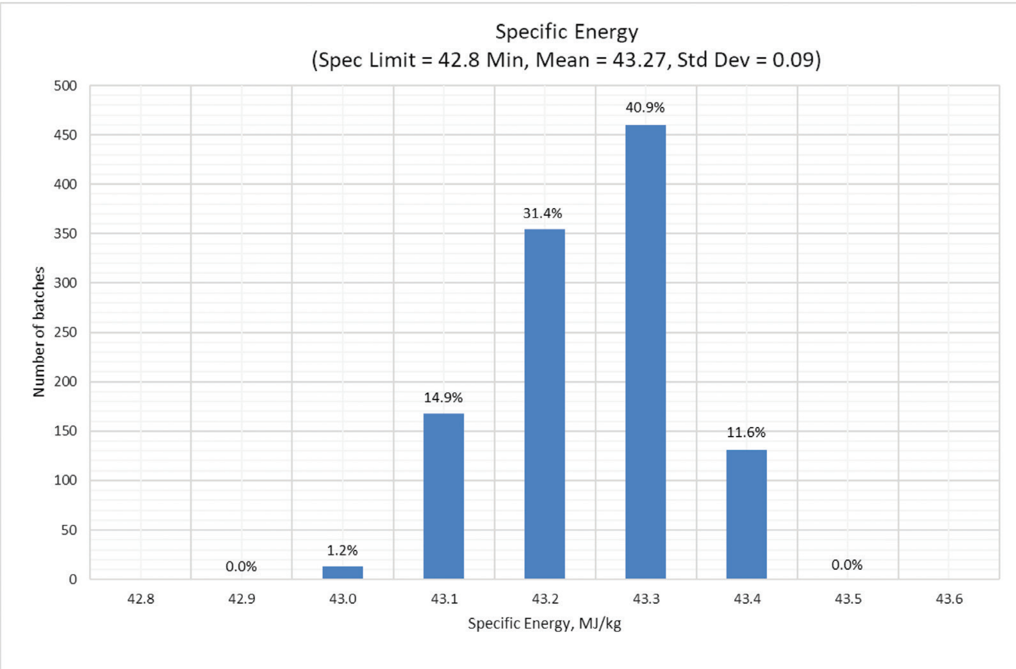

Figure B44: Specific energy histogram (2018)

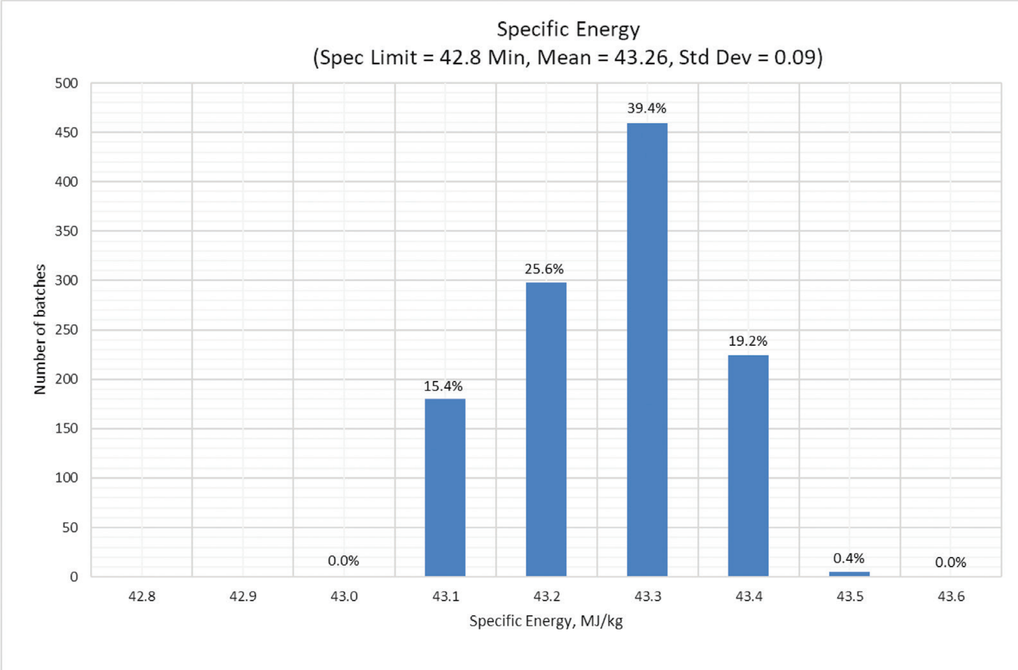

Figure B45: Specific energy histogram (2019)

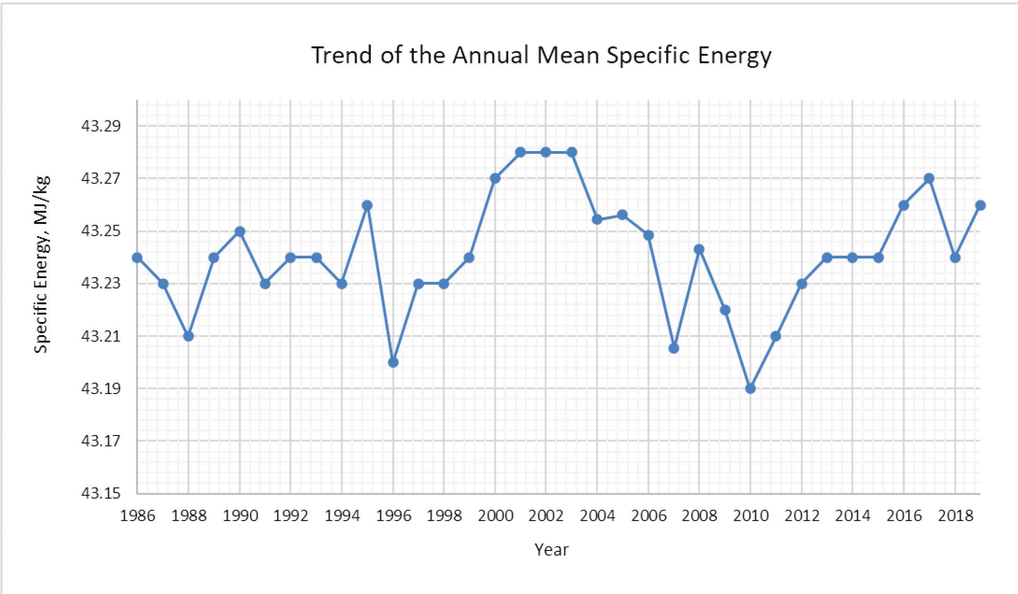

Figure B46: Specific energy trend graph

B.16 SMOKE POINT

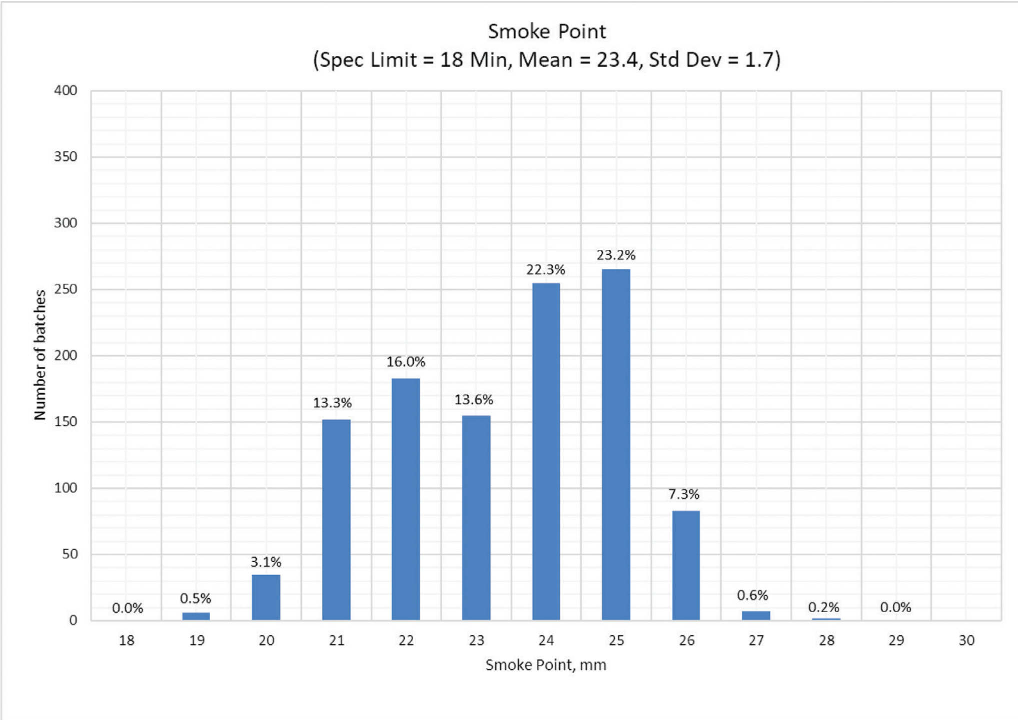

Figure B47: Smoke point histogram (2018)

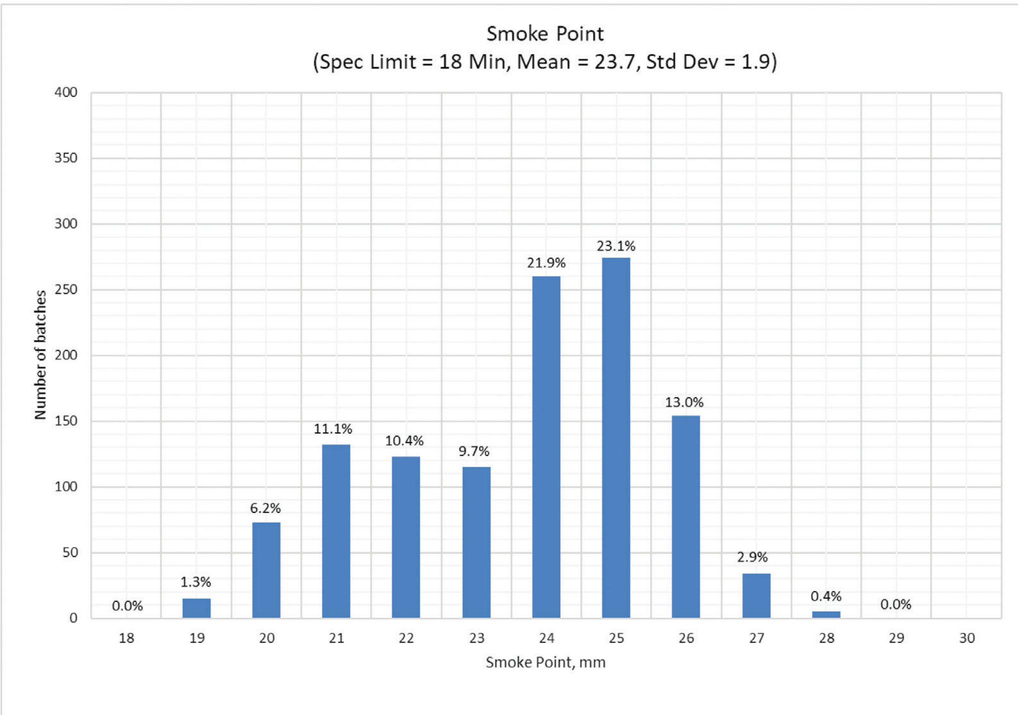

Figure B48: Smoke point histogram (2019)

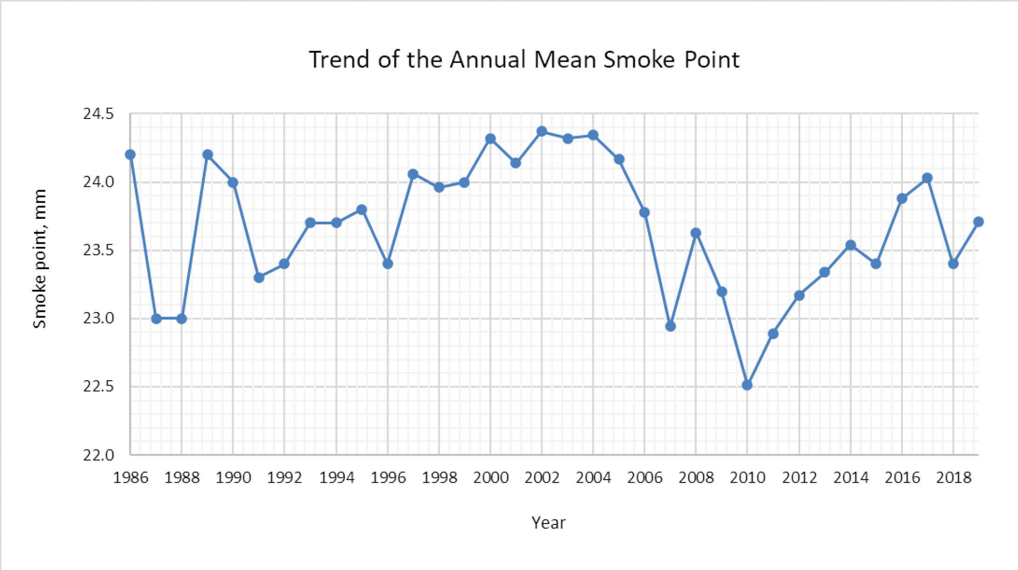

Figure B49: Smoke point trend graph

B.17 NAPHTHALENES

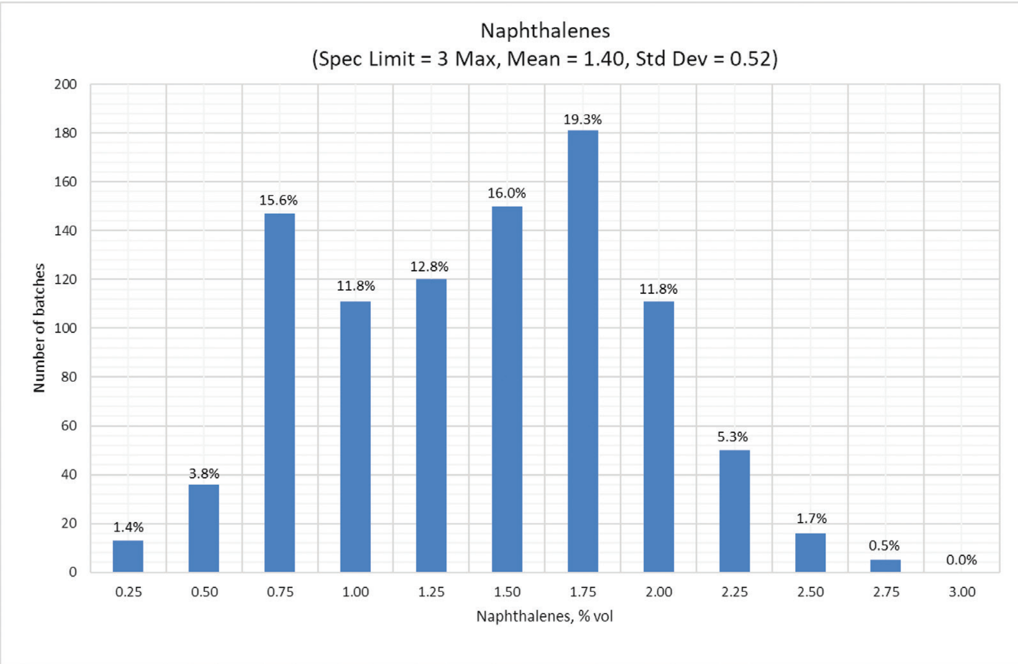

Figure B50: Naphthalenes histogram (2018)

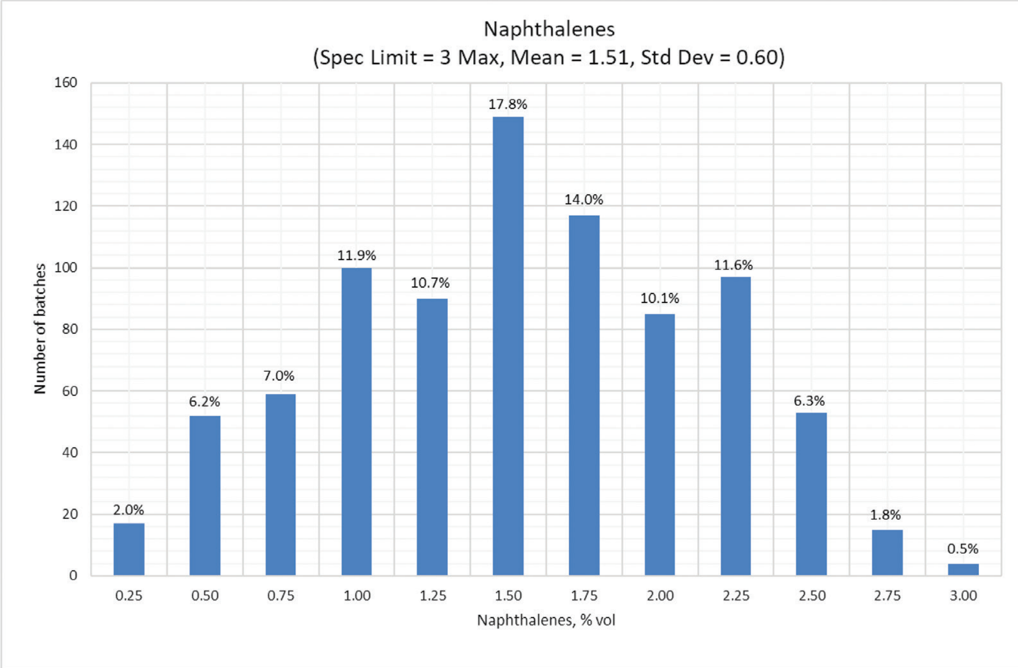

Figure B51: Naphthalenes histogram (2019)

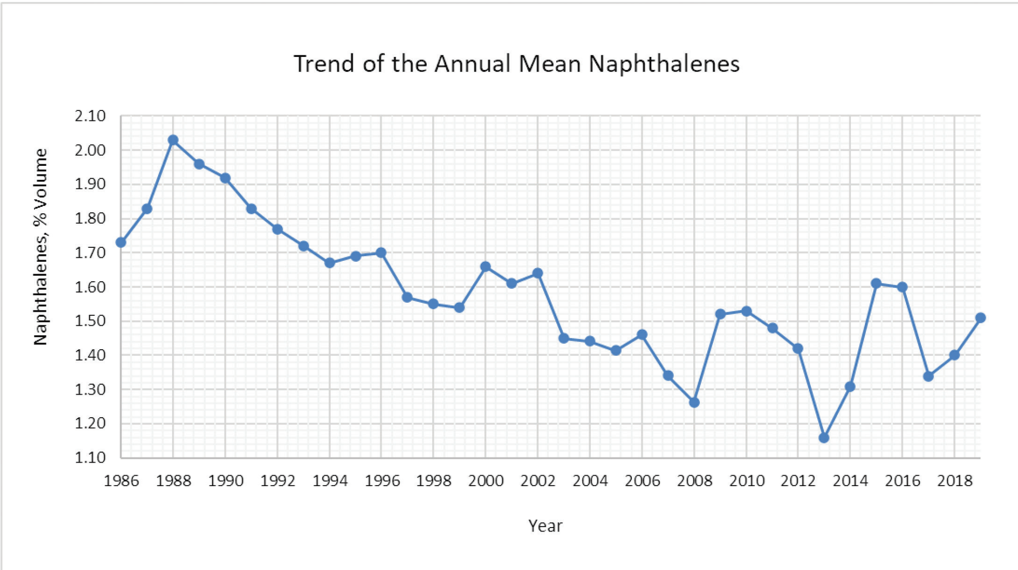

Figure B52: Naphthalenes trend graph

B.18 EXISTENT GUM

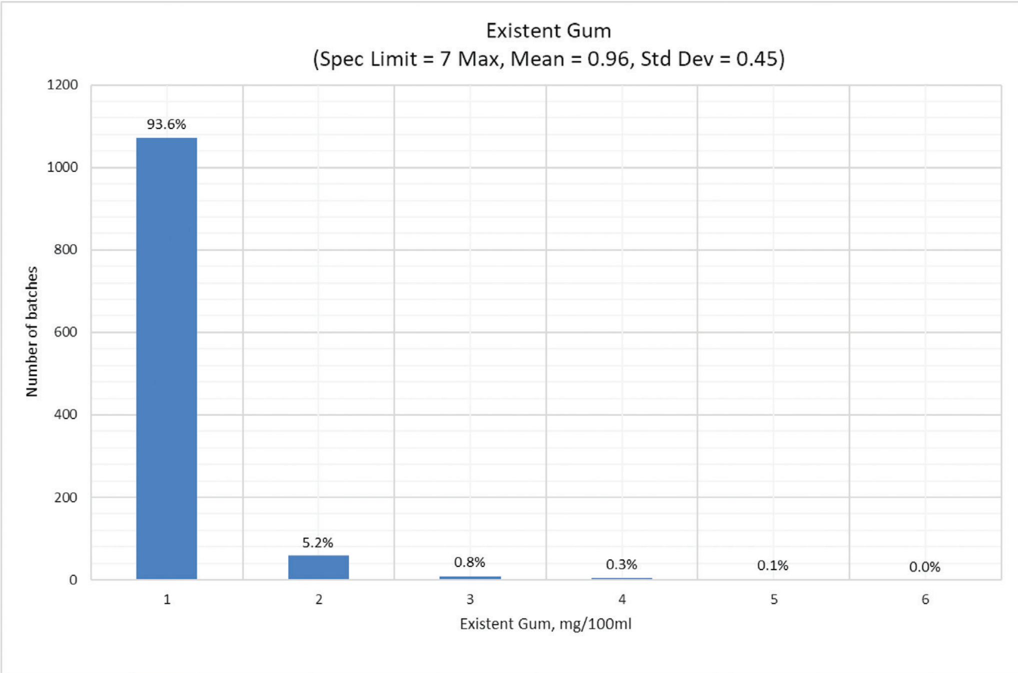

Figure B53: Existent gum histogram (2018)

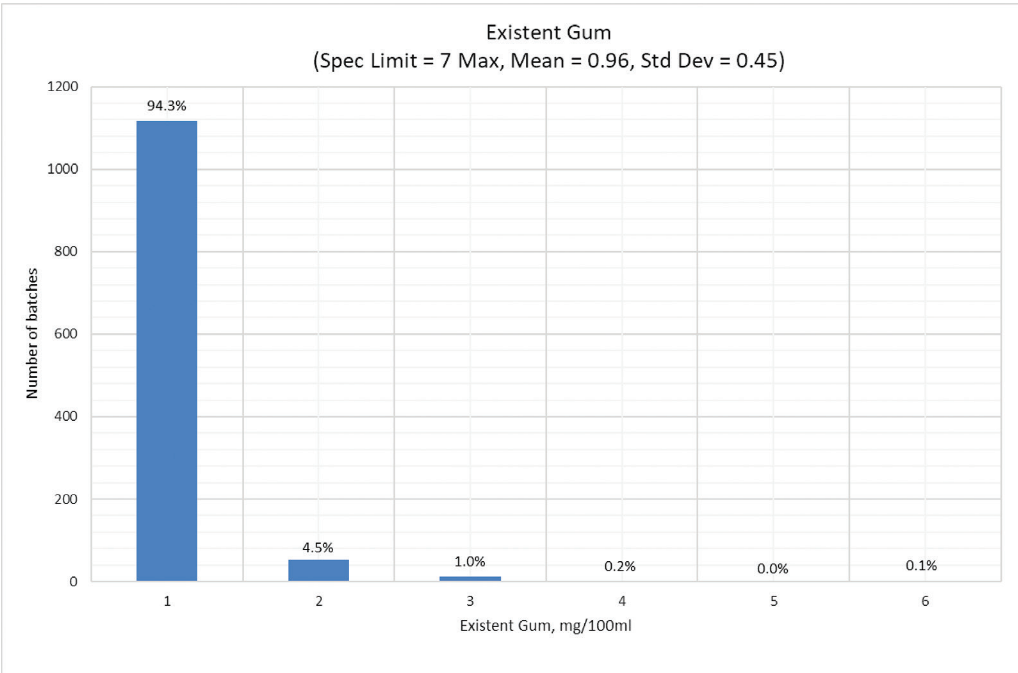

Figure B54: Existent gum histogram (2019)

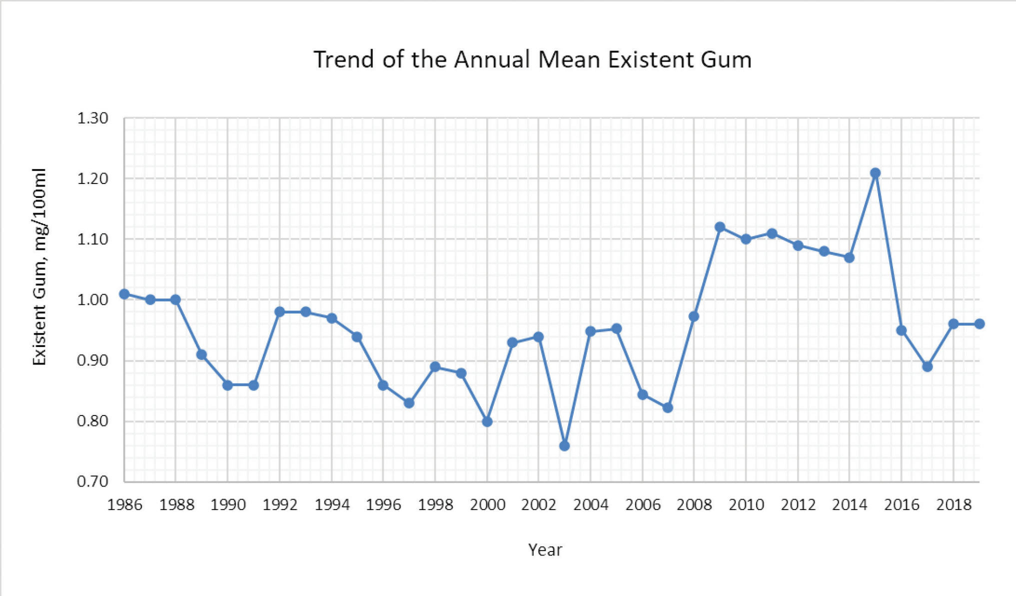

Figure B55: Existent gum trend graph

B.19 MSEP®

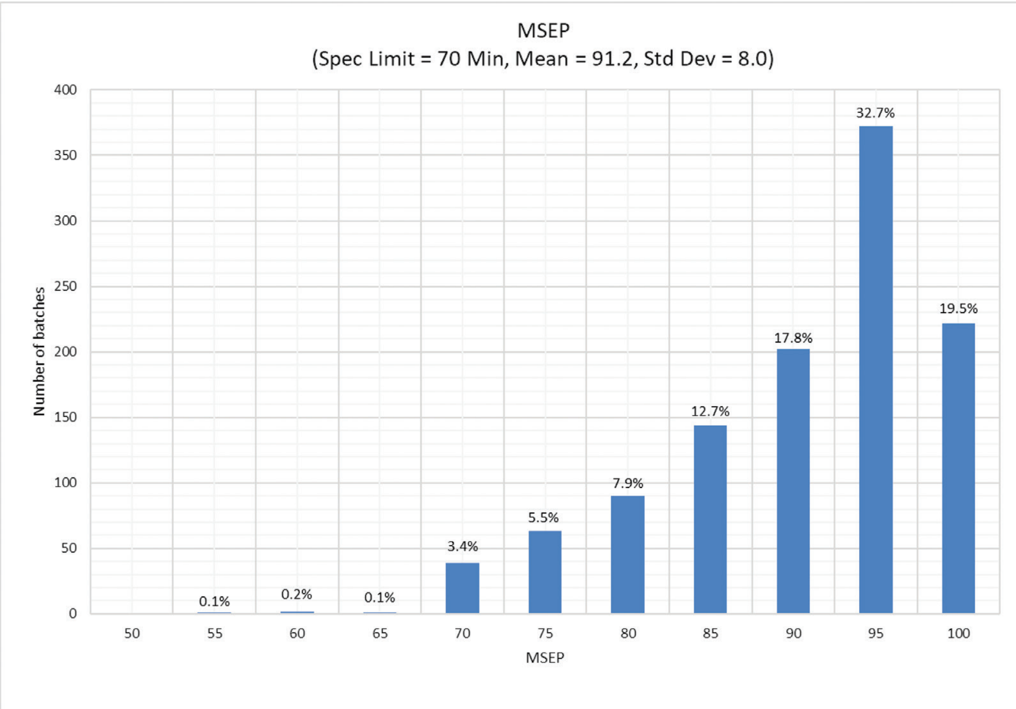

Figure B56: MSEP® histogram (2018)

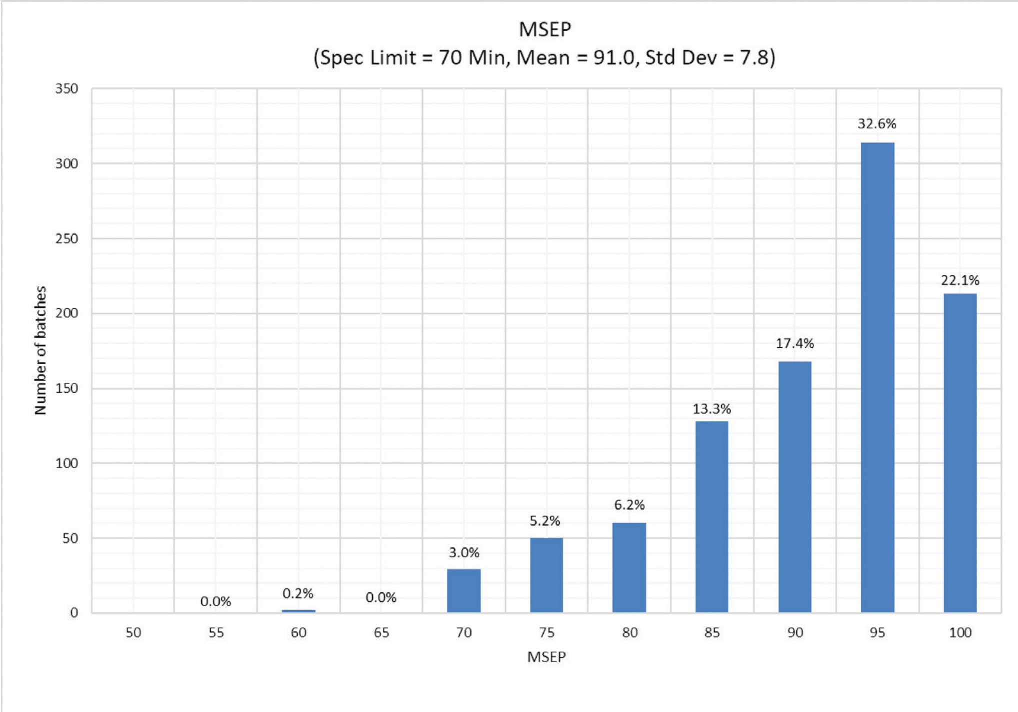

Figure B57: MSEP® histogram (2019)

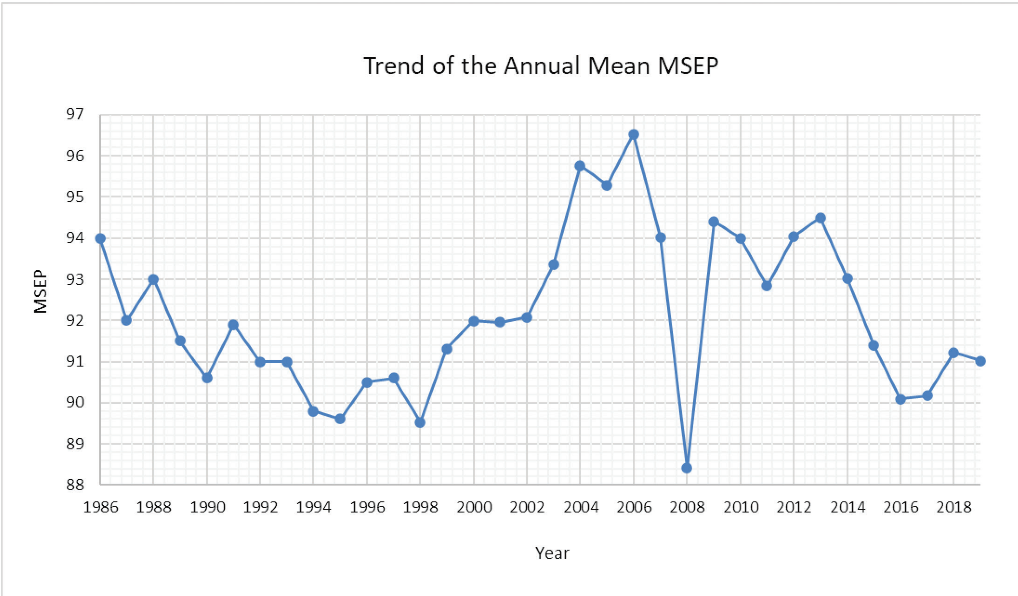

Figure B58: MSEP® trend graph

B.20 PARTICULATE (GRAVIMETRIC)

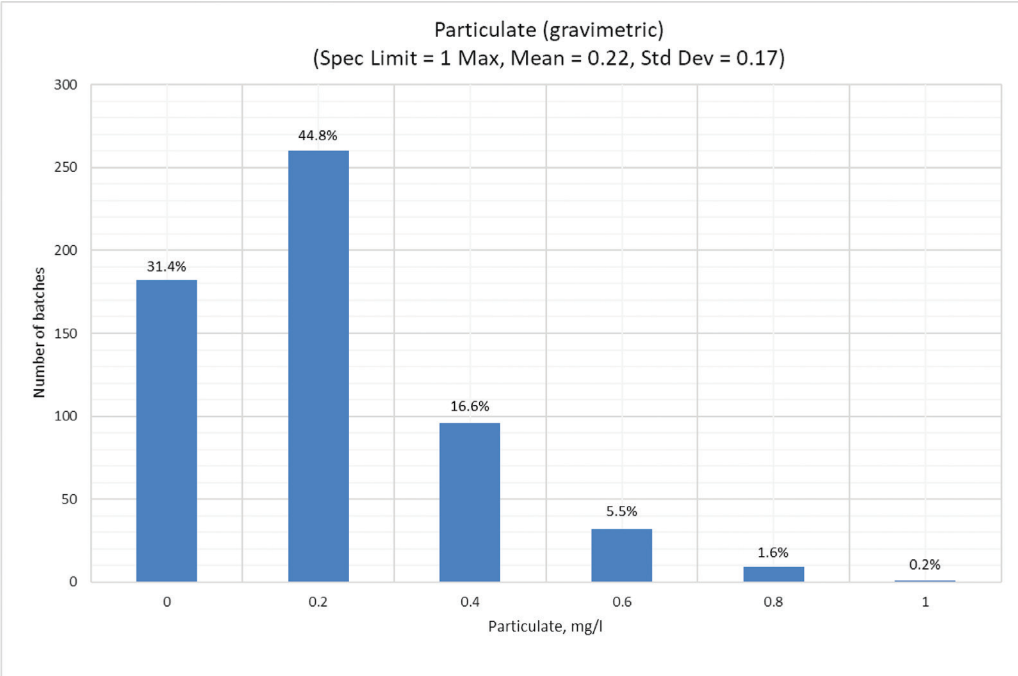

Figure B59: Particulate histogram (2018)

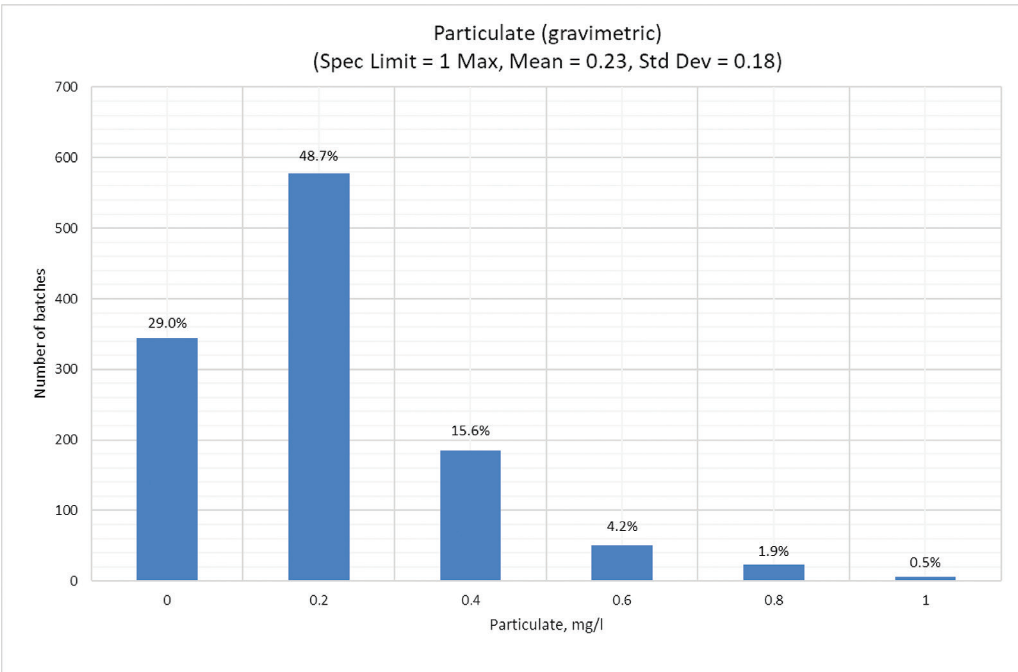

Figure B60: Particulate histogram (2019)

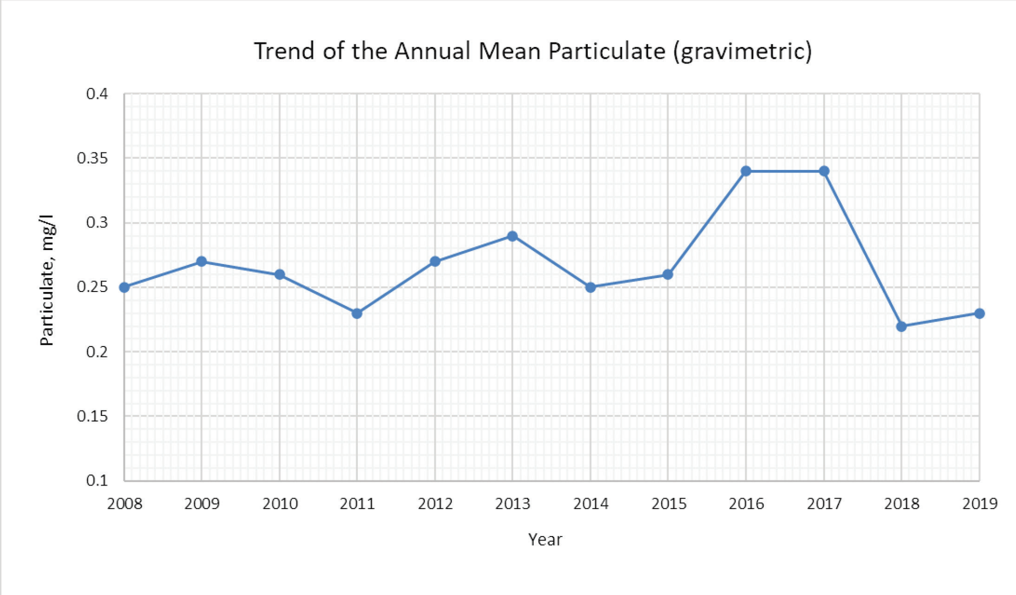

Figure B61: Particulate trend graph

B.21 SAYBOLT COLOUR

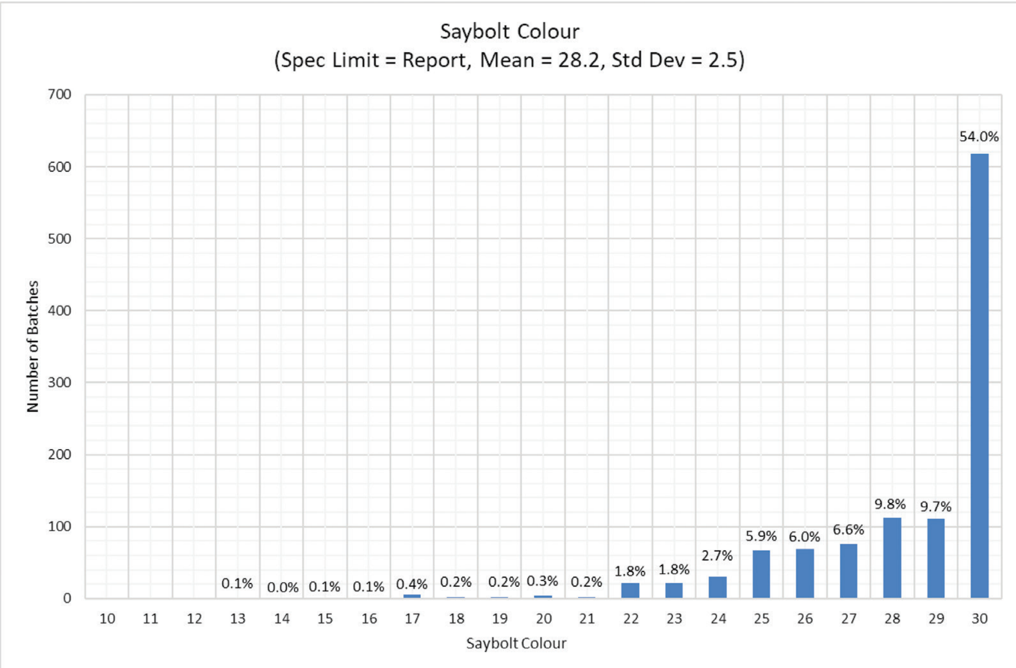

Figure B62: Saybolt colour histogram (2018)

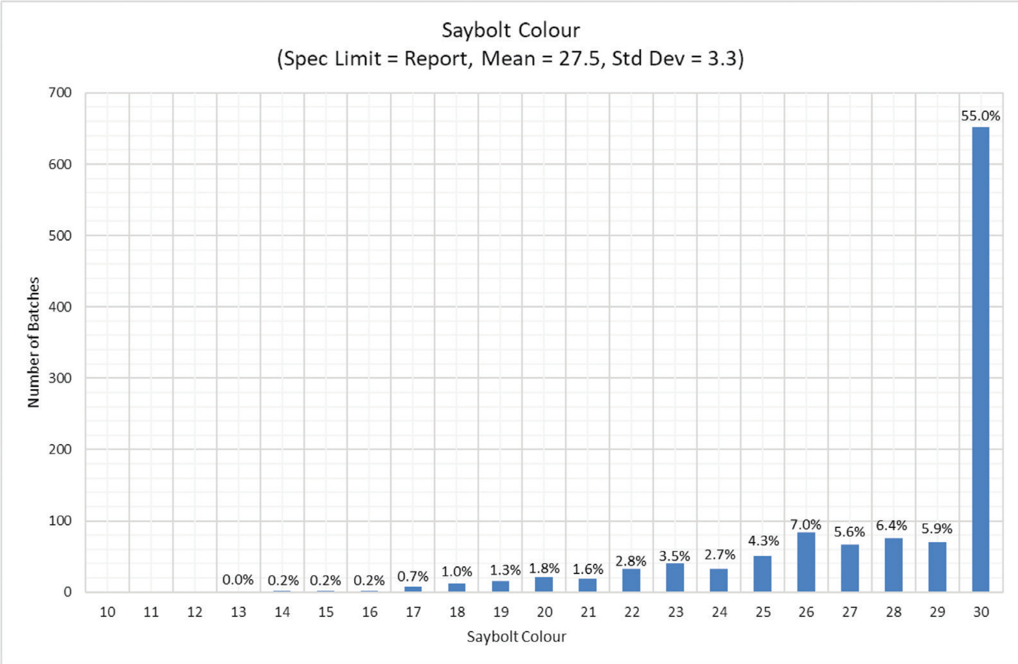

Figure B63: Saybolt colour histogram (2019)

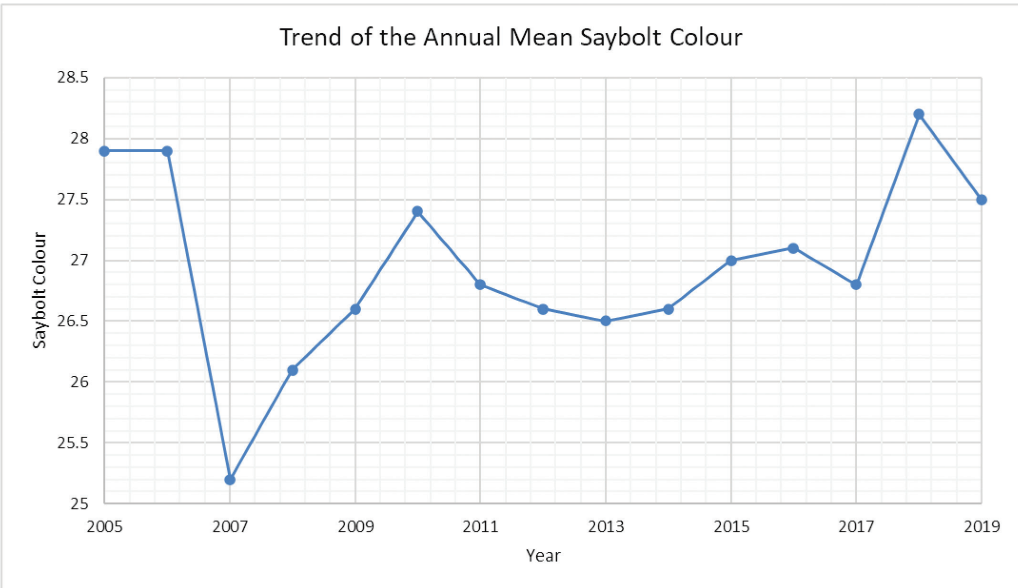

Figure B64: Saybolt colour trend graph

B.22 PARTICLE COUNTS

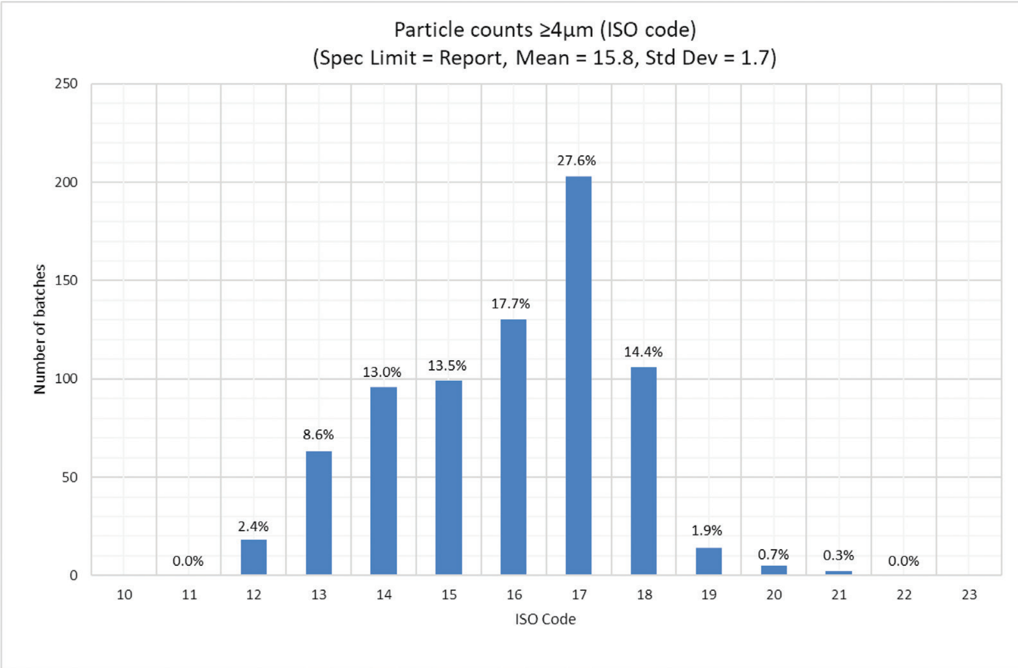

Figure B65: Particle counts ≥4 µm ISO code (2018)

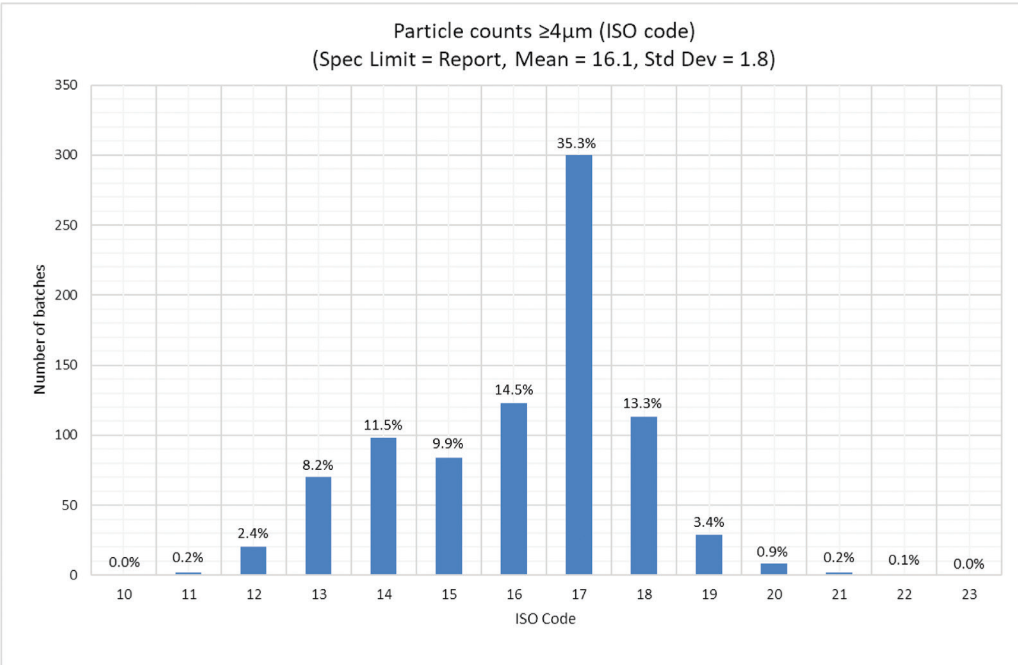

Figure B66: Particle counts ≥4 µm ISO code (2019)

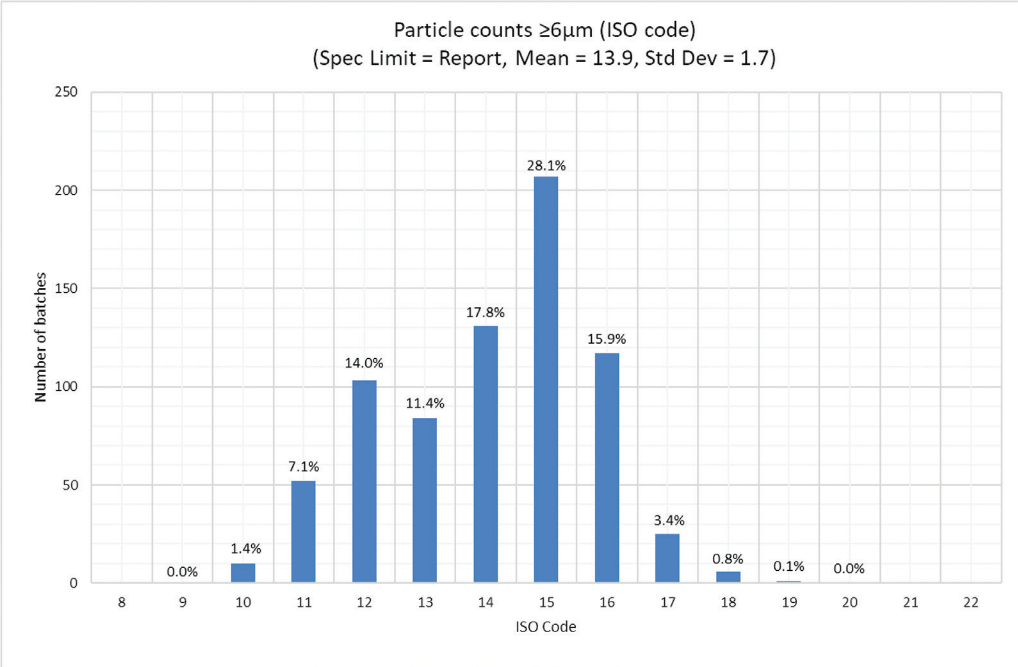

Figure B67: Particle counts ≥6 µm ISO code (2018)

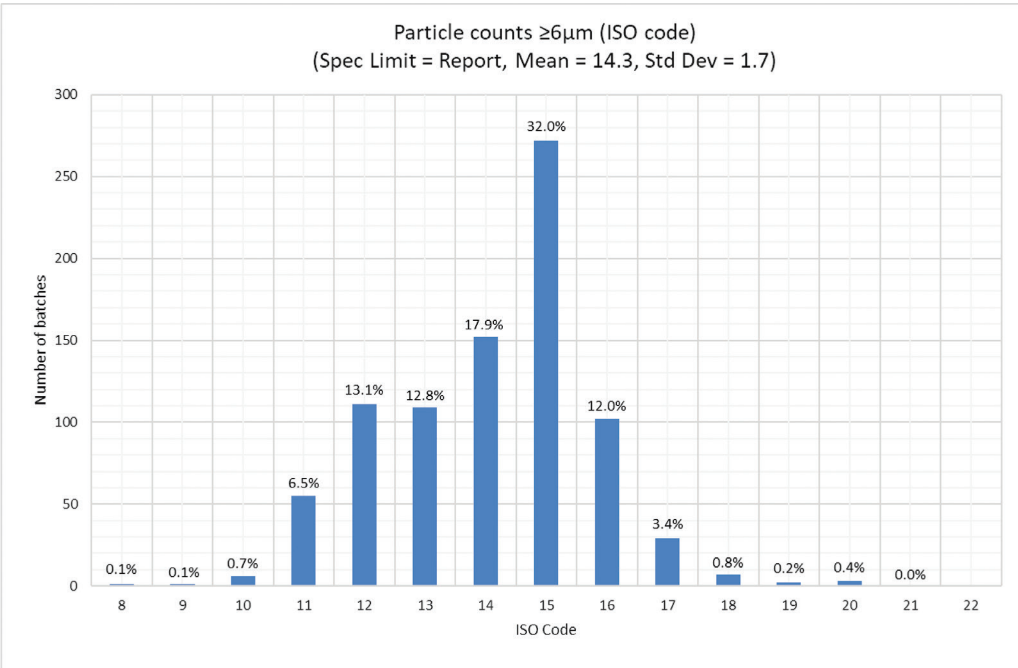

Figure B68: Particle counts ≥6 µm ISO code (2019)

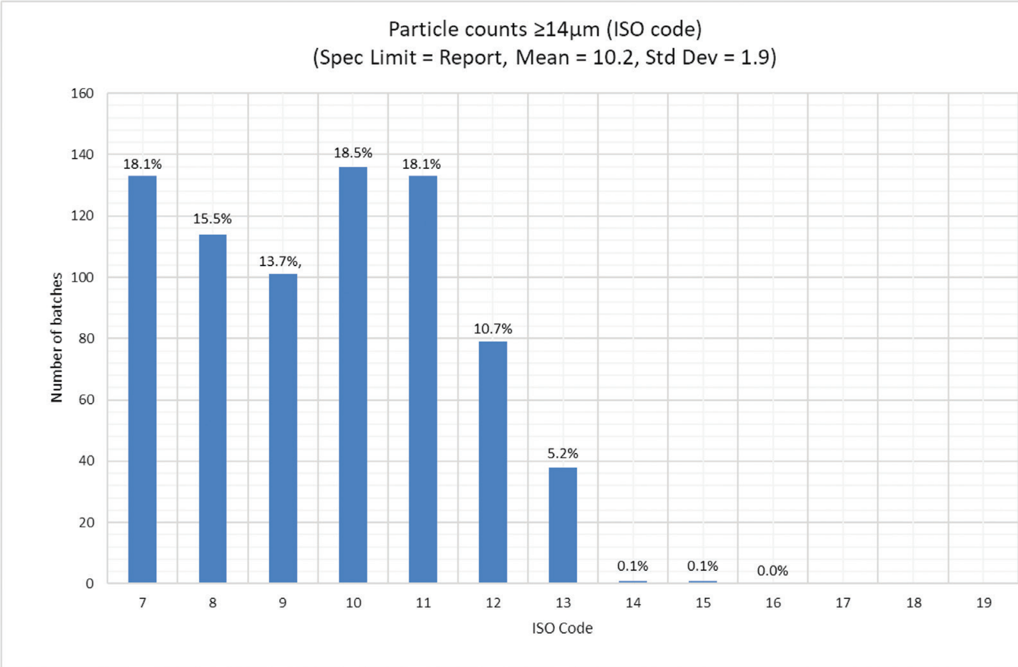

Figure B69: Particle counts ≥14 µm ISO code (2018)

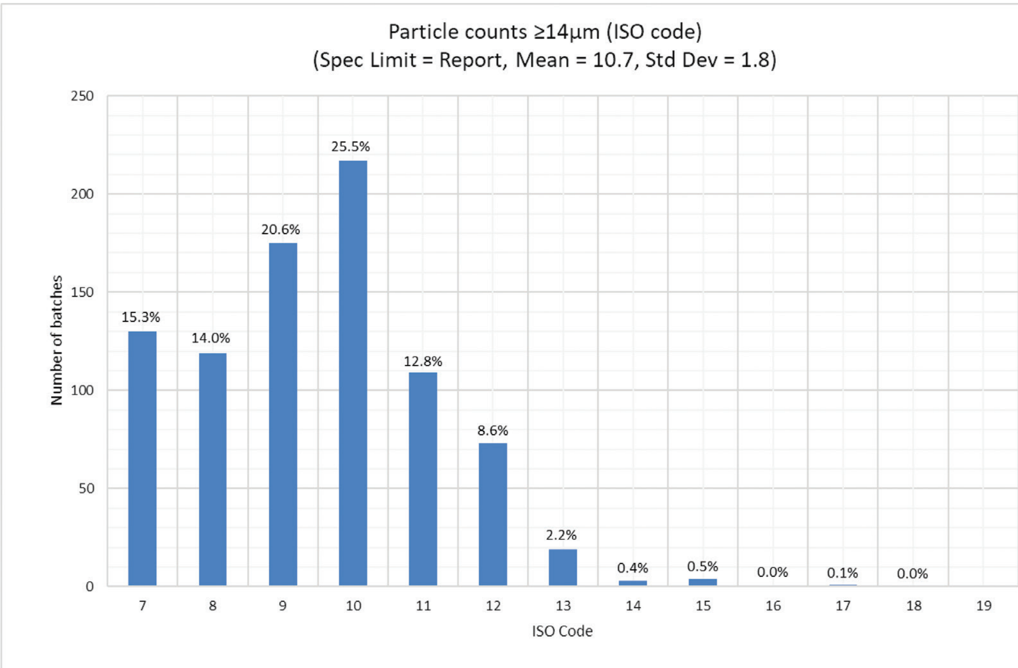

Figure B70: Particle counts ≥14 µm ISO code (2019)

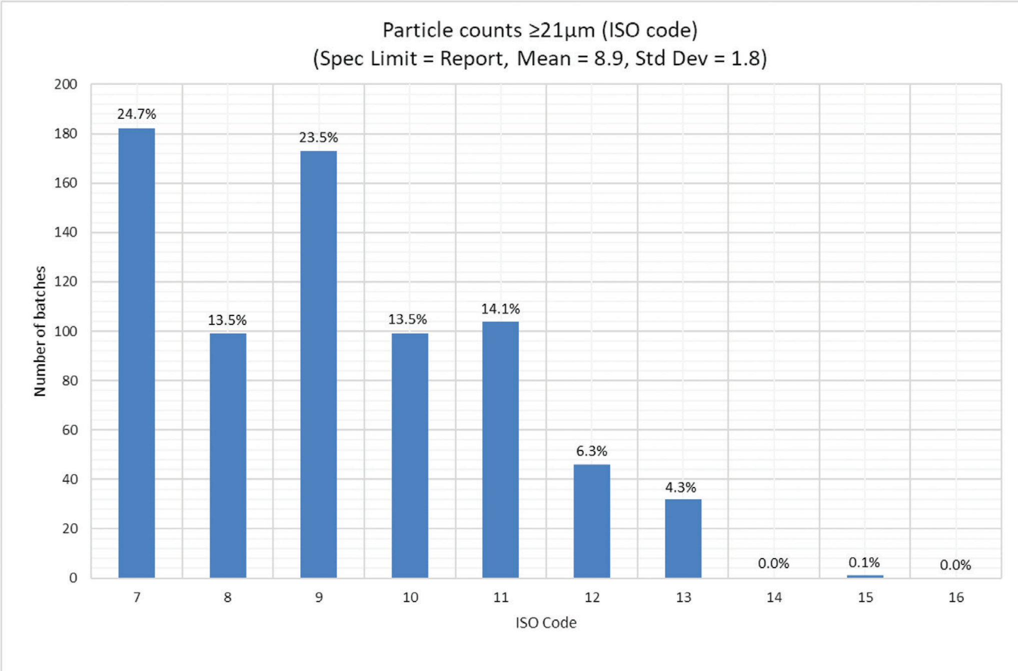

Figure B71: Particle counts ≥21 µm ISO code (2018)

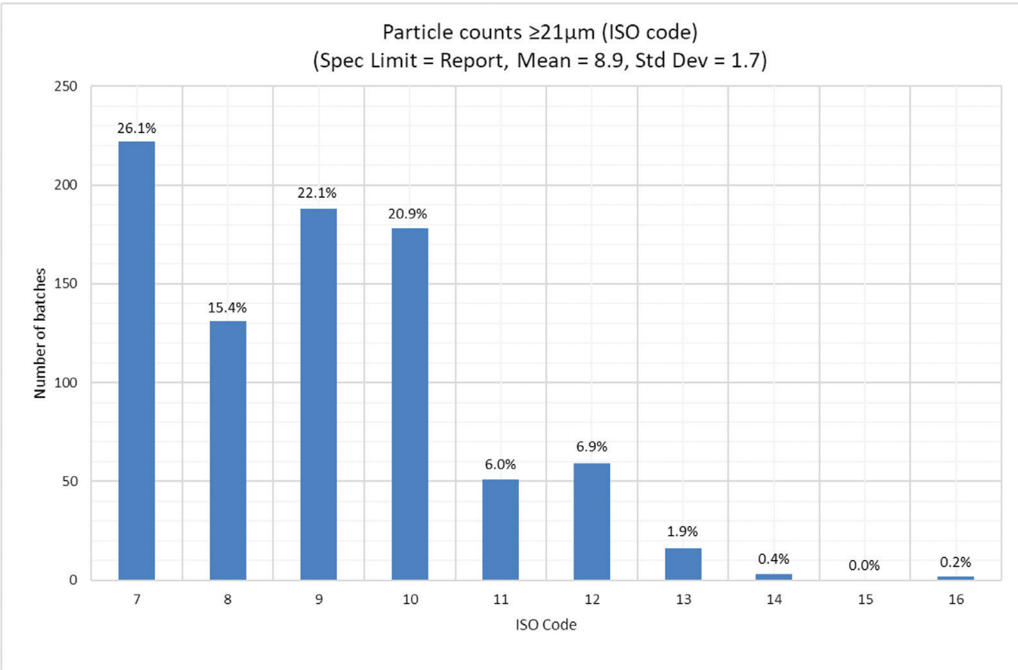

Figure B72: Particle counts ≥21 µm ISO code (2019)

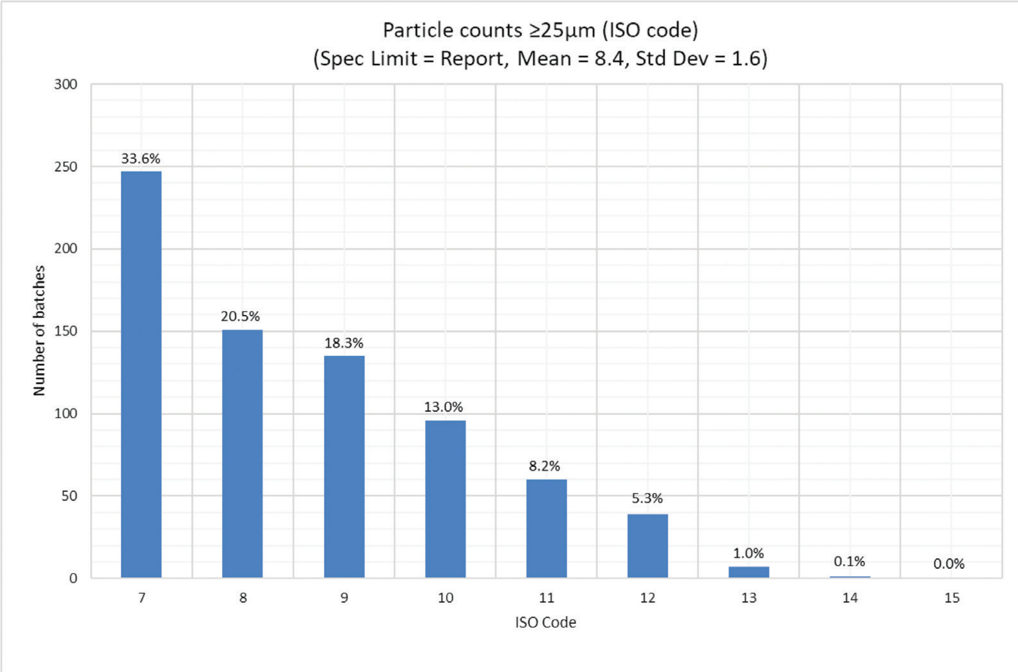

Figure B73: Particle counts ≥25 µm ISO code (2018)

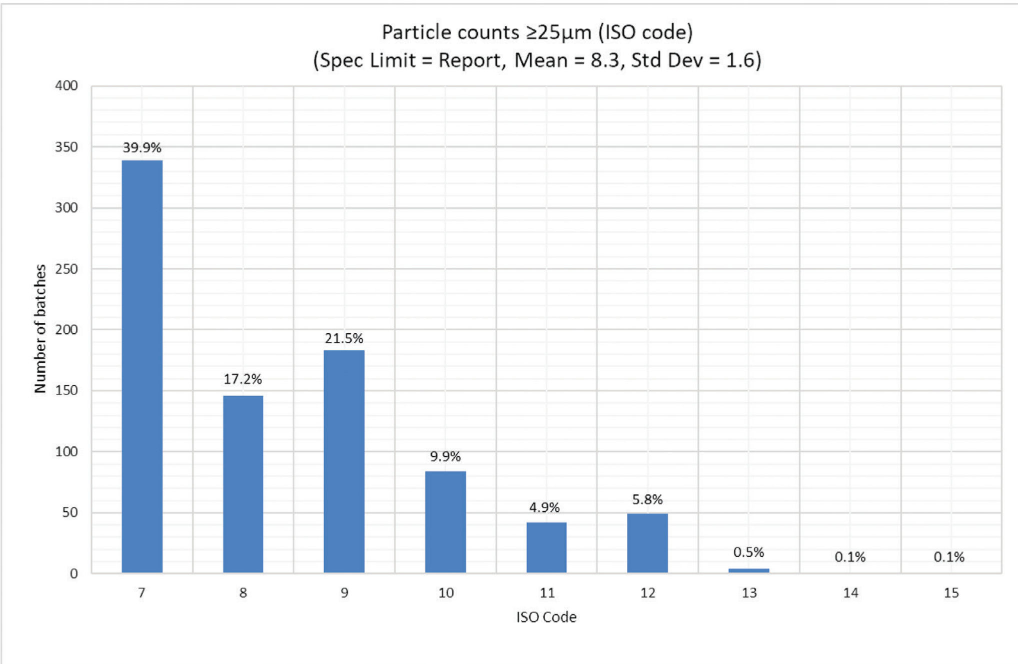

Figure B74: Particle counts ≥25 µm ISO code (2019)

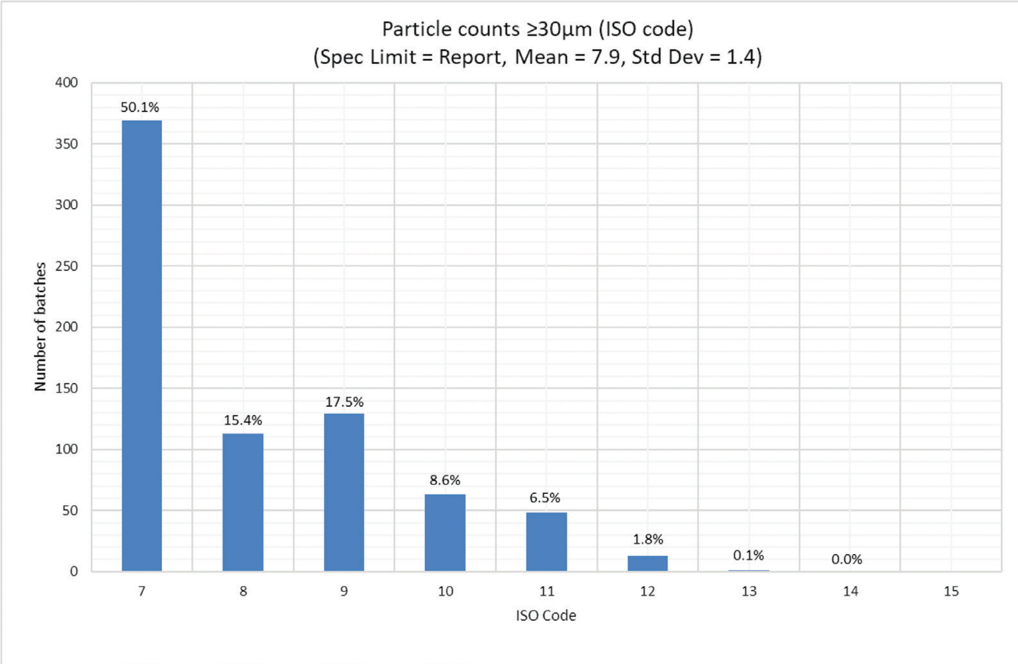

Figure B75: Particle counts ≥30 μm ISO code (2018)

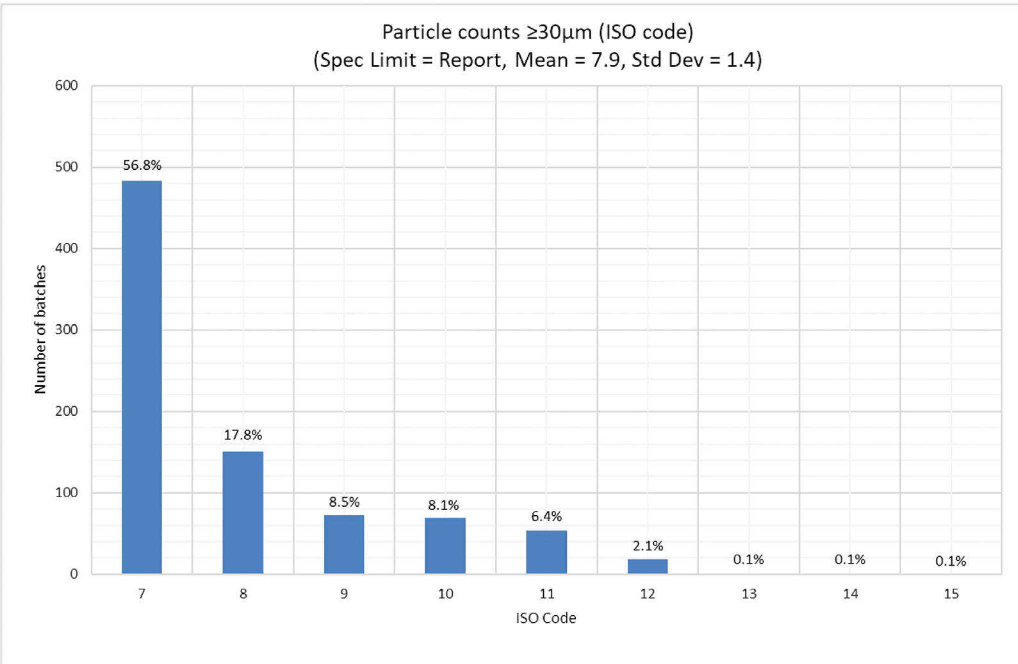

Figure B76: Particle counts ≥30 μm ISO code (2019)

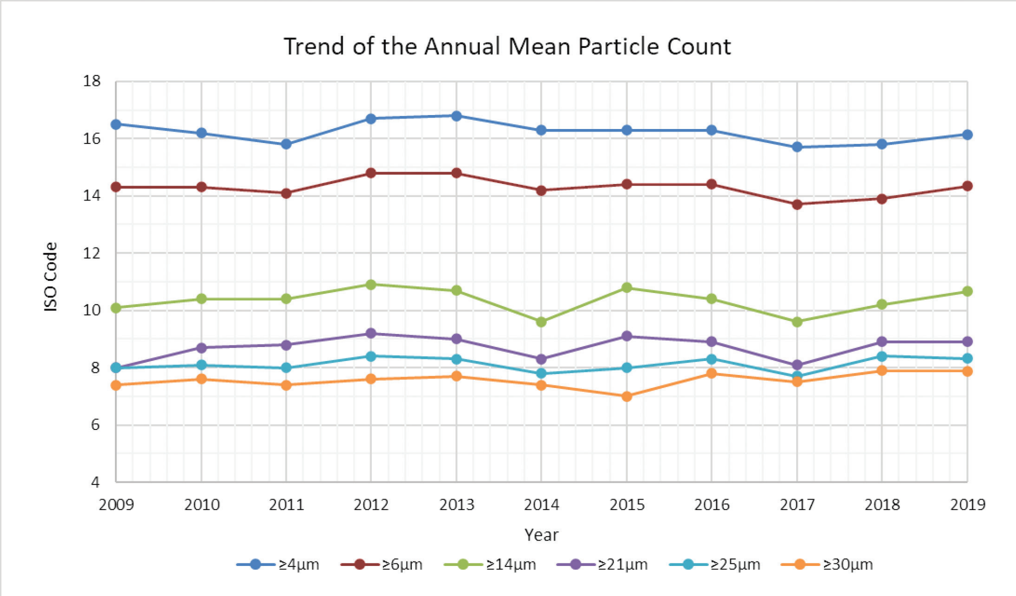

Figure B77: Particle count trend graph

B.23 NEAR SPECIFICATION LIMIT TREND ANALYSIS

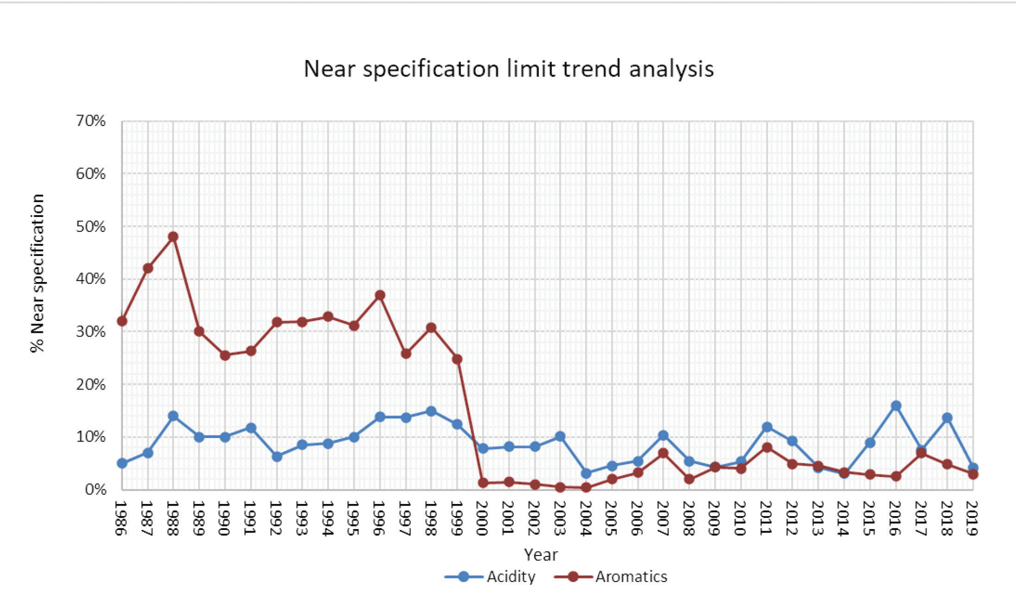

Figure B78: Near specification trend, acidity and aromatics

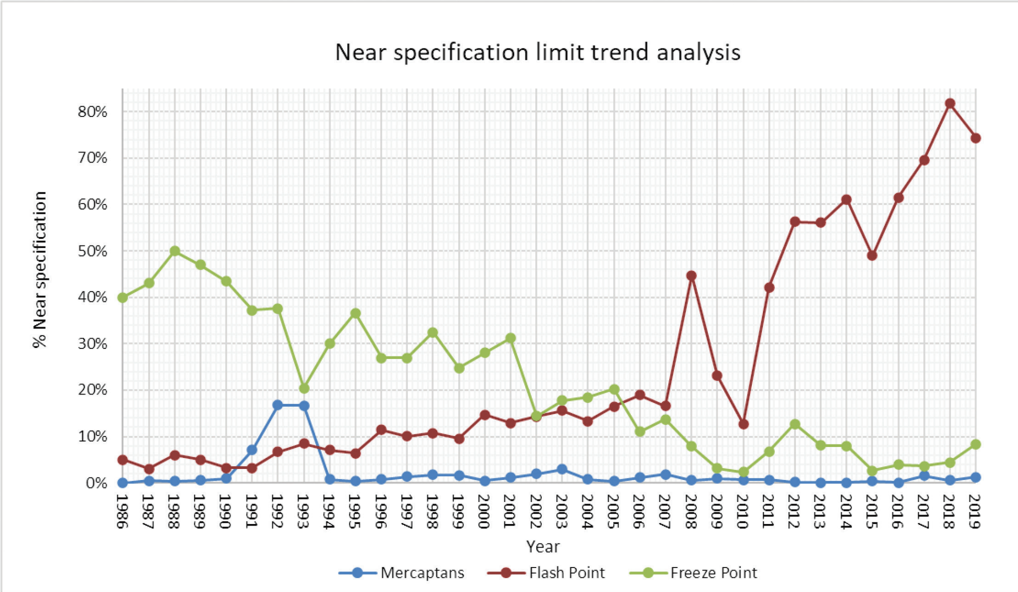

Figure B79: Near specification trend, mercaptans, flash point and freezing point

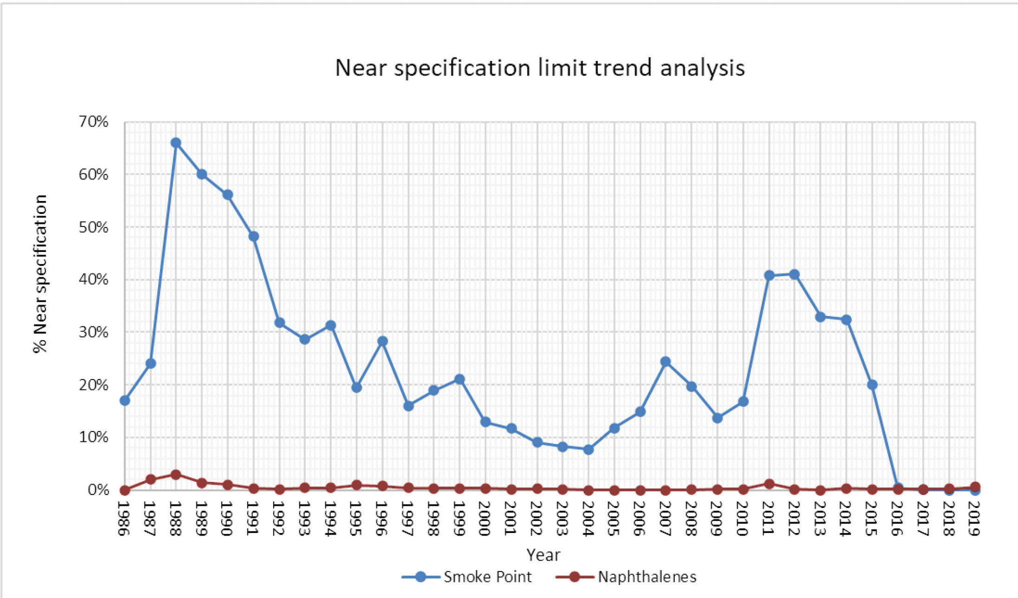

Figure B80: Near specification trend, smoke point and naphthalenes

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