ASTM D02.B0.07 Semi-Annual Report Bench Test Monitoring

D6417, D5133 (GI), D5800, D6335 (TEOST), D7097(MTEOS), D6082, D874 and D7528 (ROBO)

Fall 2021

Calibrated Labs and Stands*

Test	Labs	Stands
D6417	7	9
D5800	9	23
D5133 (GI)	8	50
D6335 (TEOST)	7	9
D7097 (MTEOS)	8	37
D6082	5	6
D874	3	––
D7528 (ROBO)	5	22

*As of 9/30/2021

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B0.07 Bench Testing Executive Summary

- ## [D6417](#) (Volatility by GC)

- Precision (Pooled s) is comparable to prior periods
  - Same as target precision

- Performance (Mean Δ/s) is –0.28 s mild.

- CUSUM severity plot shows a mild trend developing last three periods, with a sharp increase (mild) last period, but overall less mild again this period.

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B0.07 Bench Testing Executive Summary

- ## D5800 (Volatility by Noack)

- Precision (Pooled s) is less precise than target precision (in natural log transformed units).
  ◦ Less precise than prior period
  ◦ Procedure B rigs are less precise, Procedure D rigs are more precise than target

- Performance (Mean Δ/s) is 0.45 s severe.
  ◦ Procedure B rigs are trending 0.72 s severe while Procedure D rigs are trending −0.14 s mild.

- CUSUM severity plots shows a continuing overall severe trend with reference testing, completely attributable (this period) to procedure B tests. Procedure D tests are, overall, only slightly mild for the period.

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B0.07 Bench Testing
Executive Summary

- ## D5133 (Gelation Index)

- Fail rate of operationally valid tests is 12% this period
  - Compared to 18% fail rate last period
  - Fail rate of (new) discrimination runs reported as operationally valid was also 12%
  - Historic period fail rates have ranged between 6% and 26%

- Precision (Pooled s) is significantly more precise than last period
  - Less precise than updated target precision

- Performance (Mean Δ/s) is −0.20 s mild
  - Six of eight labs performing overall mild

- A round robin is underway to evaluate a calibration oil that performs closer to the GF-5/6 pass/fail limit of 12 GI
  - To replace oil 58 that was reclassified as a discrimination oil

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B0.07 Bench Testing Executive Summary

- ## D6335 (TEOST-33C)

  - Precision (Pooled s) is comparable to the prior period but remains imprecise compared to other periods
    - Much less precise than target precision
      - Only one test this period used oil 75; oil is nearly used up

  - Performance (Mean Δ/s) is -0.36 s mild this period (compared to 0.42 s severe last period)

  - Period fail rate of 23% on tests reported as operationally valid
    - Fail rates continue to be high.

  - All tests this period report using Rod Batch M or N.

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B0.07 Bench Testing
Executive Summary

‣ **D7097** (MHT-4 TEOST)

‣ Precision (Pooled s) has been less precise for the past two report periods than for most prior report periods
  ◦ Significantly less precise than prior or updated target precision

‣ Performance (Mean Δ/s) is on-target (-0.02 s)

‣ All operationally valid tests this period report using Rod Batches M or N (new).

‣ All operationally valid calibration tests this period report using Catalyst Batch 18AB (n=1) or 19BA (n=80)
  ◦ Lab P continues to report using catalyst batch 18AB

‣ Overall severity on catalyst batch 19BA (n=217) appears to be on-target, and on target for oils 432 and 434.
  ◦ Replacement oil 434-3 introduced this period, running -0.72 s mild (n=10).

B0.07 Bench Testing Executive Summary

- ## [D6082](link) (High Temperature Foam)

- Foam Tendency Precision (Pooled s) is the same as last period
  - More precise than oil FOAMB18 target precision
    - Oil 1007 is entirely used up, first report period of all reference tests on replacement oil FOAMB18 only.

- Performance (Mean Δ/s) is –0.48 s mild
  - Fifth consecutive period of mild performance on FOAMB18.
    - Target performance, set on 18 runs in a RR, may need revisited.

- No non-zero occurrences of Foam Stability

- All six severe oil discrimination runs (on TMC oil 66) demonstrated acceptable discrimination on foam tendency (>100 ml).

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B0.07 Bench Testing Executive Summary

- ## D874 (Sulfated Ash)

- Precision (Pooled s) is less precise than prior periods
  - Less precise than target precision

- Performance (Mean Δ/s) is 0.37 s severe

B0.07 Bench Testing Executive Summary

- [D7528](#) (ROBO)

- Precision (Pooled s) is more precise than prior periods
  - Significant improvement in precision
  - Likely due to new reference oil and targets
    - Dropped imprecise oil 438-2 mid-period, replaced by more precise oil 436
  - Continues to be less precise than target
  - Target precision updated to include current reference oils 434-3, 435-1 and 436
    - Dropped oils 438-2 and 434-2 from the pooled target precision for this period's statistics.

- Performance (Mean Δ/s) is -0.37 s mild for this report period

- CUSUM severity plot shows variable performance the past three report period

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D02.B0.07 TMC Monitored Tests

April 1, 2021 –

September 30, 2021

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D6417: Estimation of Engine Oil Volatility by Capillary GC

Test Status	Validity Code	No. Tests
Acceptable Calibration Test	AC	17
Failed Calibration Test	OC	0
Operationally Invalidated by Lab	LC, XC	0
Operationally Invalidated After Initially Reported as Valid	RC	0
Total		17

Number of Labs Reporting Data: 7
Fail Rate of Operationally Valid Tests: 0%

D6417: Estimation of Engine Oil Volatility by Capillary GC

Statistically Unacceptable Tests (OC)	No. Of Tests
Volatility Loss Mild	0
Volatility Loss Severe	0

- There were no operationally or statistically invalid tests reported this period

- No D6417 TMC technical updates were issued this report period.

- D6417 calibration requirement updates are issued as LTMS document updates

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D6417: Estimation of Engine Oil Volatility by Capillary GC

Period Precision and Severity Estimates

Area % Volatized @ 371°C	n	df	Pooled s	Mean Δ/s
Initial Selected Oils from RR	54	51	0.39	-----
10/1/18 through 3/31/19	19	16	0.43	0.35
4/1/19 through 9/30/19	19	16	0.18	0.10
10/1/19 through 3/31/20	17	14	0.30	0.09
4/1/20 through 9/30/20*	16	13	0.41	−0.34
4/1/20 through 9/30/20*	14	11	0.31	0.01
10/1/20 through 3/31/21*	21	18	0.47	−0.81
10/1/20 through 3/31/21*	19	16	0.37	−0.43
4/1/21 through 9/30/21	17	14	0.39	−0.28

*Period statistics with two mild results from rigs D5/D6 included and excluded (operational problem suspected but lab never confirmed)

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D6417 Precision Estimates

Area % Volatized @ 371°C
Pooled s

Bar chart data:

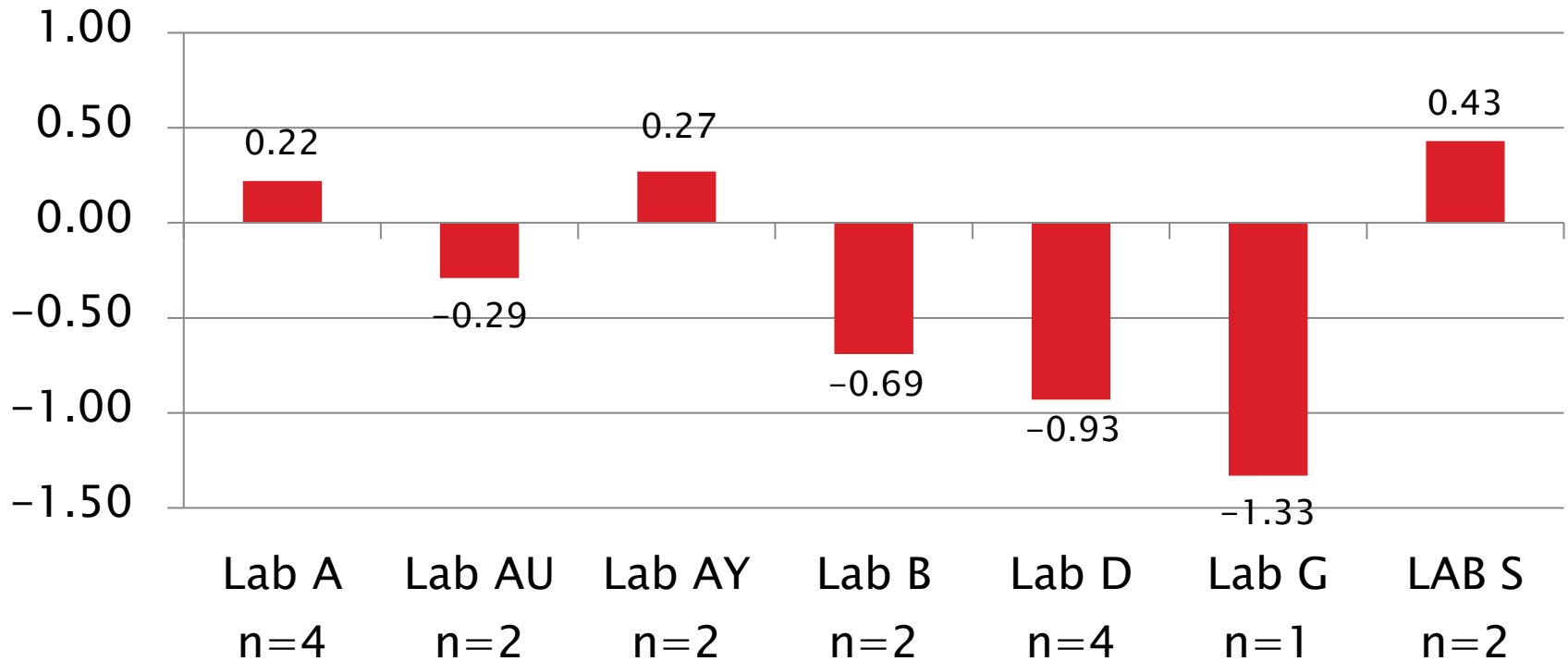| Category	Value
Target df=51	0.39
OCT '18	0.36
APR '19	0.43
OCT '19	0.18
APR '20	0.30
OCT '20	0.41
APR '21	0.47
OCT '21	0.39
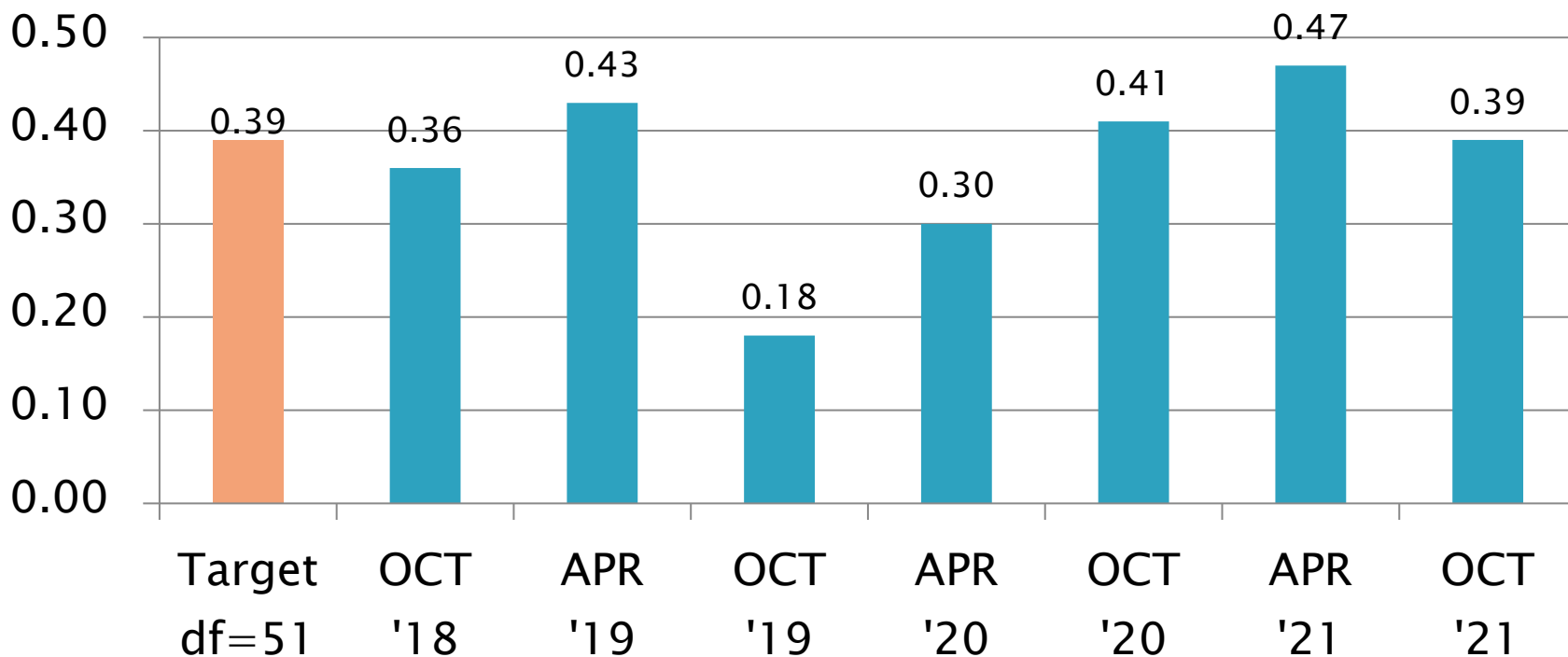
D6417 Severity Estimates

Area % Volatized @ 371°C
Mean Δ/s
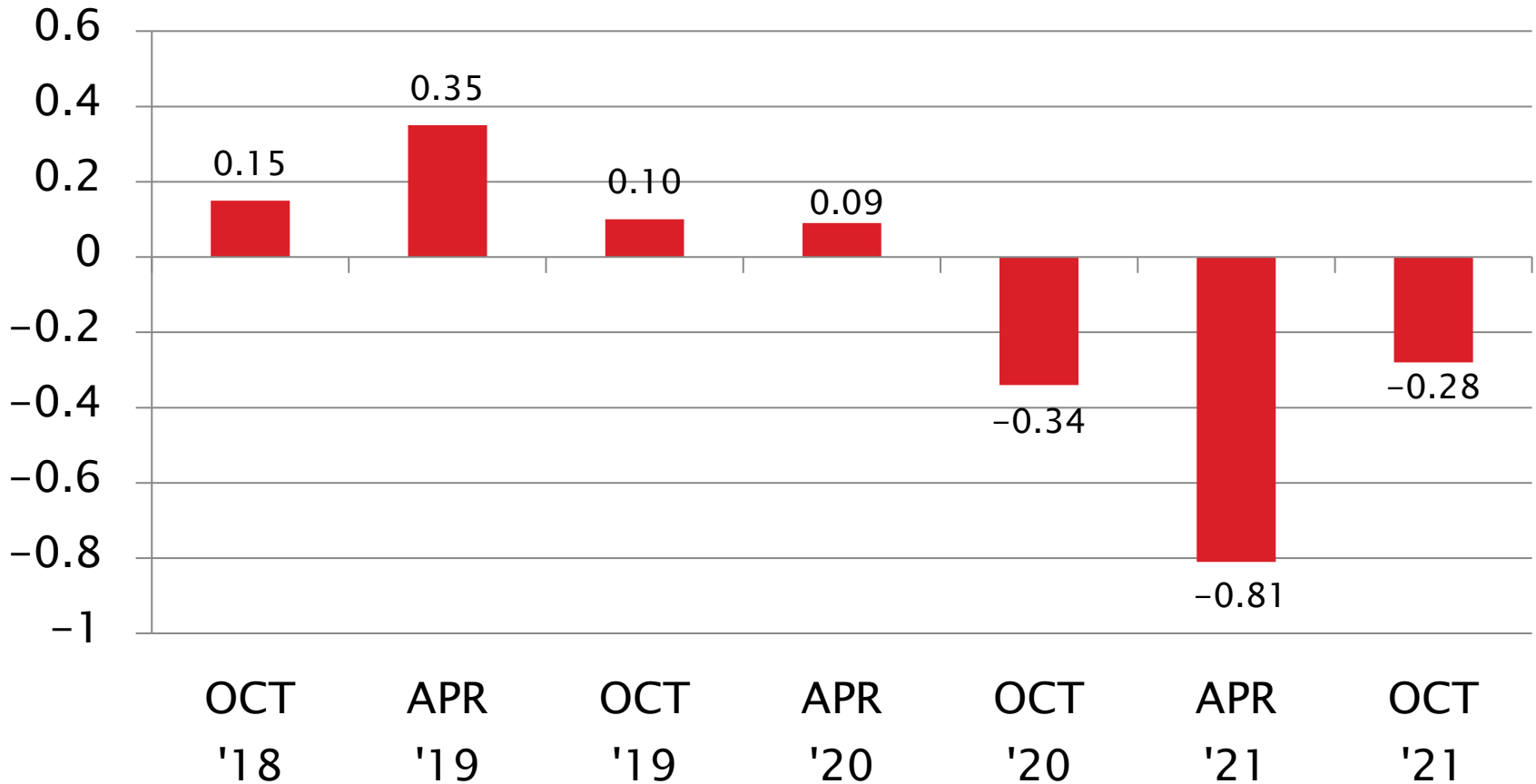
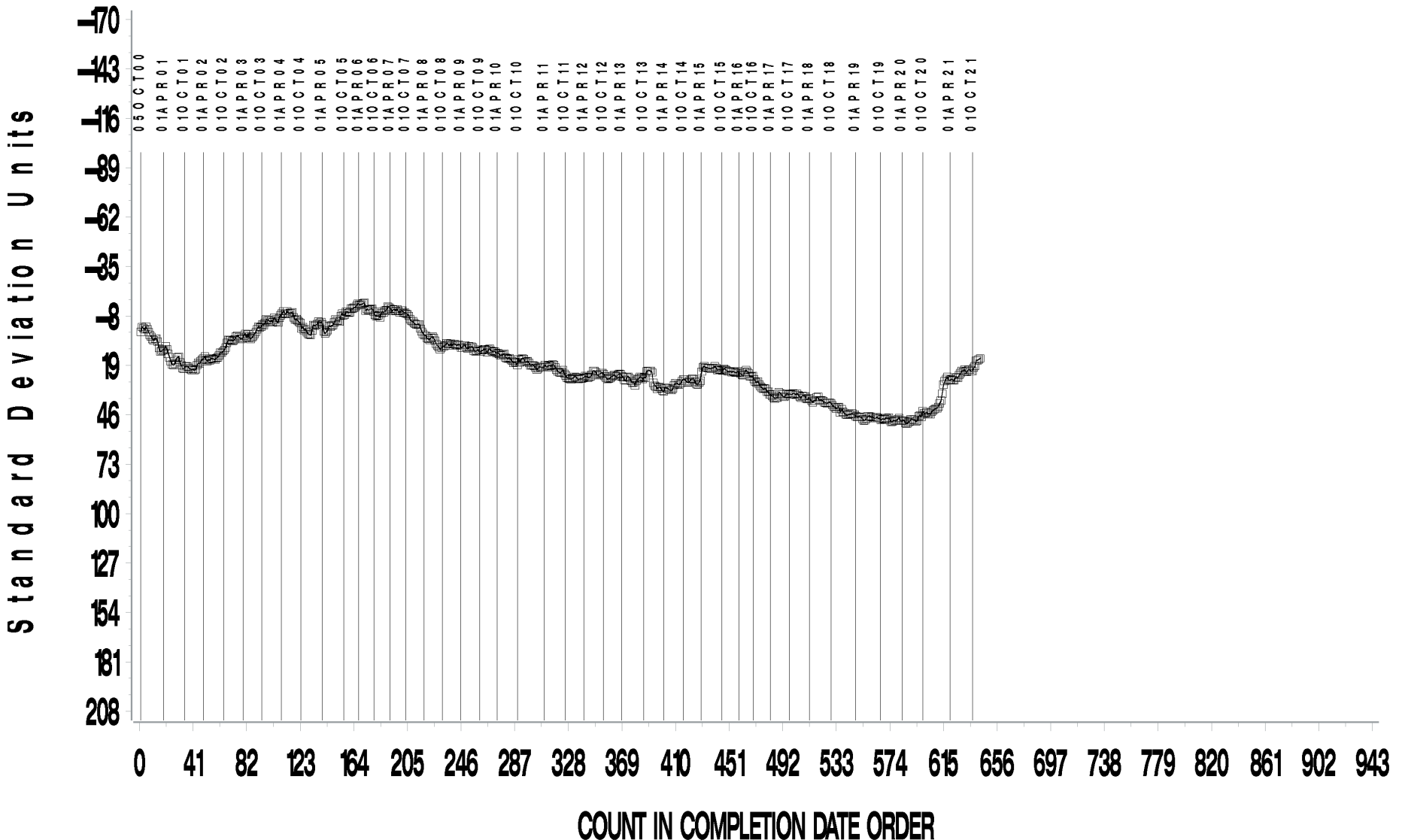# D6417 Lab Severity Estimates

Area % Volatized @ 371°C

Mean Δ/s

D6417: Estimation of Engine Oil Volatility by Capillary GC

▸ Precision (Pooled s) is comparable to prior periods
  ◦ Same as target precision

▸ Performance (Mean Δ/s) is −0.28 s mild.

▸ CUSUM severity plot shows a mild trend developing last three periods, with a sharp increase (mild) last period, but overall less mild again this period.
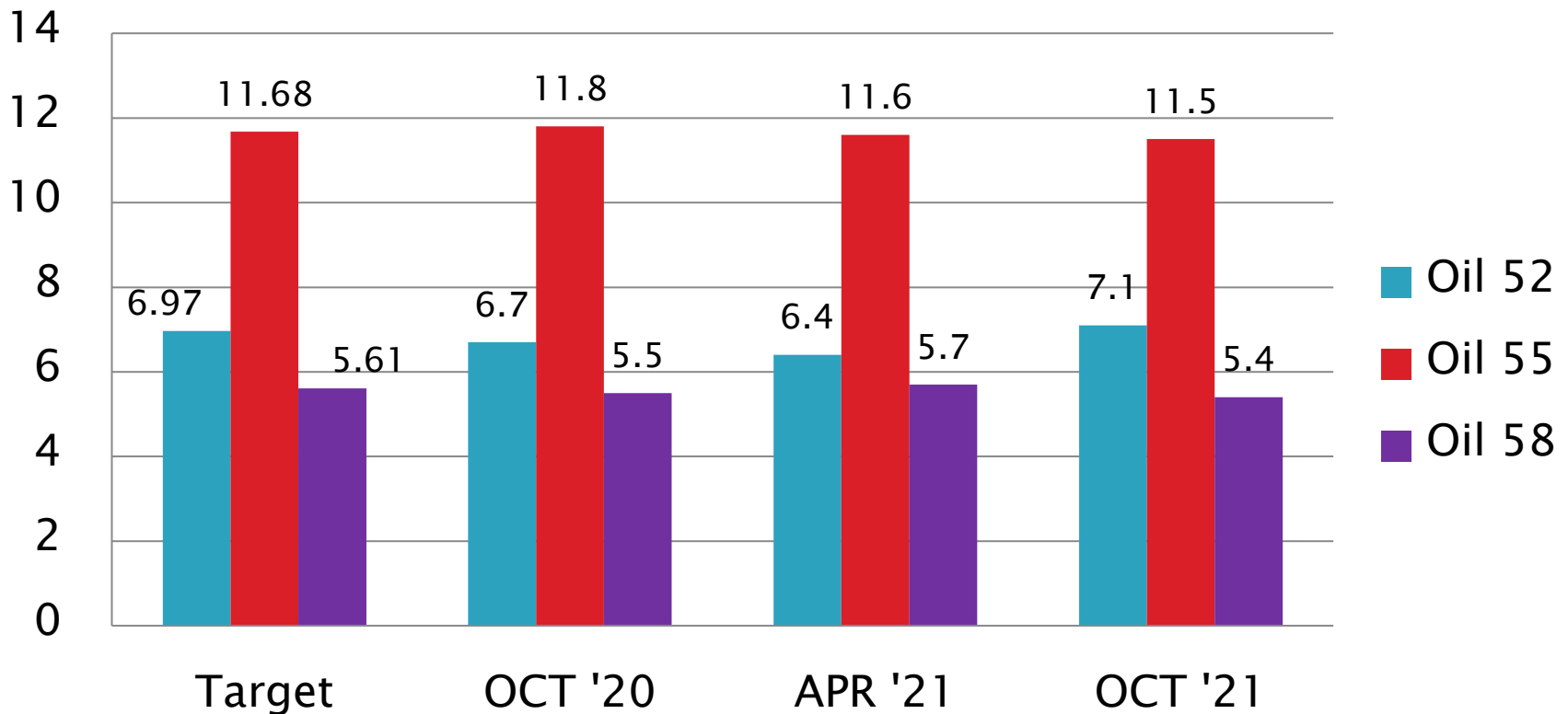
D6417 VOLATILITY BY GC INDUSTRY OPERATIONALLY VALID DATA

SAMPLE AREA % VOLATIZED

CUSUM Severity Analysis

Standard Deviation Units (y-axis): −170, −143, −116, −89, −62, −35, −8, 19, 46, 73, 100, 127, 154, 181, 208

COUNT IN COMPLETION DATE ORDER (x-axis): 0, 41, 82, 123, 164, 205, 246, 287, 328, 369, 410, 451, 492, 533, 574, 615, 656, 697, 738, 779, 820, 861, 902, 943

Date labels: 05OCT00, 01APR01, 01OCT01, 01APR02, 01OCT02, 01APR03, 01OCT03, 01APR04, 01OCT04, 01APR05, 01OCT05, 01APR06, 01OCT06, 01APR07, 01OCT07, 01APR08, 01OCT08, 01APR09, 01OCT09, 01APR10, 01OCT10, 01APR11, 01OCT11, 01APR12, 01OCT12, 01APR13, 01OCT13, 01APR14, 01OCT14, 01APR15, 01OCT15, 01APR16, 01OCT16, 01APR17, 01OCT17, 01APR18, 01OCT18, 01APR19, 01OCT19, 01APR20, 01OCT20, 01APR21, 01OCT21

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D6417 Performance by Oil

Area % Volatized @ 371°C
Mean

D6417 Performance by Oil

Area % Volatized @ 371°C

S_R

Legend: Oil 52, Oil 55, Oil 58

Categories: Target, OCT '20, APR '21, OCT '21

Values:
- Target: Oil 52 = 0.31, Oil 55 = 0.51, Oil 58 = 0.30
- OCT '20: Oil 52 = 0.49, Oil 55 = 0.43, Oil 58 = 0.23
- APR '21: Oil 52 = 0.47, Oil 55 = 0.59, Oil 58 = 0.34
- OCT '21: Oil 52 = 0.00, Oil 55 = 0.48, Oil 58 = 0.21

D6417 Performance by Oil

Area % Volatized @ 371°C

Mean Δ/s
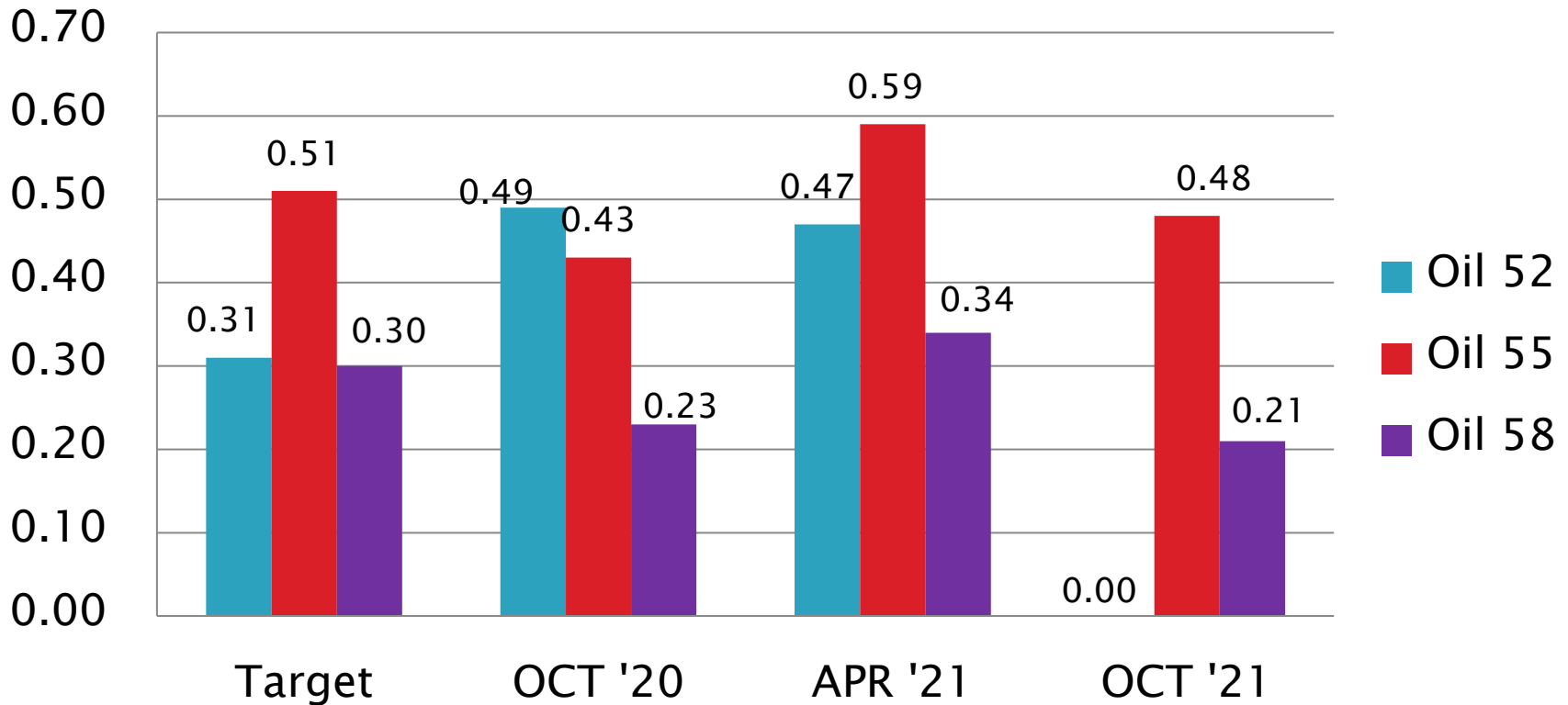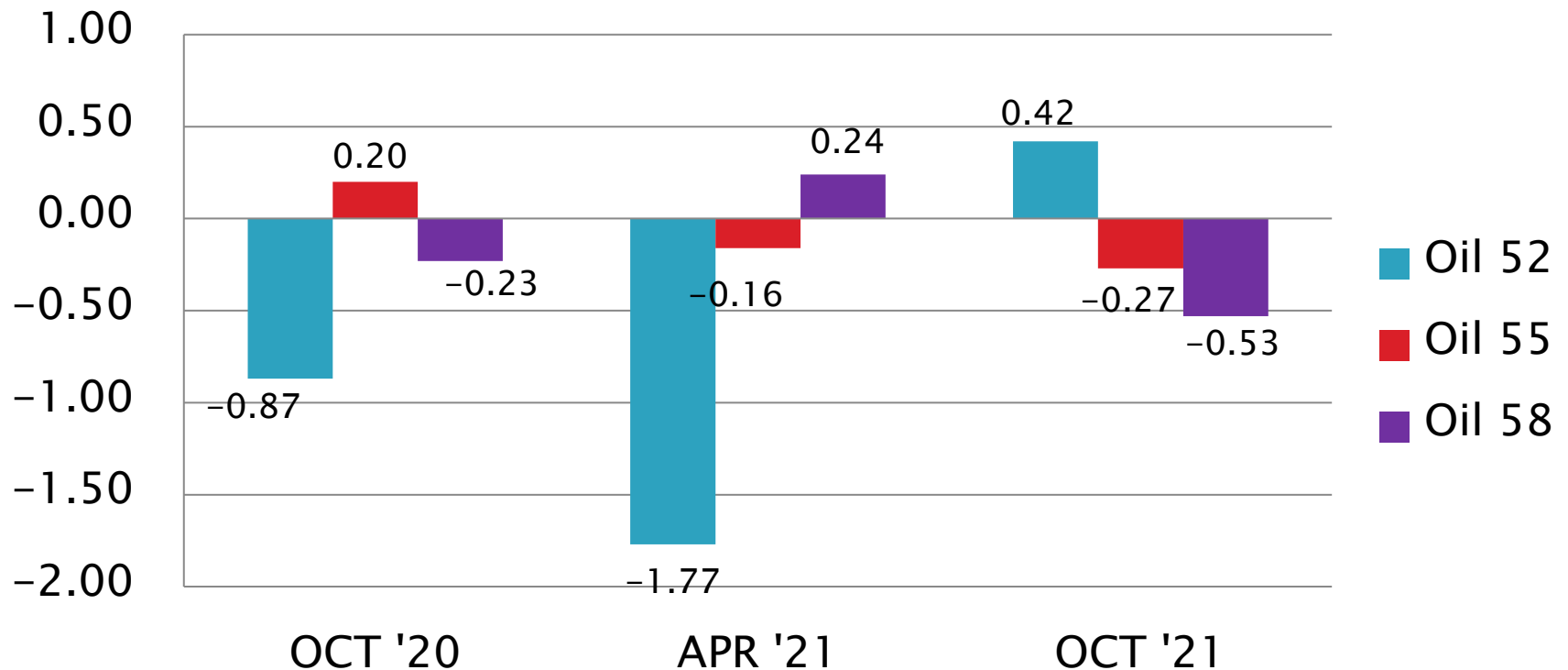
Return to Executive Summary

D5800: Evaporation Loss of Lubricating Oil by Noack Method

Test Status	Validity Code	No. Tests
Acceptable Calibration Test	AC	129
Failed Calibration Test	OC	7
Operationally Invalidated by Lab	LC, XC	2
Operationally Invalidated After Initially Reported as Valid	RC	2
Rig Shakedown Runs	AN, ON	2
Total		142

Number of Labs Reporting Data: 10
Fail Rate of Operationally Valid Tests: 5%

D5800: Evaporation Loss of Lubricating Oil by Noack Method

Statistically Unacceptable Tests (OC)	No. Of Tests
Ei Level 3 Precision Alarm Mild	0
Ei Level 3 Precision Alarm Severe	4
Zi Level 2 Severity Alarm Mild	0
Zi Level 2 Severity Alarm Severe	4

- The 7 OC tests were on five different rigs at five labs.
    - Three on rig A8
    - One test (rig A8) triggered both Ei L3 and Zi L2 alarms (both severe)

- Rig A8 had two consecutive Zi L2 (severe) alarms before alarm cleared on the third and fourth calibrations, with another Zi L2 severe alarm later in the report period (three OC fails total on the rig for the period).

- No operationally valid tests exceed ±3 s this period.

D5800: Evaporation Loss of Lubricating Oil by Noack Method

- Four operationally invalid calibration runs were reported this period:
  - One test pressure control failure discovered post-test after being informed of failing calibration (RC)
  - One test invalidated by TMC due to failing QC result on the day of calibration (RC)
  - One test aborted by lab due to failing QC result (XC)
  - One test where the test sample was spilled (XC)

- No D5800 technical memos were issued by the TMC this period.

- D5800 calibration requirement updates are issued as LTMS document updates.

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D5800: Evaporation Loss of Lubricating Oil by Noack Method

Period Precision and Severity Estimates

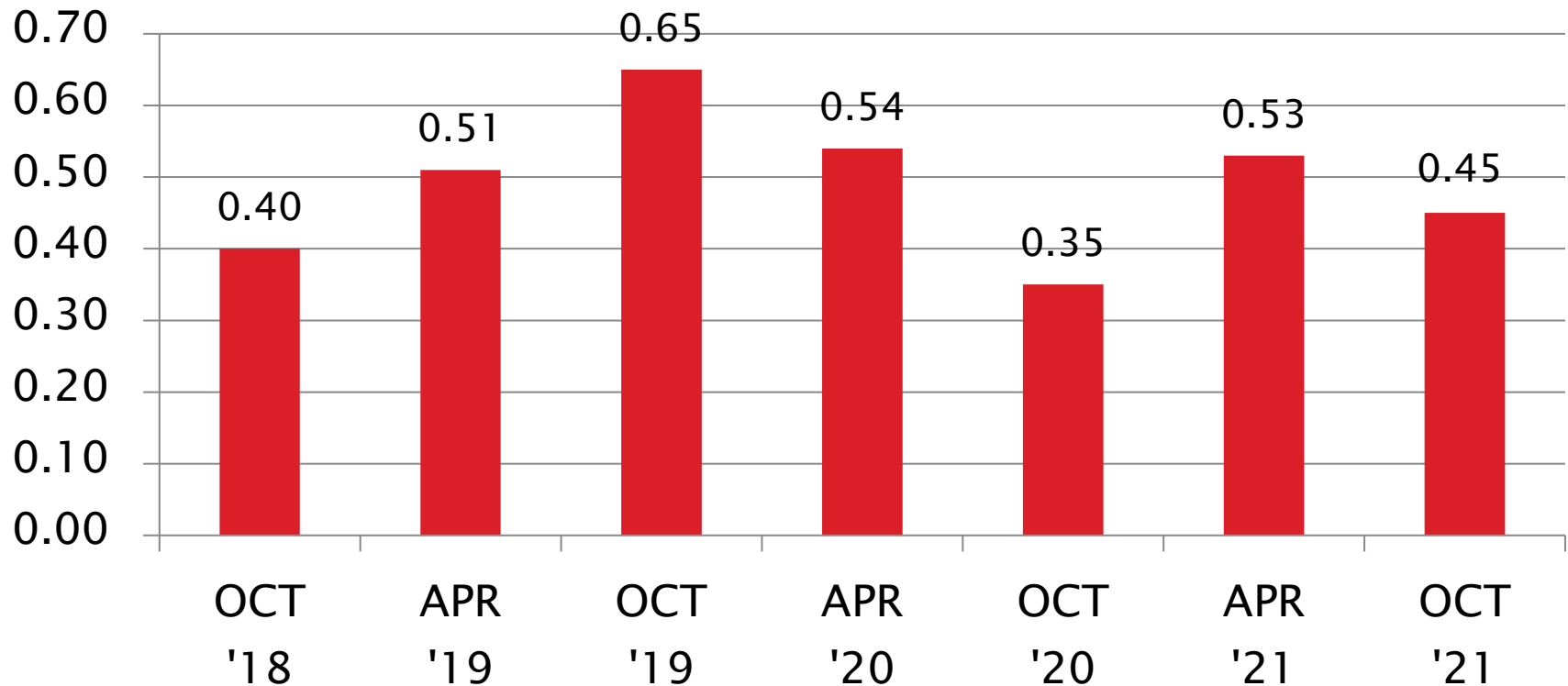| Sample Evaporation Loss, mass %	n	df	Pooled s	Mean Δ/s
Targets Effective 02/07/20[1]	78	75	0.0465	-----
10/1/18 through 3/31/19	151	148	0.81	0.51
4/1/19 through 9/30/19	164	161	0.81	0.65
10/1/19 through 3/31/20[1]	146	143	0.0503	0.54
4/1/20 through 9/30/20[1]	136	133	0.0659	0.35
10/1/20 through 3/31/21[1]	140	137	0.0495	0.53
4/1/21 through 9/30/21[1]	136	133	0.0510	0.45

[1]Began monitoring natural log transformed test results on 20200207 making logarithmic scale changes for target and period precision estimates starting April 2020 report period.
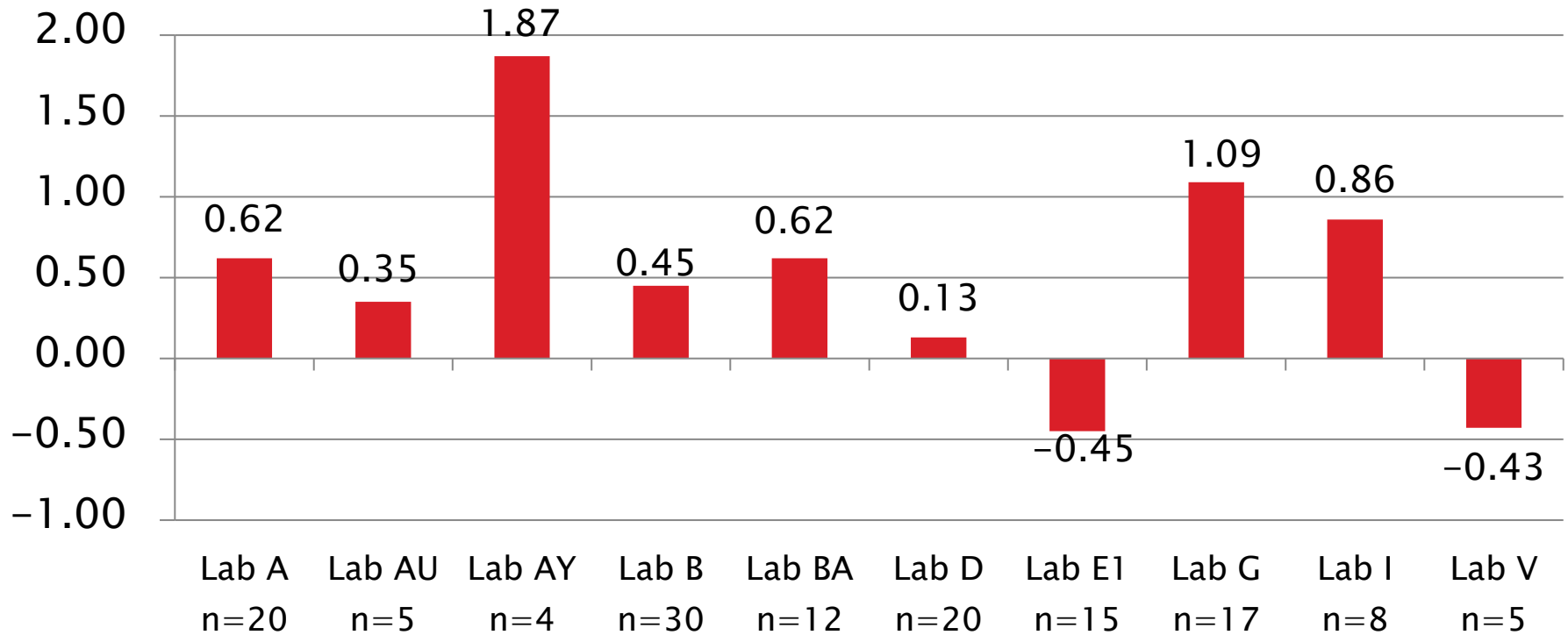
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D5800: Evaporation Loss of Lubricating Oil by Noack Method

Performance Comparison by Procedure & Model
Sample Evaporation Loss, Mass %

Procedure	n	df	Pooled s	Mean Δ/s
Procedure B	94	91	0.0486	0.72
Procedure C	No Procedure C tests reported this period.			
Procedure D	42	39	0.0449	−0.14

Model	n	df	Pooled s	Mean Δ/s
NCK2	5	2	0.0115	−0.05
NCK25G	89	86	0.0492	0.76
NS2	42	39	0.0449	−0.14

1 Procedure B NCK2 Rig
18 Procedure B NCK25G Rigs
7 Procedure D NS2 Rigs
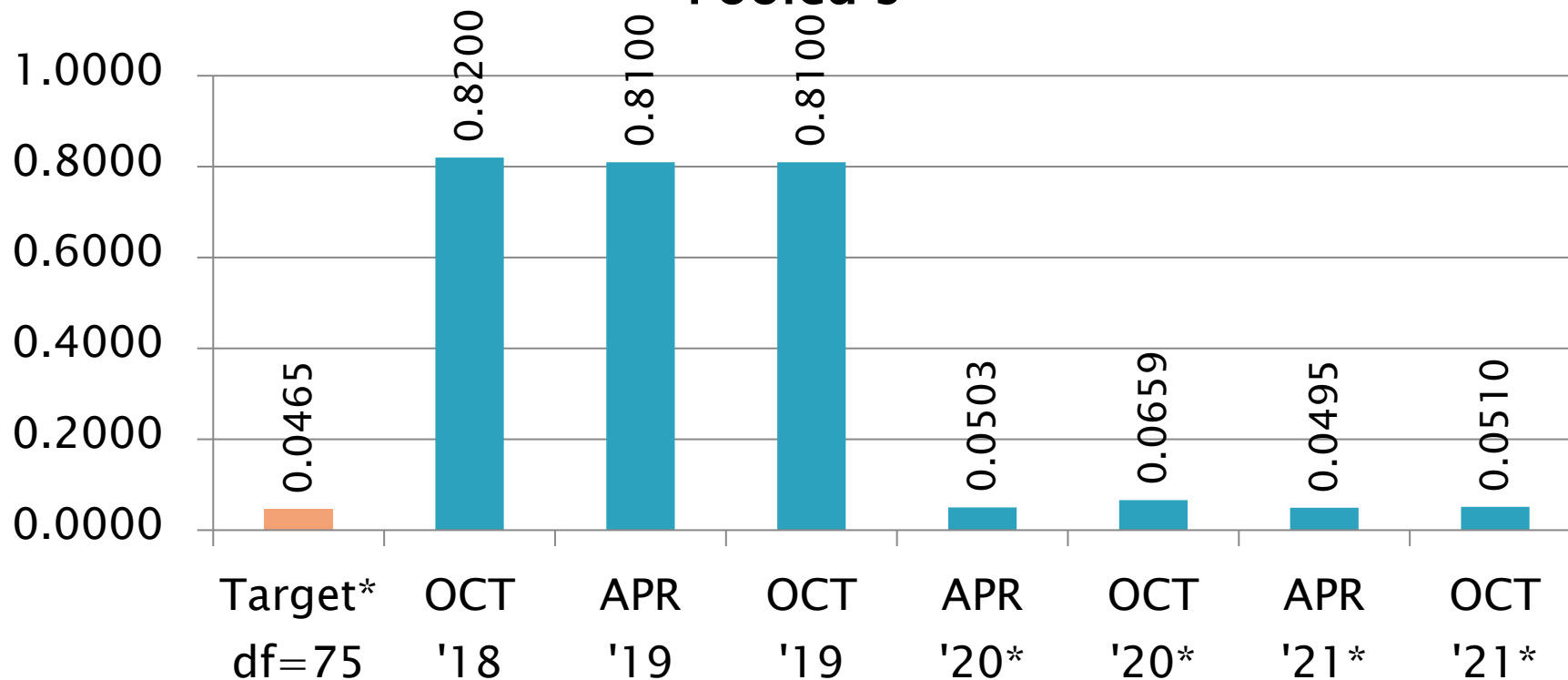
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D5800 Precision Estimates

Sample Evaporation Loss, mass %
Pooled s

*Began monitoring natural log transformed test results on 20200207 making logarithmic scale changes for target and period precision estimates starting April 2020 report period.

D5800 Precision Estimates
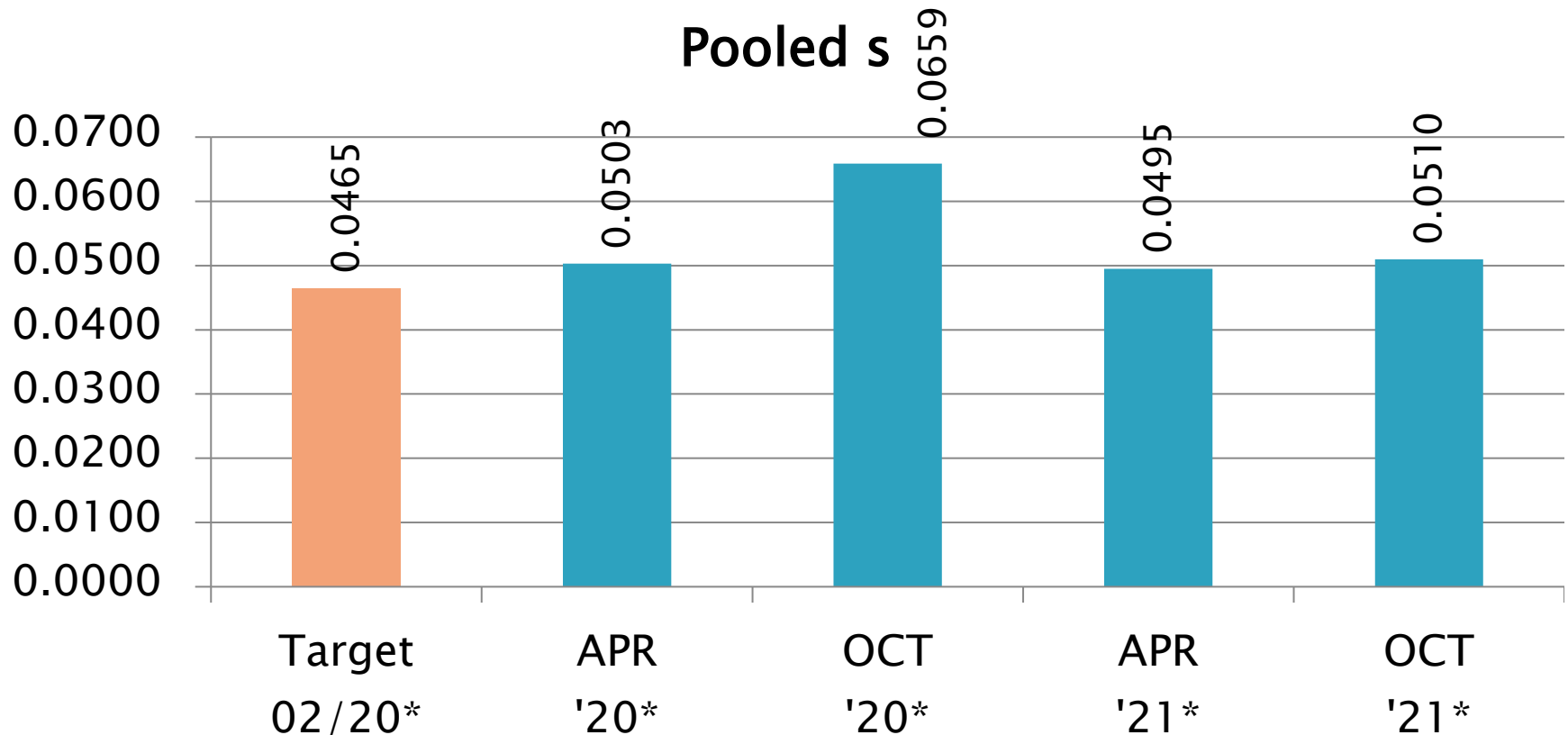
Sample Evaporation Loss, mass %
Pooled s

*Began monitoring natural log transformed test results on 20200207 making logarithmic scale changes for target and period precision estimates starting April 2020 report period.

	Target 02/20*	APR '20*	OCT '20*	APR '21*	OCT '21*
Pooled s	0.0465	0.0503	0.0659	0.0495	0.0510

D5800 Severity Estimates

Sample Evaporation Loss, mass %
Mean Δ/s

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D5800 Lab Severity Estimates

Sample Evaporation Loss, mass %

Mean Δ/s

D5800: Evaporation Loss of Lubricating Oil by Noack Method

- Precision (Pooled s) is less precise than target precision (in natural log transformed units).
  - Less precise than prior period
  - Procedure B rigs are less precise, Procedure D rigs are more precise than target

- Performance (Mean Δ/s) is 0.45 s severe.
  - Procedure B rigs are trending 0.72 s severe while Procedure D rigs are trending –0.14 s mild.

- CUSUM severity plots shows a continuing overall severe trend with reference testing, completely attributable (this period) to procedure B tests. Procedure D tests are, overall, only slightly mild for the period.

D5800 VOLATILITY BY NOACK INDUSTRY OPERATIONALLY VALID DATA

EVAPORATION LOSS, MASS%

CUSUM Severity Analysis

Standard Deviation Units (y-axis): −130, −10, 110, 230, 350, 470, 590, 710, 830, 950, 1070, 1190, 1310, 1430, 1550

COUNT IN COMPLETION DATE ORDER (x-axis): 0, 240, 480, 720, 960, 1200, 1440, 1680, 1920, 2160, 2400, 2640, 2880, 3120, 3360, 3600, 3840, 4080

Vertical line labels: 01APR02, 01OCT02, 01APR03, 01OCT03, 01APR04, 01OCT04, 01APR05, 01OCT05, 01APR06, 01OCT06, 01APR07, 01OCT07, 01APR08, 01OCT08, 01APR09, 01OCT09, 01APR10, 01OCT10, 01APR11, 01OCT11, 01APR12, 01OCT12, 01APR13, 01OCT13, 01APR14, 01OCT14, 01APR15, 01OCT15, 01APR16, 01OCT16, 01APR17, 01OCT17, 01APR18, 01OCT18, 01APR19, 01OCT19, 01APR20, 01OCT20, 01APR21, 01OCT21

19OCT21: 10:22

D5800 VOLATILITY BY NOACK INDUSTRY OPERATIONALLY VALID DATA

EVAPORATION LOSS, MASS%

CUSUM Severity Analysis

Y-axis: **Standard Deviation Units** — -130, -10, 110, 230, 350, 470, 590, 710, 830, 950, 1070, 1190, 1310, 1430, 1550

X-axis: **COUNT IN COMPLETION DATE ORDER** — 0, 240, 480, 720, 960, 1200, 1440, 1680, 1920, 2160, 2400, 2640, 2880, 3120, 3360, 3600, 3840, 4080

Vertical annotations:
- NEW PROCEDURES NEW TARGETS
- D5800 B WORKSHOP 1
- REVISED OIL TARGETS
- D5800 B WORKSHOP 2
- NEW OILS AND TARGETS
- D5800 C WORKSHOP 1
- NEW LTMS PROTOCOL
- D5800 B WORKSHOP 3
- FIRST PRCDR D TEST
- BEGIN USING LN TRANSFORM

19OCT21: 14:18

D5800 VOLATILITY BY NOACK INDUSTRY OPERATIONALLY VALID DATA
DTCOMP> = '20161019'
EVAPORATION LOSS, MASS%

LTMS Severity Analysis

EWMA

OFF SCALE   *

Mild

EWMA Action Limit

EWMA Warning Limit

EWMA Warning Limit

EWMA Action Limit

Standard Deviation Units

COUNT IN COMPLETION DATE ORDER

Severe

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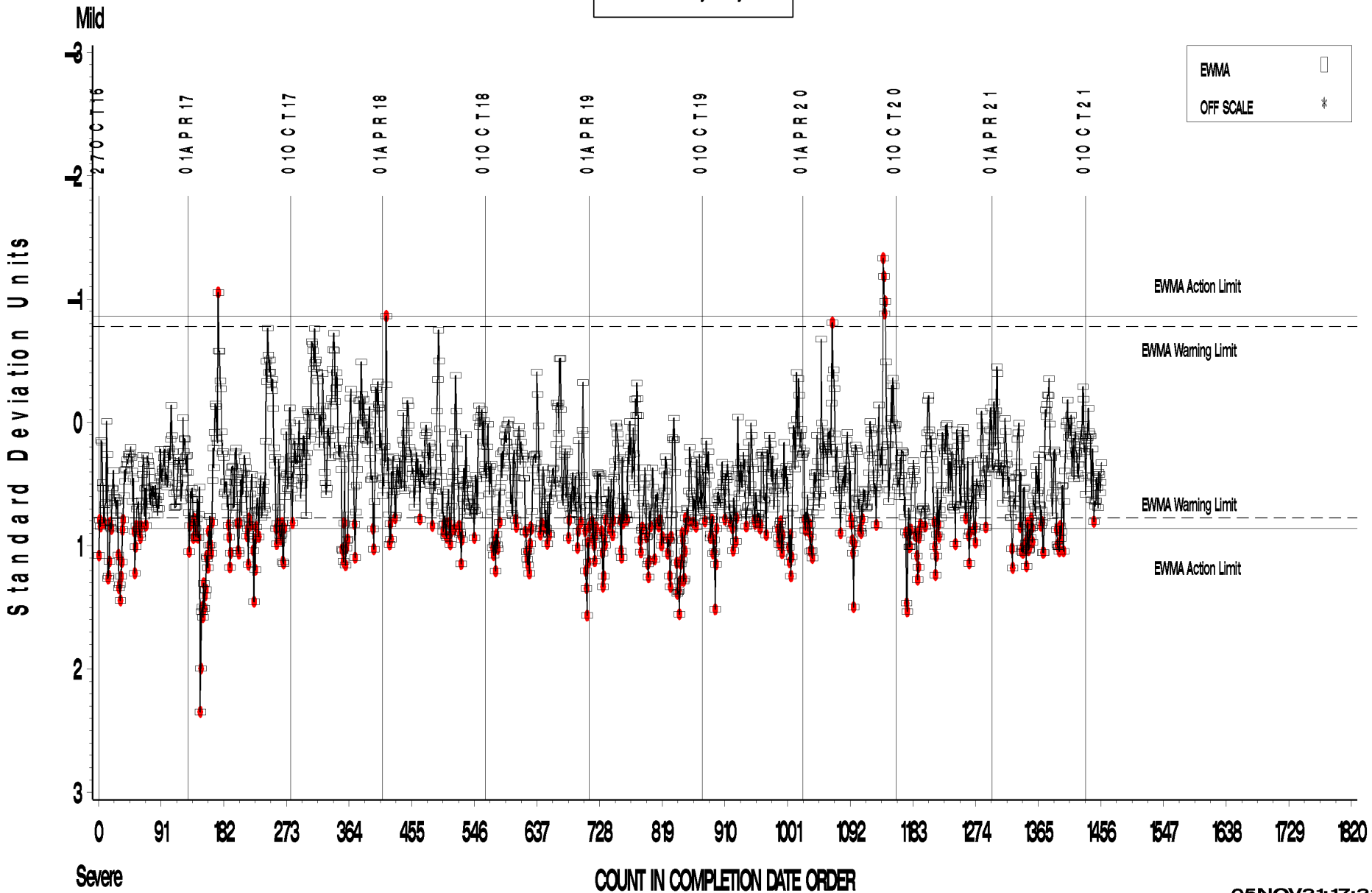
D5800 VOLATILITY BY NOACK INDUSTRY OPERATIONALLY VALID DATA
PRCDR='B'
EVAPORATION LOSS, MASS%

CUSUM Severity Analysis

Standard Deviation Units (y-axis): 56, 156, 256, 356, 456, 556, 656, 756, 856, 956, 1056, 1156, 1256, 1356, 1456, 1556

COUNT IN COMPLETION DATE ORDER (x-axis): 0, 210, 420, 630, 840, 1050, 1260, 1470, 1680, 1890, 2100, 2310, 2520, 2730, 2940, 3150, 3360, 3570

Date labels: 01 APR 17, 01 OCT 17, 01 APR 18, 01 OCT 18, 01 APR 19, 01 OCT 19, 01 APR 20, 01 OCT 20, 01 APR 21, 01 OCT 21

05NOV21:16:59
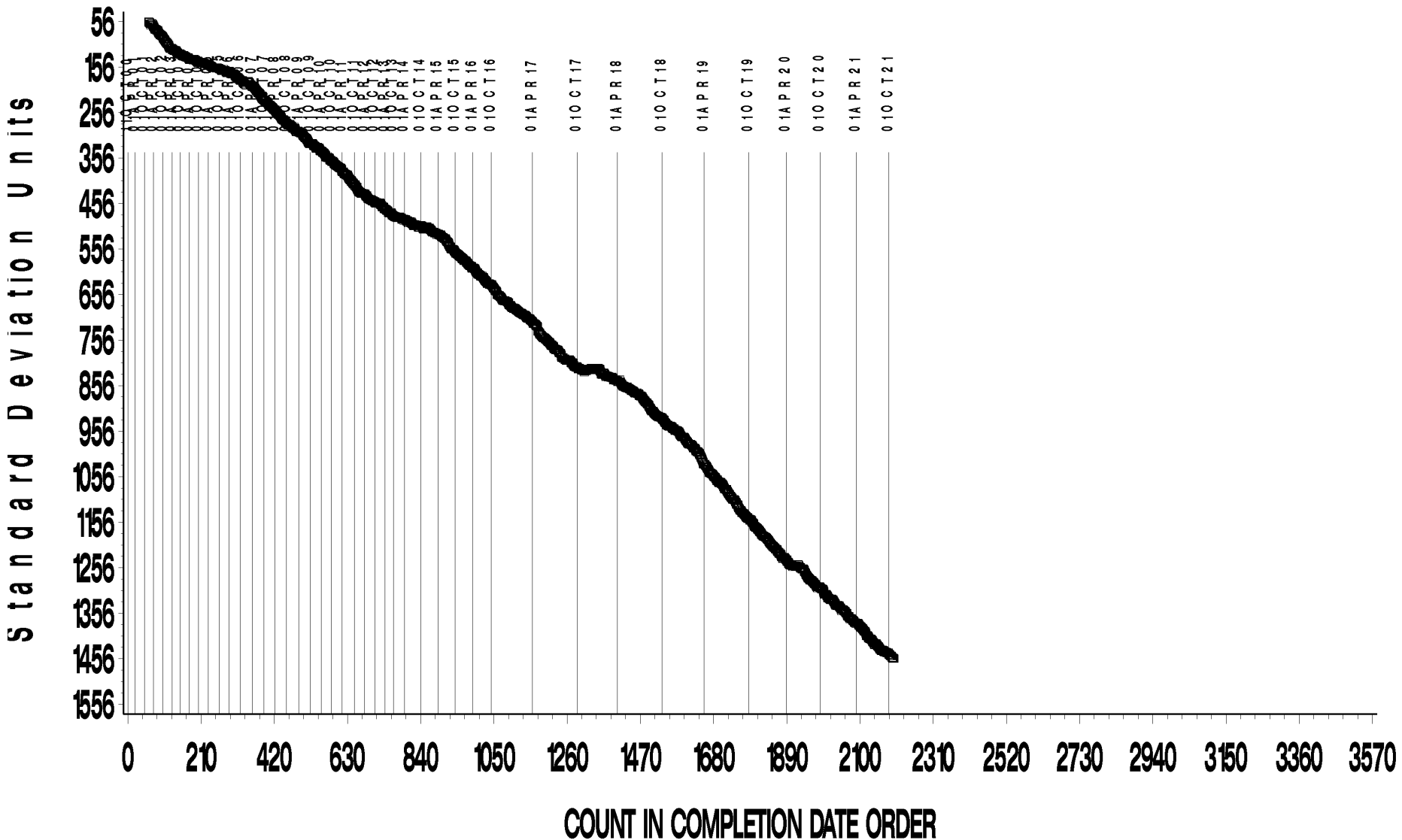
D5800 VOLATILITY BY NOACK INDUSTRY OPERATIONALLY VALID DATA
PRCDR='D'
EVAPORATION LOSS, MASS%
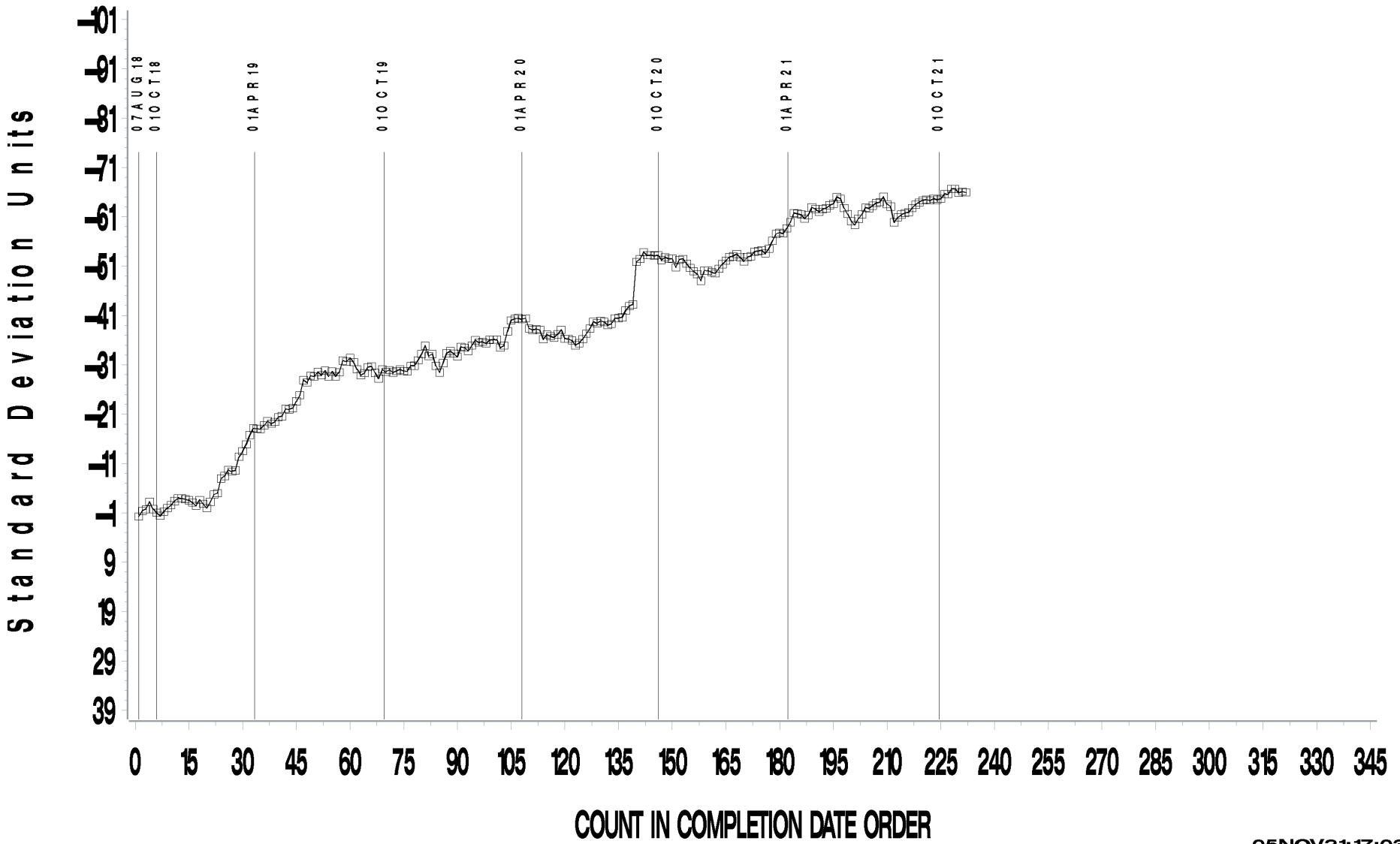
CUSUM Severity Analysis

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D5800 Performance by Oil

Sample Evaporation Loss, mass %

Mean

Legend:
- Oil VOLC12
- Oil VOLD12
- Oil VOLE12

Categories (x-axis): Target*, OCT '20*, APR '21*, OCT '21*

Data values:
- Target*: 2.6523, 2.5264, 2.8175
- OCT '20*: 2.6833, 2.5434, 2.8192
- APR '21*: 2.6739, 2.5576, 2.8390
- OCT '21*: 2.6670, 2.5436, 2.8486

*Results transformed to natural log per updated LTMS 20200207

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D5800 Performance by Oil

Sample Evaporation Loss, mass %

S_R

- Oil VOLC12
- Oil VOLD12
- Oil VOLE12

	Oil VOLC12	Oil VOLD12	Oil VOLE12
Target*	0.0465	0.0465	0.0465
OCT '20*	0.0573	0.0431	0.0881
APR '21*	0.0519	0.0510	0.0454
OCT '21	0.0517	0.0452	0.0556

*Results transformed to natural log per updated LTMS 20200207

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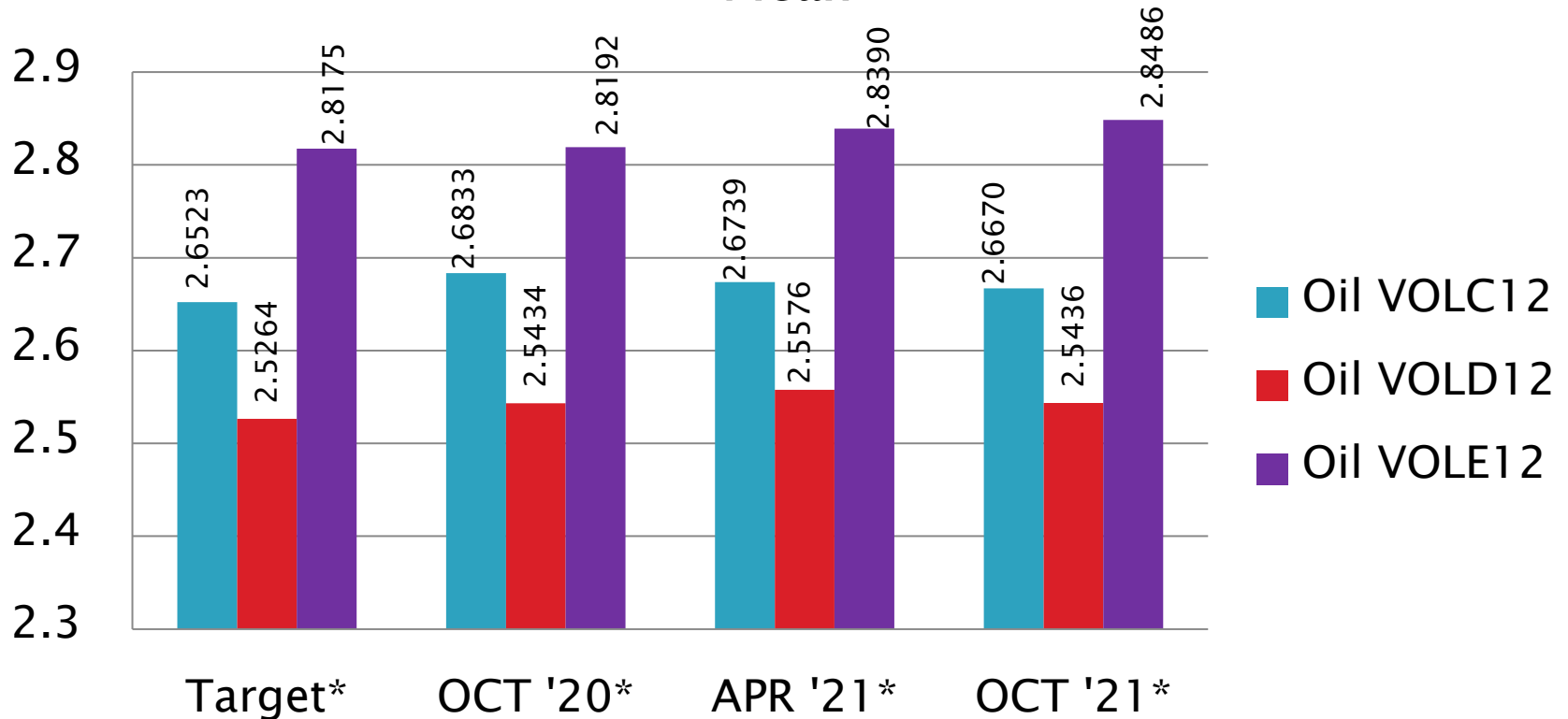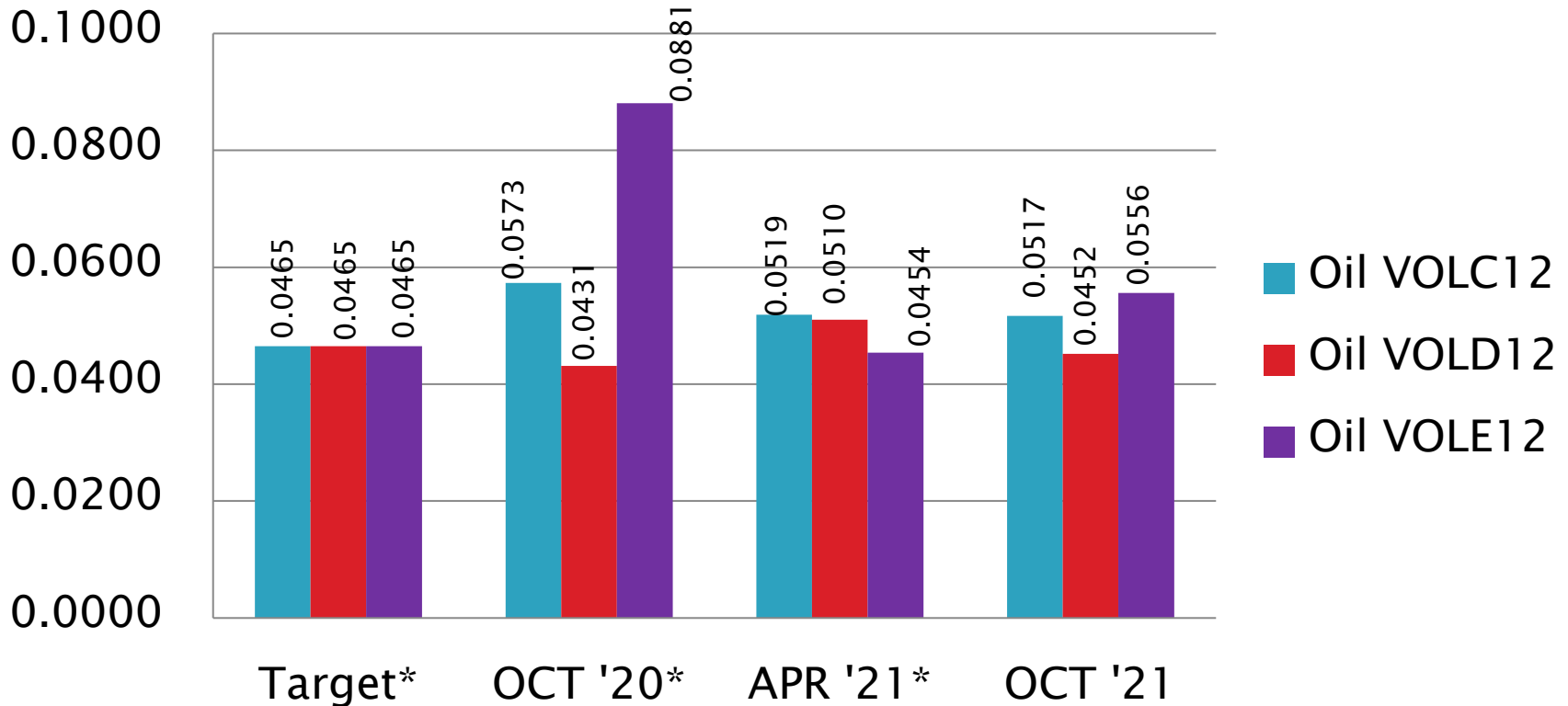
D5800 Performance by Oil

Sample Evaporation Loss, mass %
Mean Δ/s
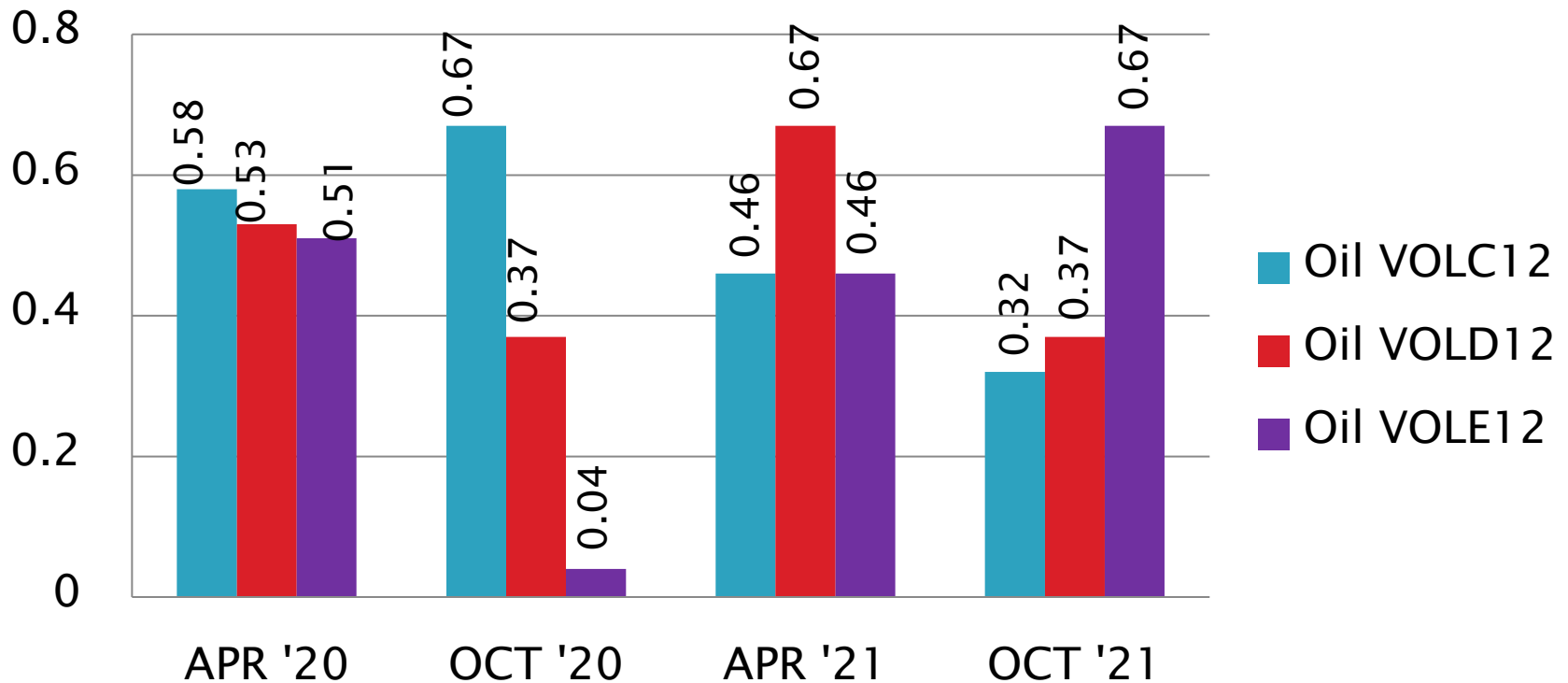
D5133: Gelation Index

Test Status	Validity Code	No. Tests
Acceptable Calibration Test	AC	66
Failed Calibration Test	OC	9
Operationally Invalidated by Lab	LC, LS, XC, XS	2
Operationally Invalidated After Initially Reported as Valid	RC	1
Acceptable Discrimination Tests	AS	15
Failed Discrimination Tests	OS	2
Total		95

Number of Labs Reporting Data: 9
(only 8 labs with chartable results this period)
Fail Rate of Operationally Valid Calibration Tests: 12%
Fail Rate of Operationally Valid Discrimination Tests: 12%

D5133: Gelation Index

Statistically Unacceptable Calibration Tests (OC)	No. Of Tests
Gelation Index Mild	4
Gelation Index Severe	5

▪ There were also 2 severe failing discrimination runs this period, out of 17 reported as operationally valid.

▪ Of the 9 OC tests:
- ▪ Four were between ±2-3 s from targets
- ▪ Three were between ±3-4 s from targets
- ▪ One between ±5-6 s from targets
- ▪ One was between ±7-8 s from targets

D5133: Gelation Index

Tests Excluded From Statistics (Operationally or Otherwise)	Validity Code	No. Tests
Bad Head, Needing Maintenance/Repair	LC	2
Computer or Software Failure (wrong results reported initially, data lost)	RC	1
Total		3*

*Compared to 35 invalidated tests last period, when monitoring of individual heads started.

D5133: Gelation Index

Period Precision and Severity Estimates

Gelation Index	n	df	Pooled s	Mean Δ/s
Targets Updated 20201001[1]	34	32	1.44	-----
4/1/18 through 9/30/18[2]	32	29	1.21	0.15
4/1/18 through 9/30/18[2]	31	28	1.03	−0.02
10/1/18 through 3/31/19	27	24	1.65	0.13
4/1/19 through 9/30/19	47	44	1.40	−0.25
10/1/19 through 3/31/20	41	37	2.45	−0.24
4/1/20 through 9/30/20	52	48	2.23	−0.11
10/1/20 through 3/31/21[3]	116	113	3.74	−0.86
4/1/21 through 9/30/21[3]	75	73	1.71	−0.20

[1]Target precision updated to current reference oils GIA17 and 1009 only
[2]Extreme OC results included and excluded
[3]Changed from bath to head based monitoring scheme 10/1/20

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D5133 Precision Estimates

Gelation Index
Pooled s
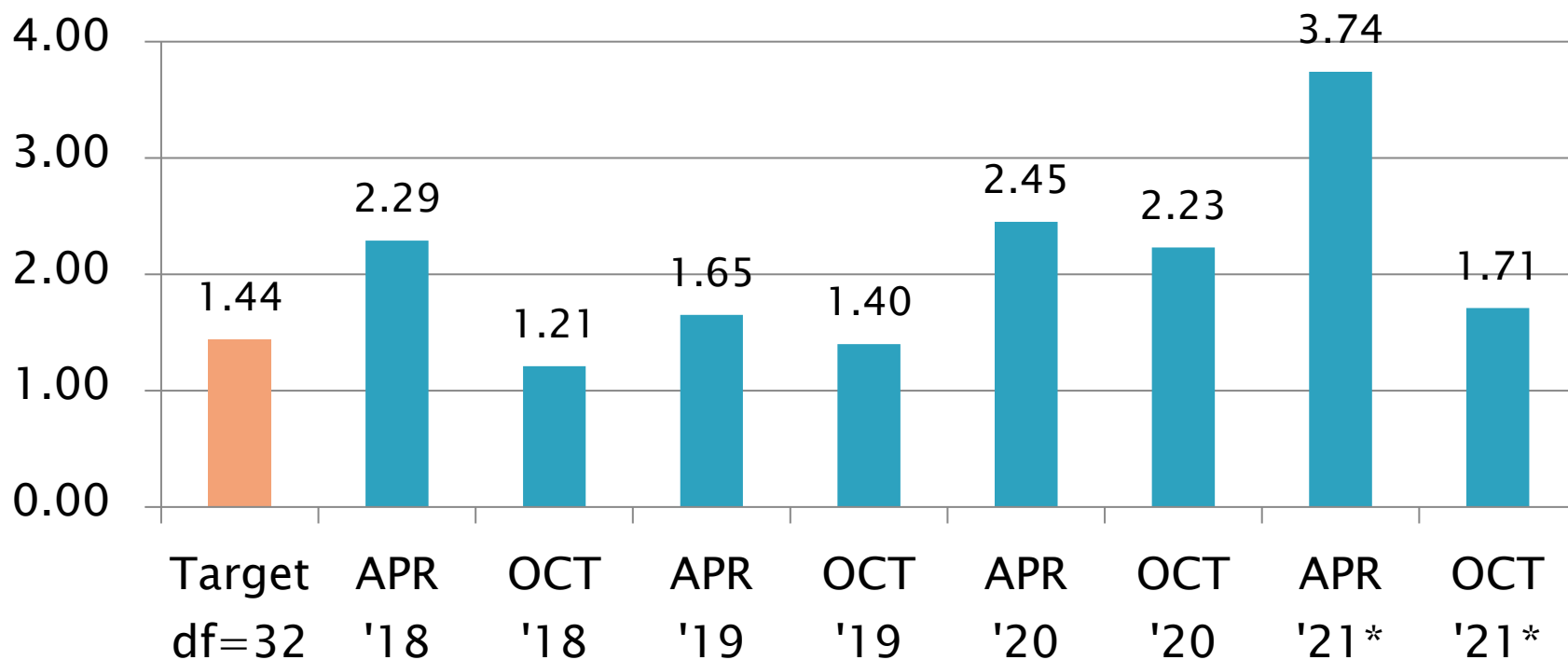
*Changed from bath to head based monitoring scheme

D5133 Severity Estimates

Gelation Index
Mean Δ/s
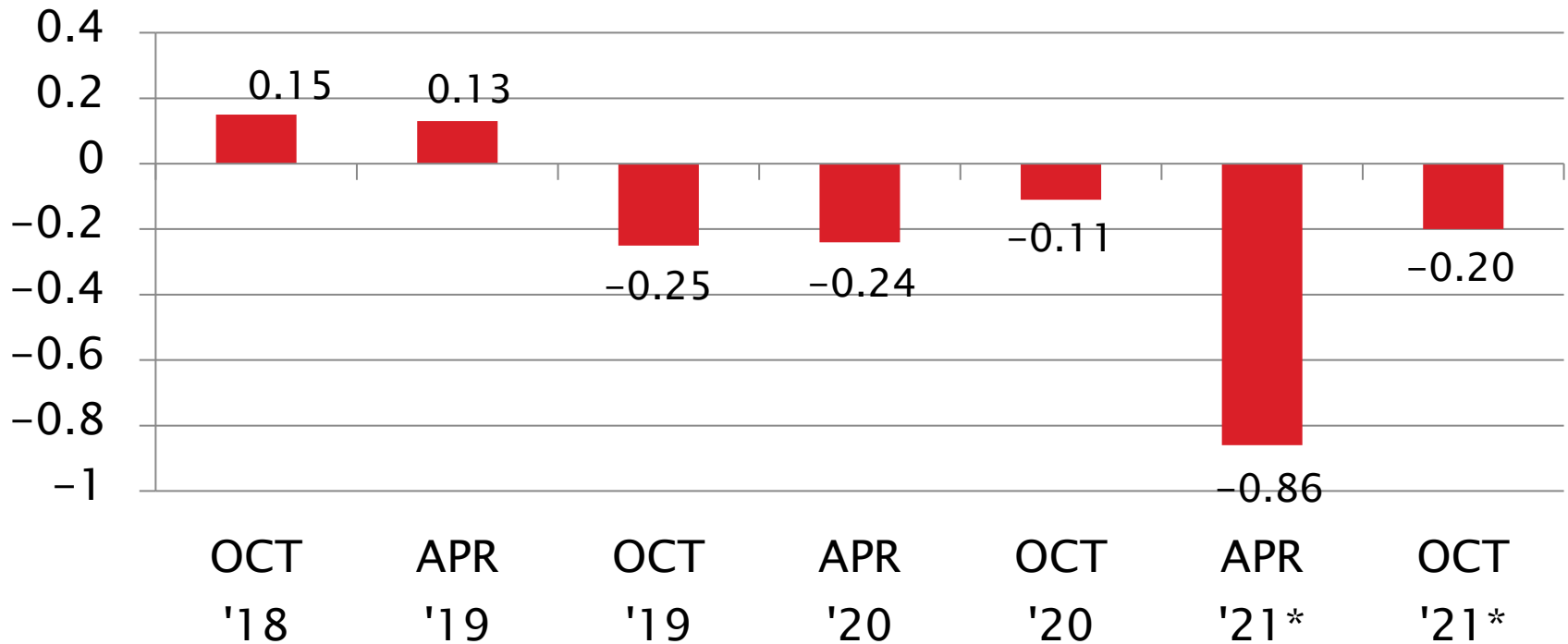
*Changed from bath to head based monitoring scheme

D5133 Lab Severity Estimates

Gelation Index

Mean Δ/s

	Lab A n=23	Lab AU n=2	Lab AY n=2	Lab B n=12	Lab D n=29	Lab E1 n=2	Lab G n=4	LAB S n=1
Mean Δ/s	−1.03	−0.66	−0.44	−0.23	0.54	−0.37	−0.38	0.15

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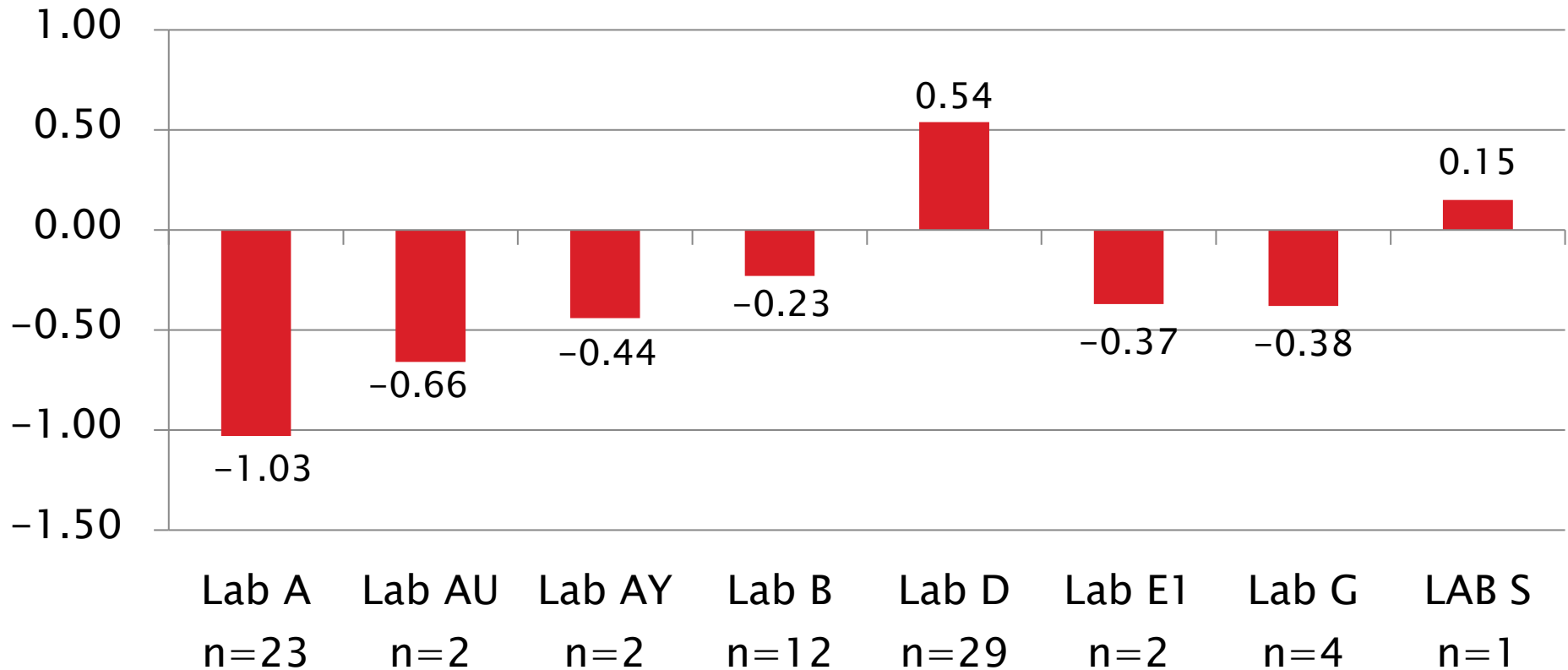
D5133: Gelation Index

- Test monitoring changed from a bath-based calibration scheme to a head-based calibration effective 10/1/2020 (where 'stand' was redefined from bath to the head/rotor/stator combination).

  - Low/non-gelling oil 58 was reclassified as a mild performing discrimination oil (non-chartable) with only a maximum performance limit.

  - Stand calibration period changed from 60 days to 180 days, with a coinciding discrimination run required with every other calibration.

D5133: Gelation Index

- Fail rate of operationally valid tests is 12% this period
  - Compared to 18% fail rate last period
  - Fail rate of (new) discrimination runs reported as operationally valid was also 12%
  - Historic period fail rates have ranged between 6% and 26%

- Precision (Pooled s) is significantly more precise than last period
  - Less precise than updated target precision

- Performance (Mean Δ/s) is −0.20 s mild
  - Six of eight labs performing overall mild

- A round robin is underway to evaluate a calibration oil that performs closer to the GF−5/6 pass/fail limit of 12 GI
  - To replace oil 58 that was reclassified as a discrimination oil

D5133 GELATION INDEX INDUSTRY OPERATIONALLY VALID DATA

GELATION INDEX

CUSUM Severity Analysis
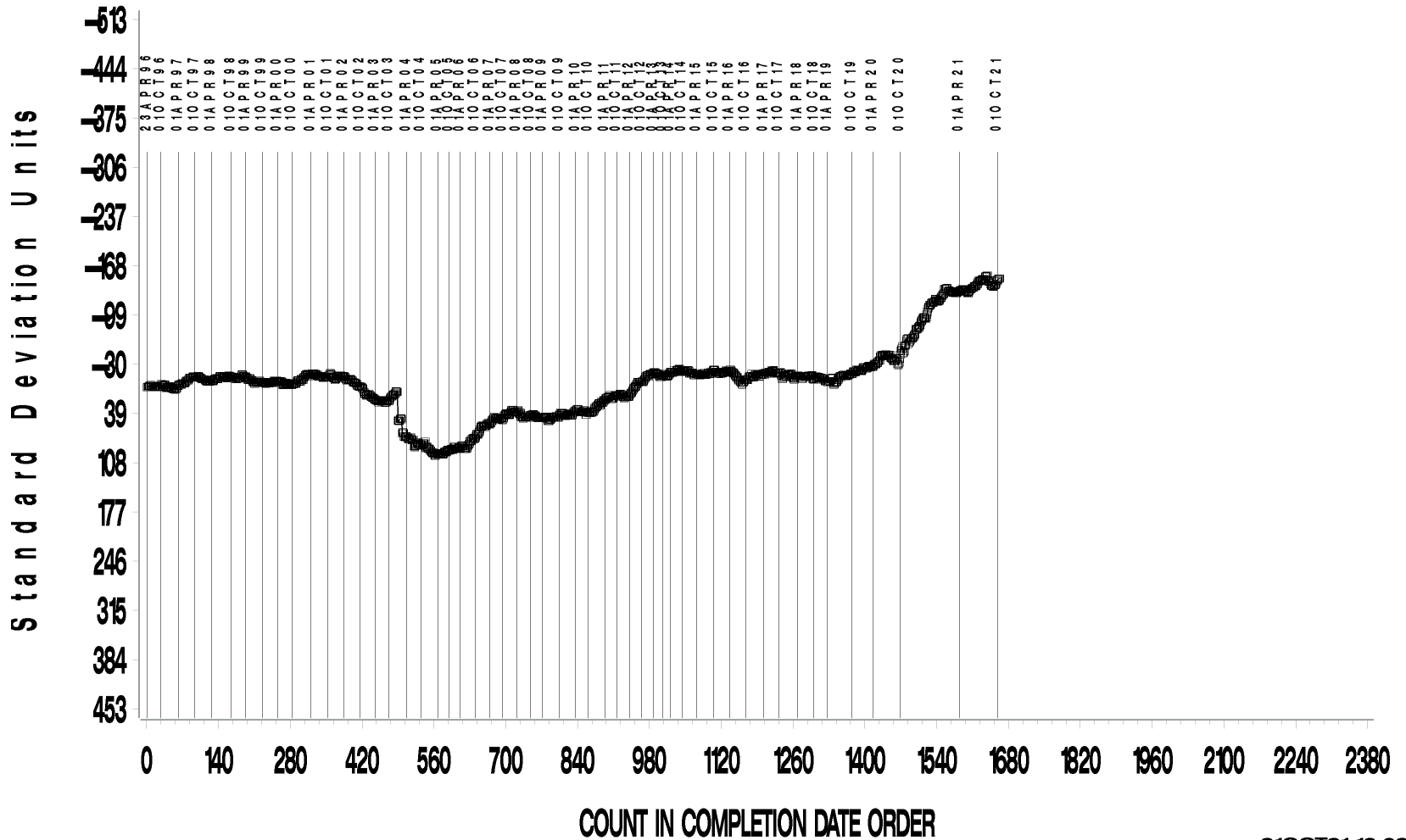
21OCT21:13:02

GELATION INDEX

CUSUM Severity Analysis

Standard Deviation Units

-513
-444
-375
-306
-237
-168
-99
-30
39
108
177
246
315
384
453

Vertical axis labels (events):

NEW REPORT FORMAT
ACCEPTANCE BANDS
PACKAGING CHANGE
REVISED STANDARD -96 TO -99
DROP OIL 51 & 55
ADD OIL 58
REVISED STANDARD -99 TO -01
REVISED PROCEDURE No 1
ADD OIL 1009, DROP 52 & 53
CAL. PERIOD CHANGE
HEAD-BASED LTMS IMPLEMENTED

Horizontal axis: **COUNT IN COMPLETION DATE ORDER**

0 140 280 420 560 700 840 980 1120 1260 1400 1540 1680 1820 1960 2100 2240 2380

21OCT21:13:05

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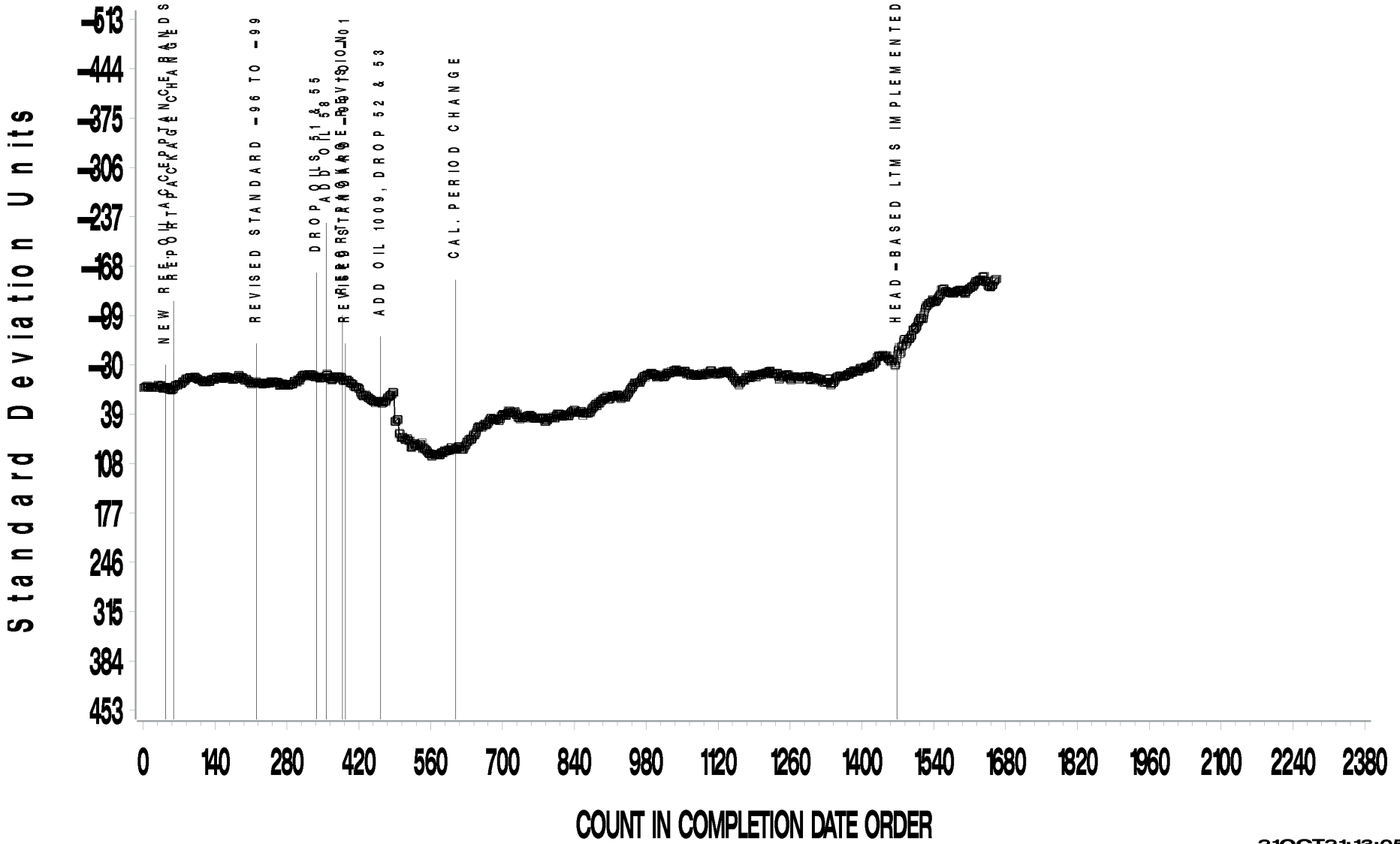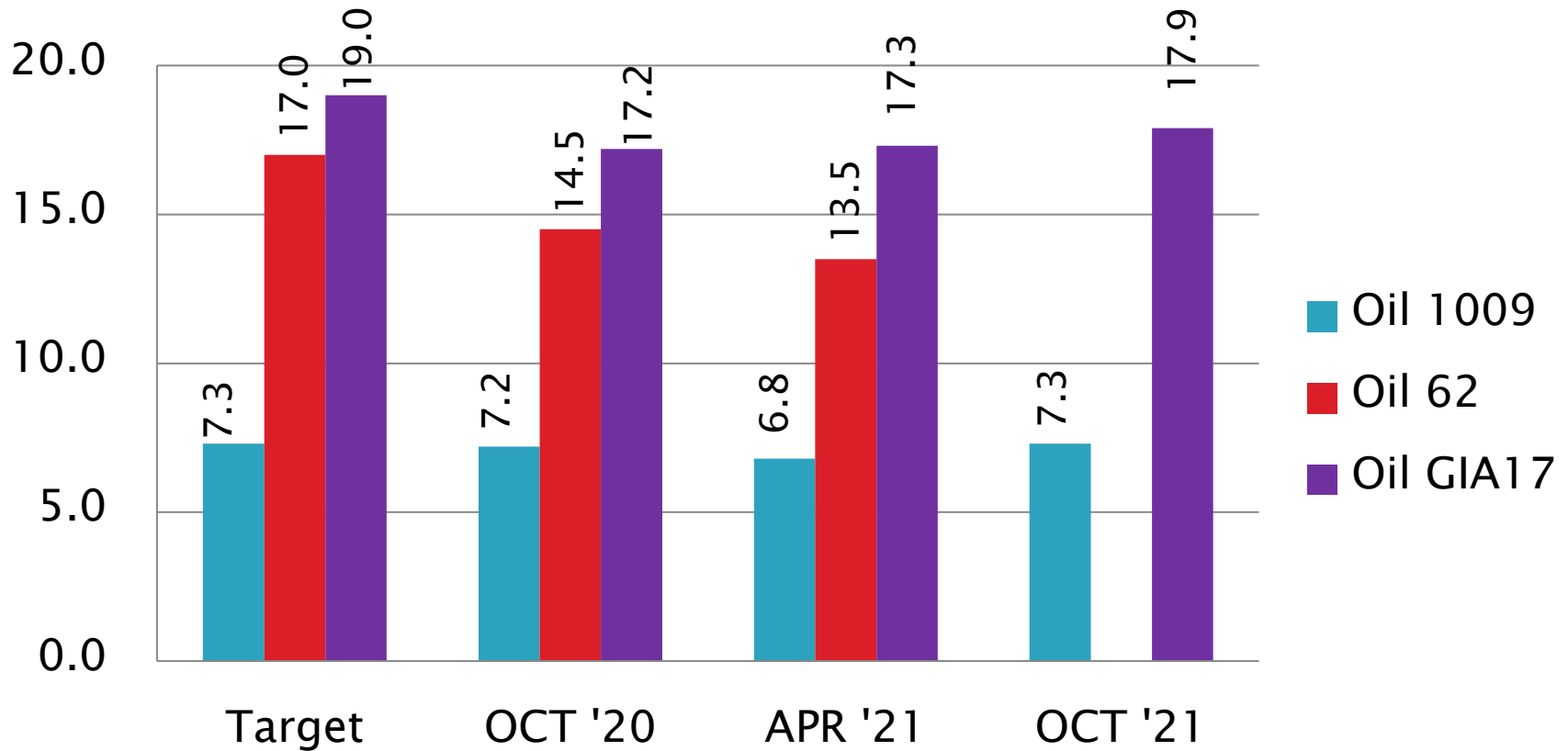
D5133 Performance by Oil

Gelation Index

S_R

D5133 Performance by Oil

Gelation Index

Mean Δ/s

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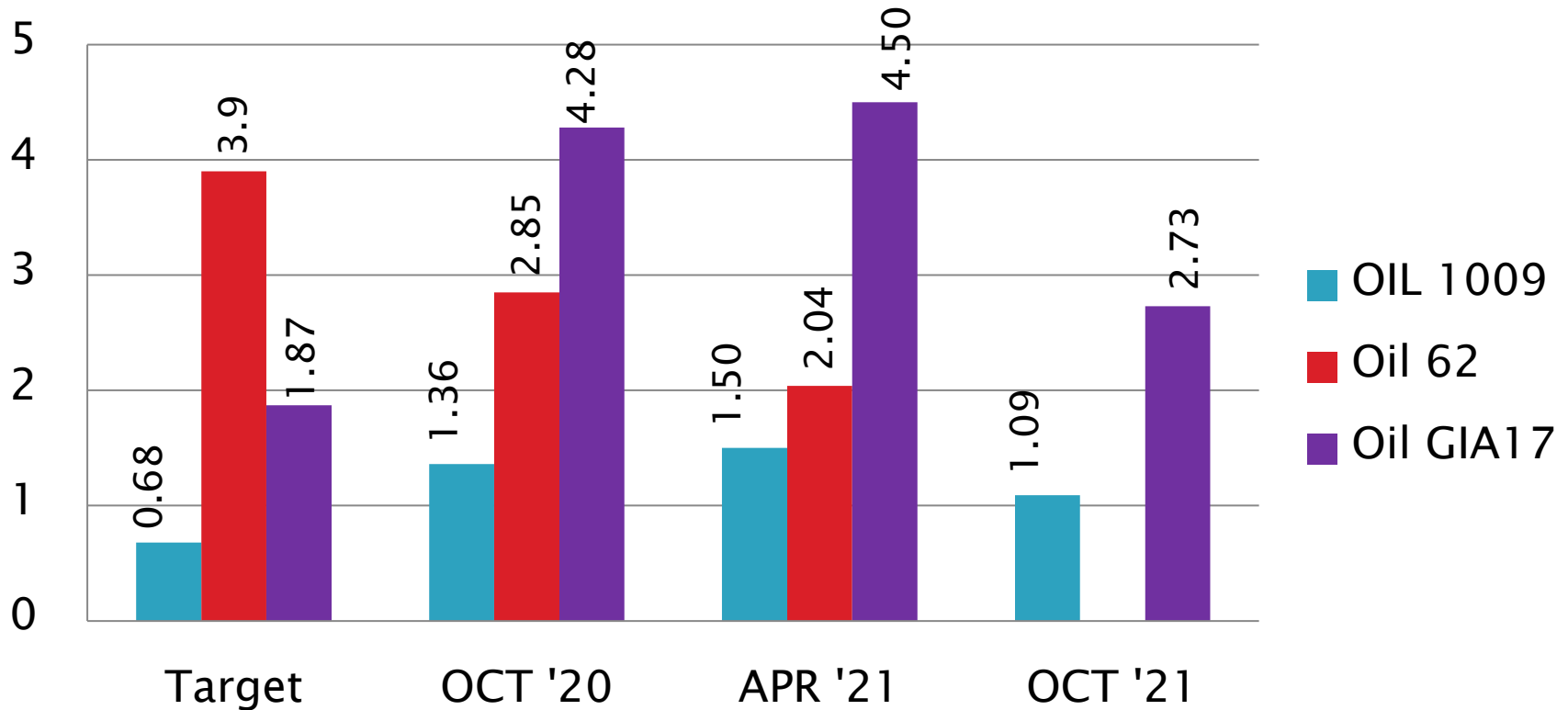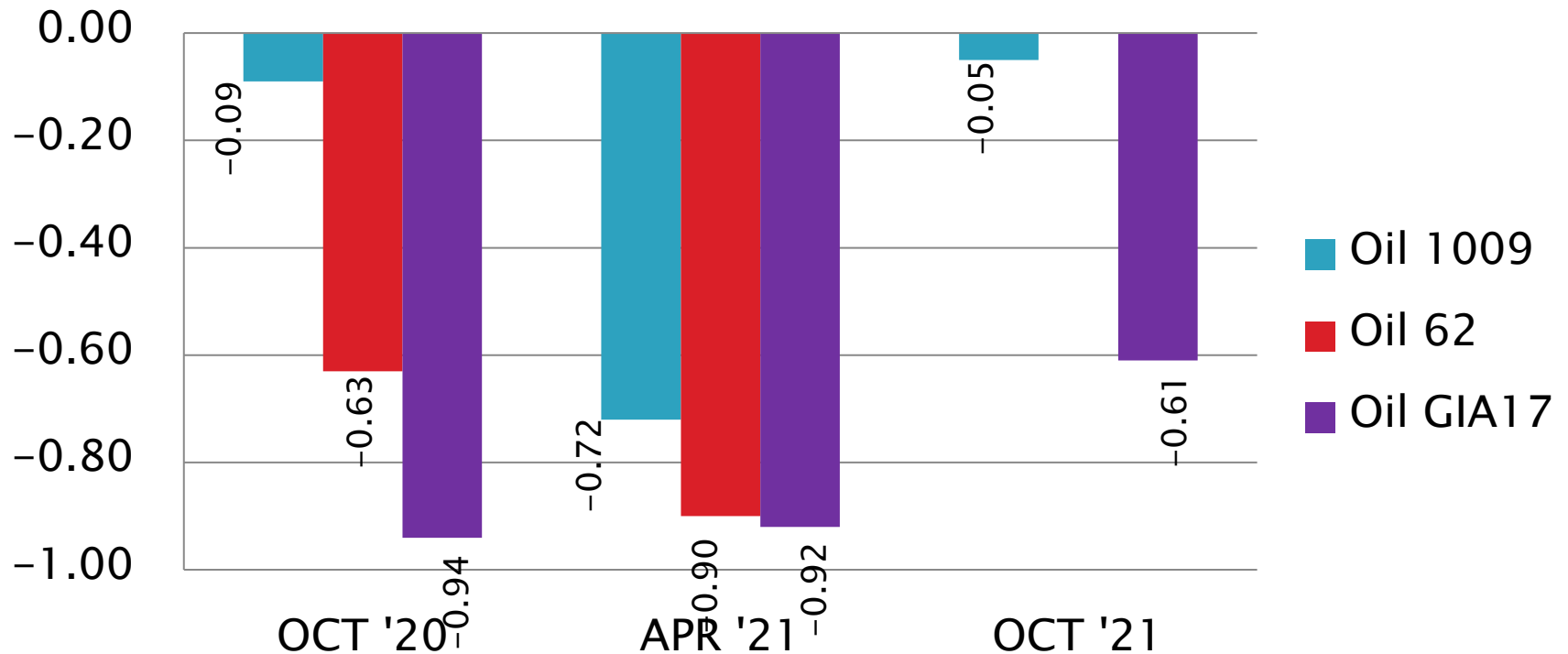
D6335: Deposits by TEOST-33C

Test Status	Validity Code	No. Tests
Acceptable Calibration Test	AC	24
Failed Calibration Test	OC	7
Operationally Invalidated by Lab	LC, XC	2
Operationally Invalidated After Initially Reported as Valid	RC	0
Stand Shakedown Run	AN, ON	21
Total		54

Number of Labs Reporting Data: 8
Fail Rate of Operationally Valid Tests: 23%

D6335: Deposits by TEOST-33C

Statistically Unacceptable Tests (OC)	No. Of Tests
Total Deposits Mild	4
Total Deposits Severe	3

- Five of the statistically unacceptable results this period were multiple fails on two stands (three on stand G3 all mild, and two on stand A1 both severe).

- There were two operationally invalid tests reported this period:
    - Contaminated filter deposits (one test, LC)
    - Test sample spilled (one test, XC)

- 21 shakedown runs to troubleshoot performance (18 on stand G3 and 3 on new stand A6).

- There were no TEOST technical update issued this report period.

- Calibration requirement updates are issued as LTMS document updates.

D6335: Deposits by TEOST-33C

Period Precision and Severity Estimates

Total Deposits, mg	n	df	Pooled s	Mean Δ/s
Updated Targets 20201001[1]	46	44	4.85	-----
10/1/18 through 3/31/19	25	23	7.37	0.11
4/1/17 through 9/30/19[2]	30	28	12.66	0.47
4/1/17 through 9/30/19[2]	26	24	7.35	−0.23
10/1/19 through 3/31/20	32	30	6.08	0.28
4/1/20 through 9/30/20[3]	33	30	11.44	0.02
4/1/20 through 9/30/20[3]	26	23	10.10	−0.02
10/1/20 through 3/31/21	26	23	8.39	0.42
4/1/21 through 9/30/21	31	28	8.27	−0.36

[1]Target precision updated to include only current oils 75-1 and 435-2
[2]Four consecutive OC results on same rig included and excluded.
[3]Rig with six OC results included and excluded.
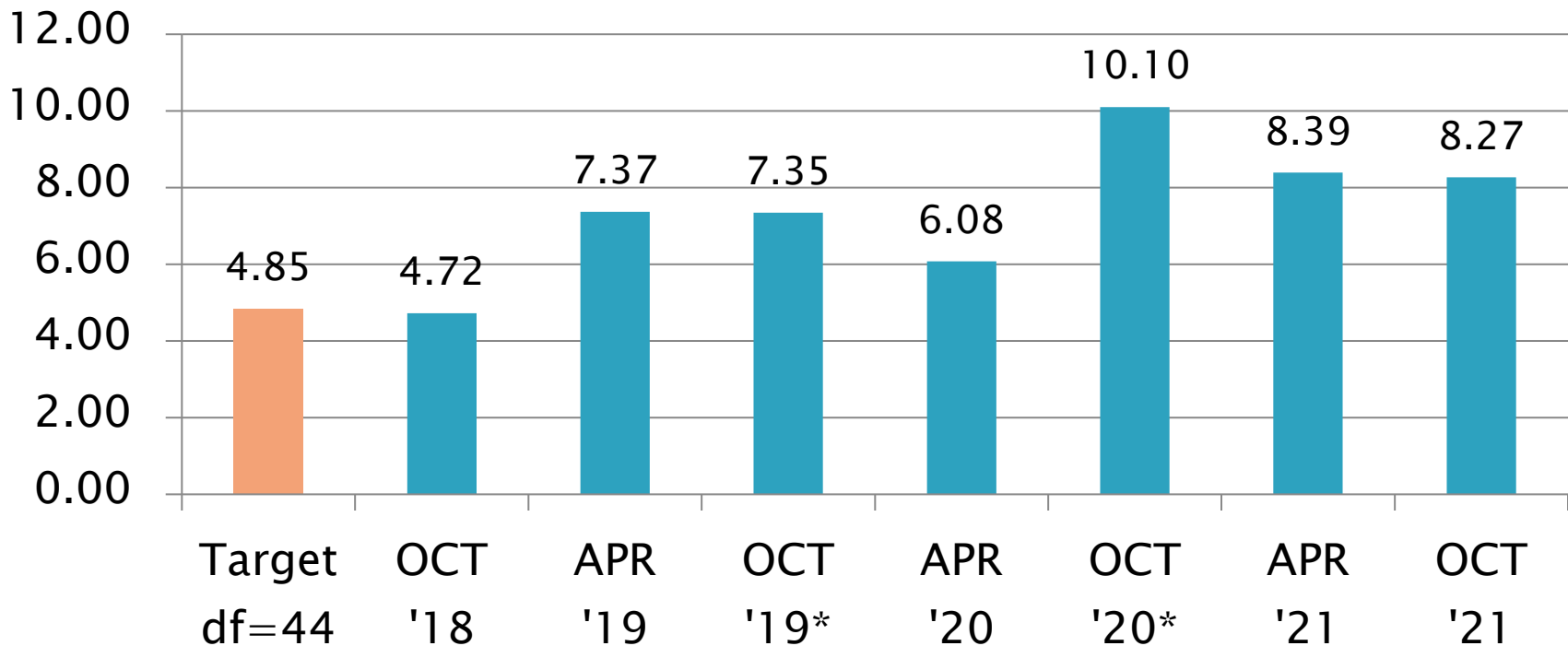
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D6335 Precision Estimates

Total Deposits, mg
Pooled s

*Multiple OC results from single excessively failing rig excluded.

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D6335 Severity Estimates

Total Deposits, mg

Mean Δ/s

*Multiple OC results from single excessively failing rig excluded.

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D6335 Lab Severity Estimates

Total deposits, mg

Mean Δ/s
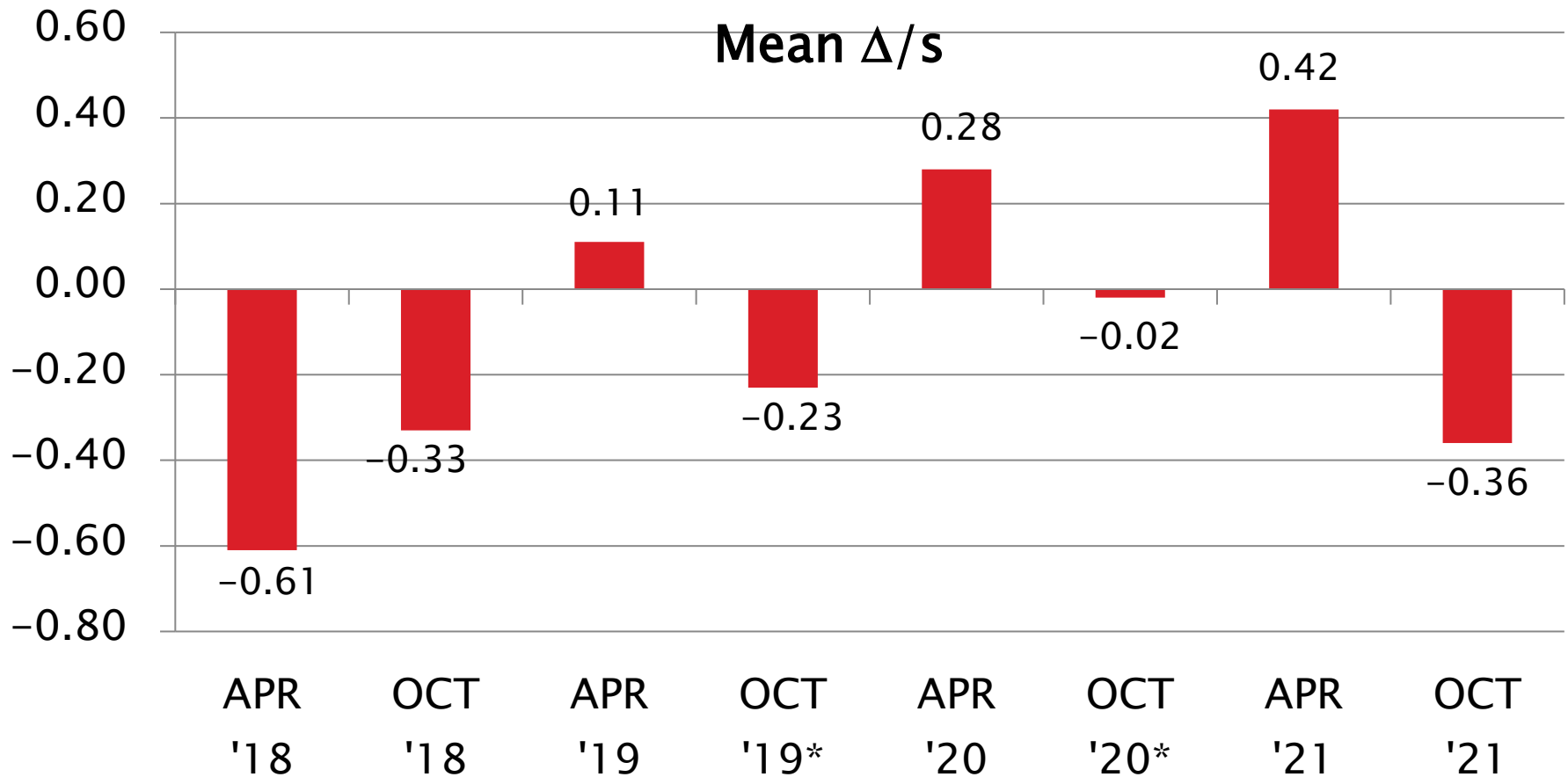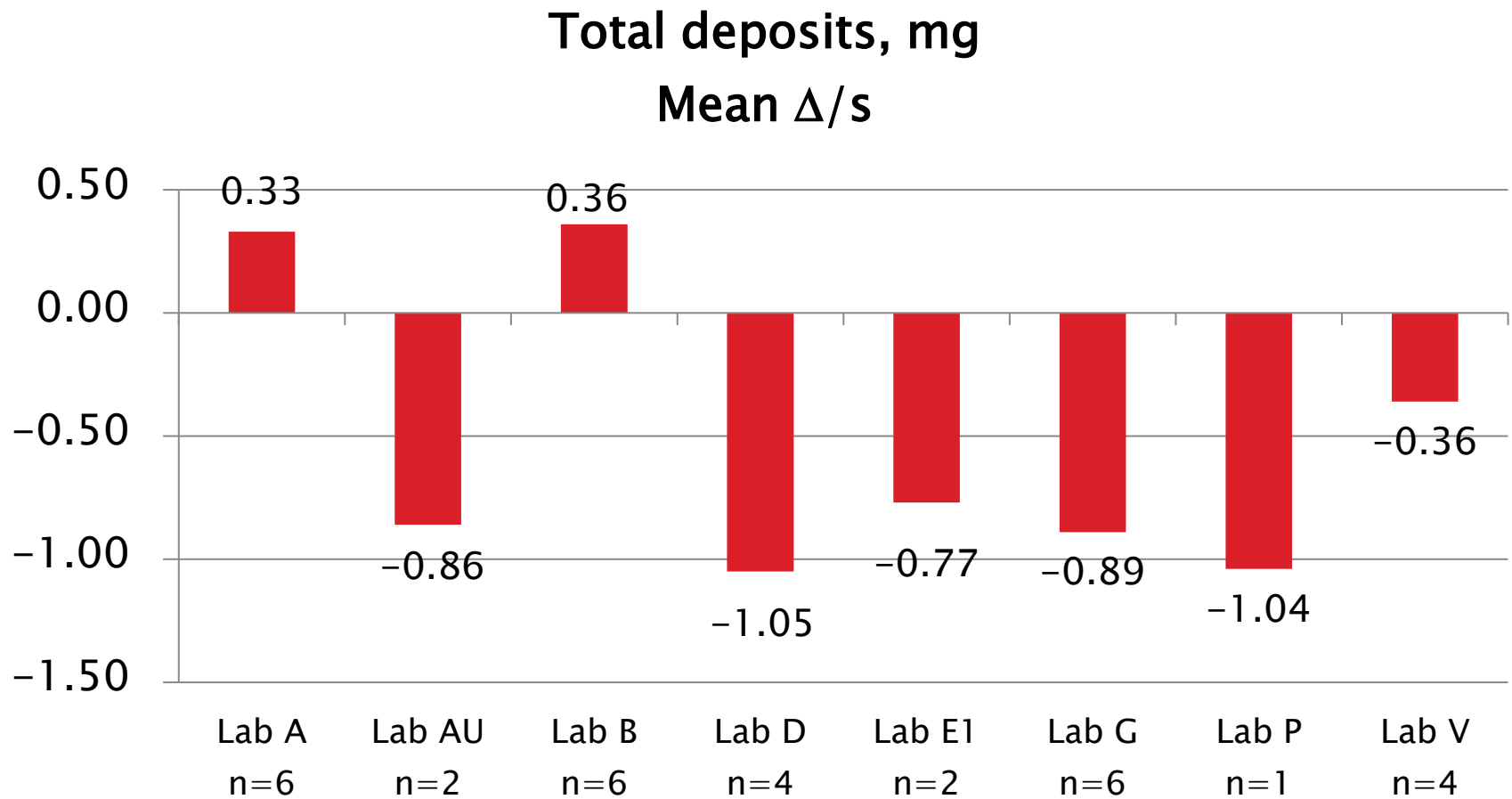
D6335: Deposits by TEOST-33C

➢ Precision (Pooled s) is comparable to the prior period but remains imprecise compared to other periods
  ➢ Much less precise than target precision
    ➢ Only one test this period used oil 75; oil is nearly used up

➢ Performance (Mean Δ/s) is -0.36 s mild this period (compared to 0.42 s severe last period)

➢ Period fail rate of 23% on test reported as operationally valid
  ➢ Fail rates continue to be high.

➢ All tests this period report using Rod Batch M or N.

TEOST—33C INDUSTRY OPERATIONALLY VALID DATA

TOTAL DEPOSITS MG

CUSUM Severity Analysis

Standard Deviation Units (y-axis)

COUNT IN COMPLETION DATE ORDER

21OCT21:16:06

TEOST –33C INDUSTRY OPERATIONALLY VALID DATA

TOTAL DEPOSITS MG

CUSUM Severity Analysis

Y-axis: **Standard Deviation Units**

Y-axis labels (top to bottom): -220, -184, -148, -112, -76, -40, -4, 32, 68, 104, 140, 176, 212, 248, 284

X-axis: **COUNT IN COMPLETION DATE ORDER**

X-axis labels: 0, 74, 148, 222, 296, 370, 444, 518, 592, 666, 740, 814, 888, 962, 1036, 1110, 1184, 1258

Vertical line labels:
- ANNAS TECHNICAL BULLETIN
- DUAL METHOD CALS DISALLOWED
- WORKSHOP
- NEW MONITORING PROTOCOL
- REPLACEMENT OIL 75 –1 APPROVED

21OCT21:16:10
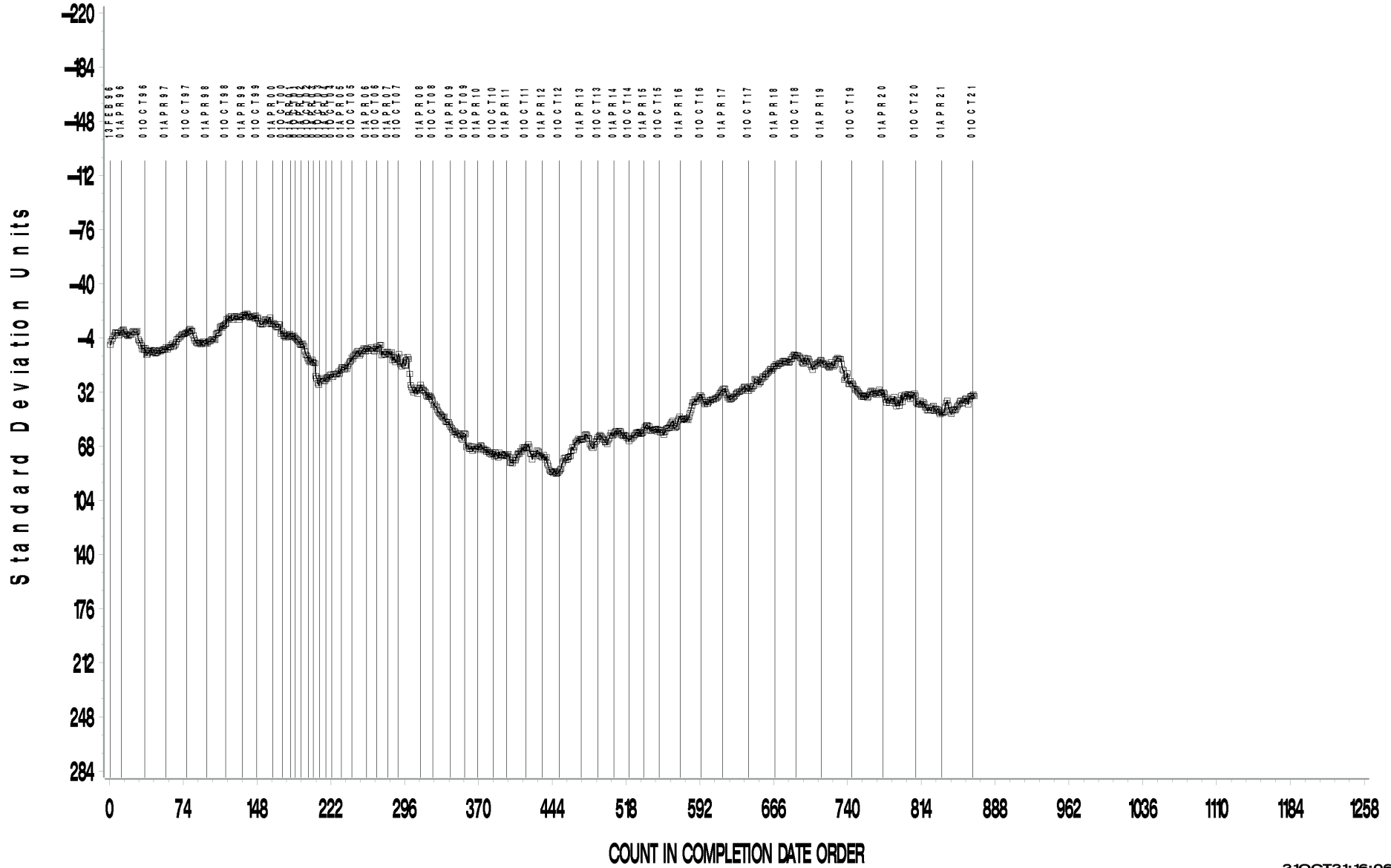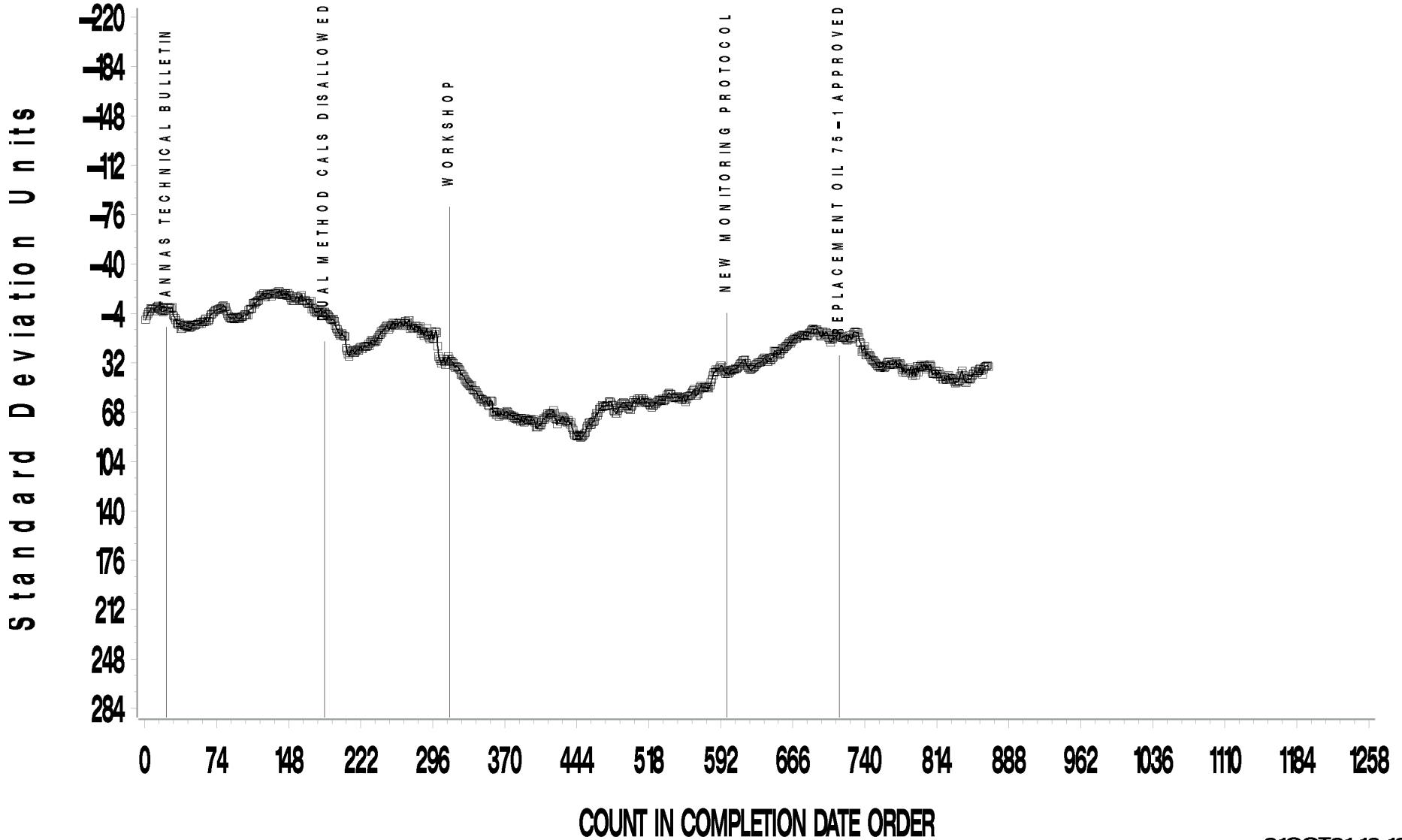
D6335 Performance by Oil

Total Deposits, mg
Mean

D6335 Performance by Oil

Total Deposits, mg

S_R

Legend:
- Oil 435-2
- Oil 75
- Oil 75-1

Target: 4.76, 6.56, 5.02
Oct '20: 8.21, 12.32, 10.68
APR '21: 6.68, 5.87, 10.56
OCT '21: 8.70, 7.88

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D6335 Performance by Oil

Total Deposits, mg

Mean Δ/s
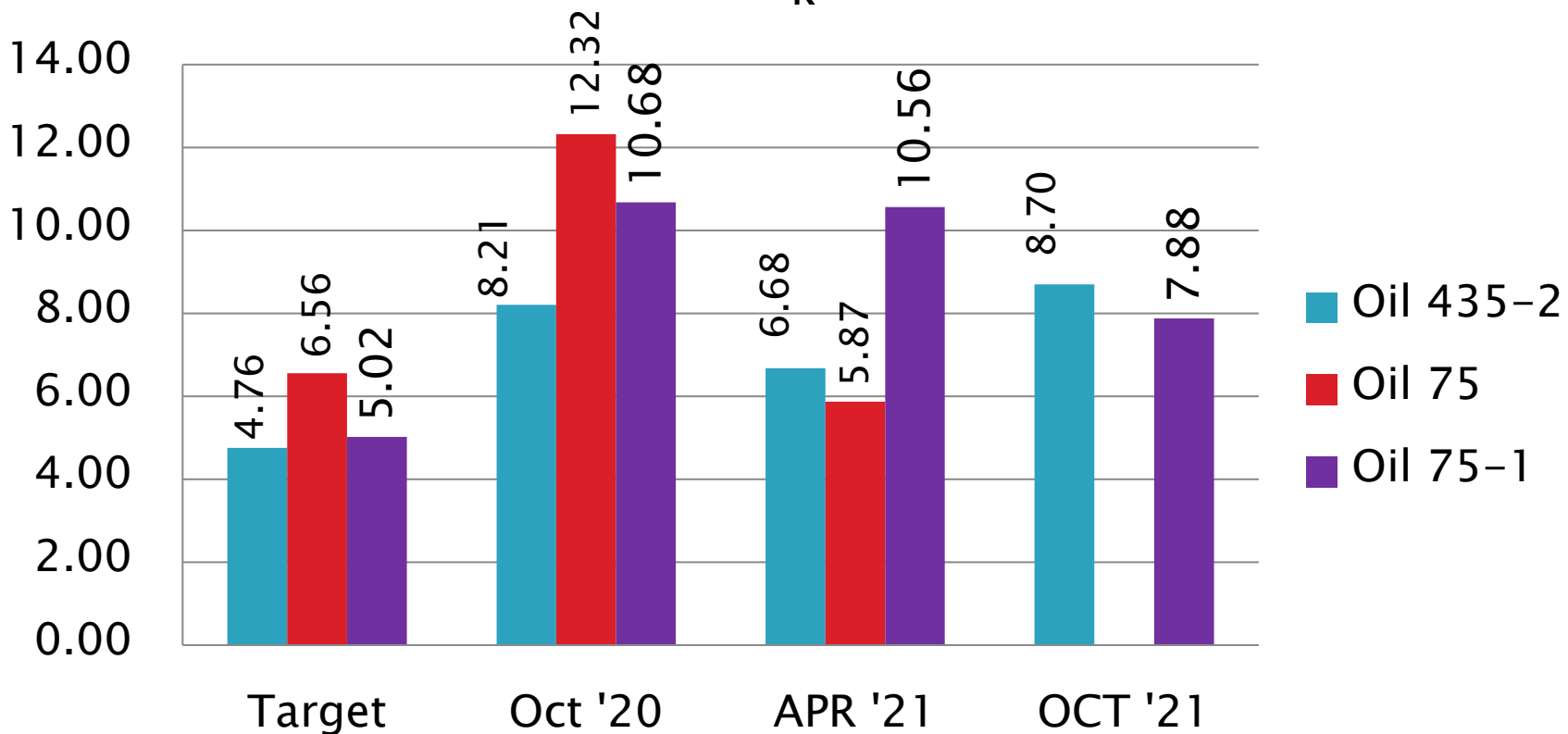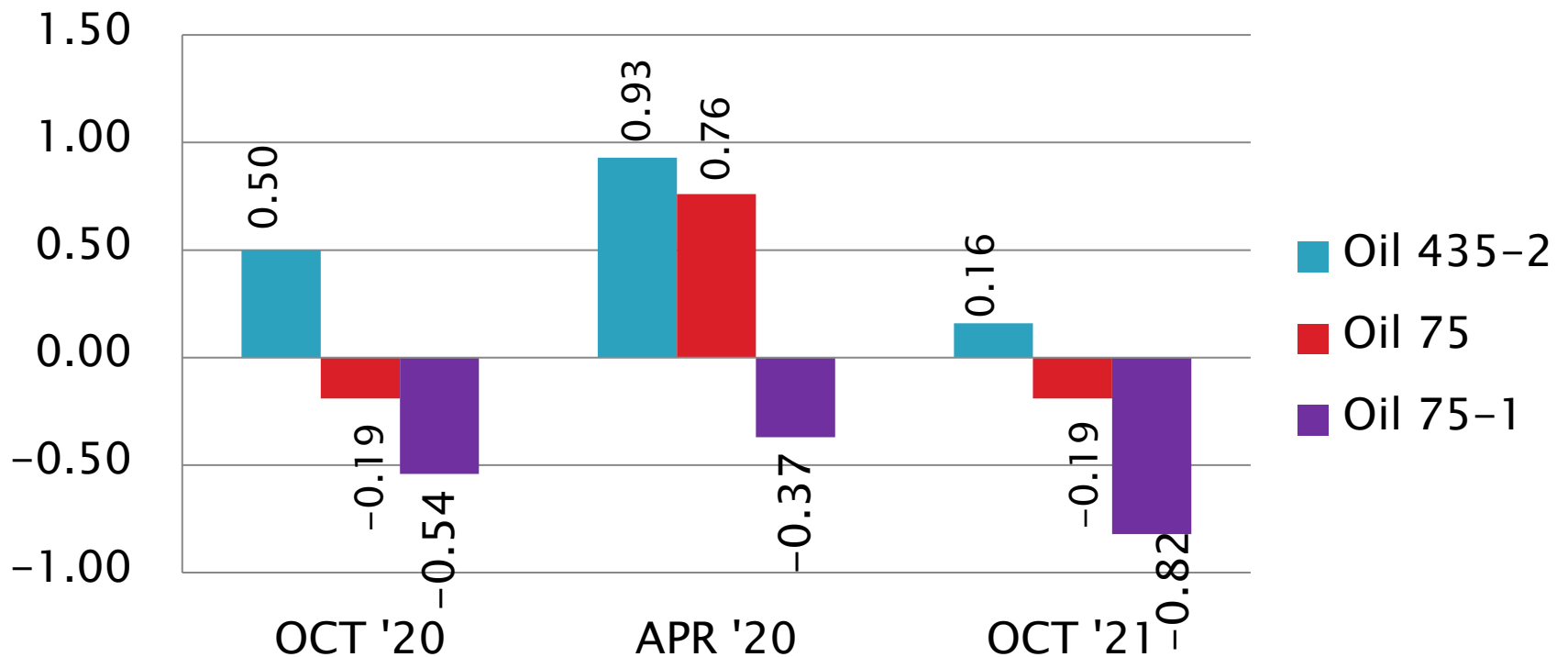
Return to Executive Summary

D7097: Deposits by MHT TEOST

Test Status	Validity Code	No. Tests
Acceptable Calibration Test	AC	74
Failed Calibration Test	OC	7
Operationally Invalidated by Lab	LC, XC	2
Operationally Invalidated After Initially Reported as Valid	RC	1
Instrument Shakedown Run	AN	2
Total		86

Number of Labs Reporting Data: 8
Fail Rate of Operationally Valid Tests: 9%

D7097: Deposits by MHT TEOST

Statistically Unacceptable Tests (OC)	No. Of Tests
Total Deposits Mild	2
Total Deposits Severe	5

- Three operationally invalid calibration test reported this period:
    - Spilled test sample (LC)
    - Airflow failure (LC)
    - Temperature Control Failure (RC, discovered after failing calibration)

- Two instrument shakedown runs.

- There were no MTEOS technical updates issued this report period.

- Calibration requirement updates are issued as LTMS document updates.

D7097: Deposits by MHT TEOST

Period Precision and Severity Estimates

Total Deposits, mg	n	df	Pooled s	Mean Δ/s
Current Targets 9/30/2021[1]	38	36	4.94	-----
4/1/18 through 9/30/18[2]	95	93	6.69	0.29
4/1/18 through 9/30/18[2]	94	92	5.46	0.20
10/1/18 through 3/31/19	97	95	5.86	−0.14
4/1/19 through 9/30/19	109	107	6.40	−0.30
10/1/19 through 3/31/20	103	101	7.02	−0.02
4/1/20 through 9/30/20	72	70	4.87	−0.22
10/1/20 through 3/31/21	101	99	8.40	0.17
4/1/21 through 9/30/21	81	78	7.25	−0.02

[1]Target precision updated to reference oils 432 and 434-3 preliminary
[2]One severe OC test from instrument G5 included and excluded (8.9 s)

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D7097 Precision Estimates

Total Deposits, mg
Pooled s

Target* df=36	OCT '18**	APR '19	OCT '19	APR '20	OCT '20	APR '21	OCT '21
4.94	5.46	5.86	6.40	7.02	4.87	8.40	7.25
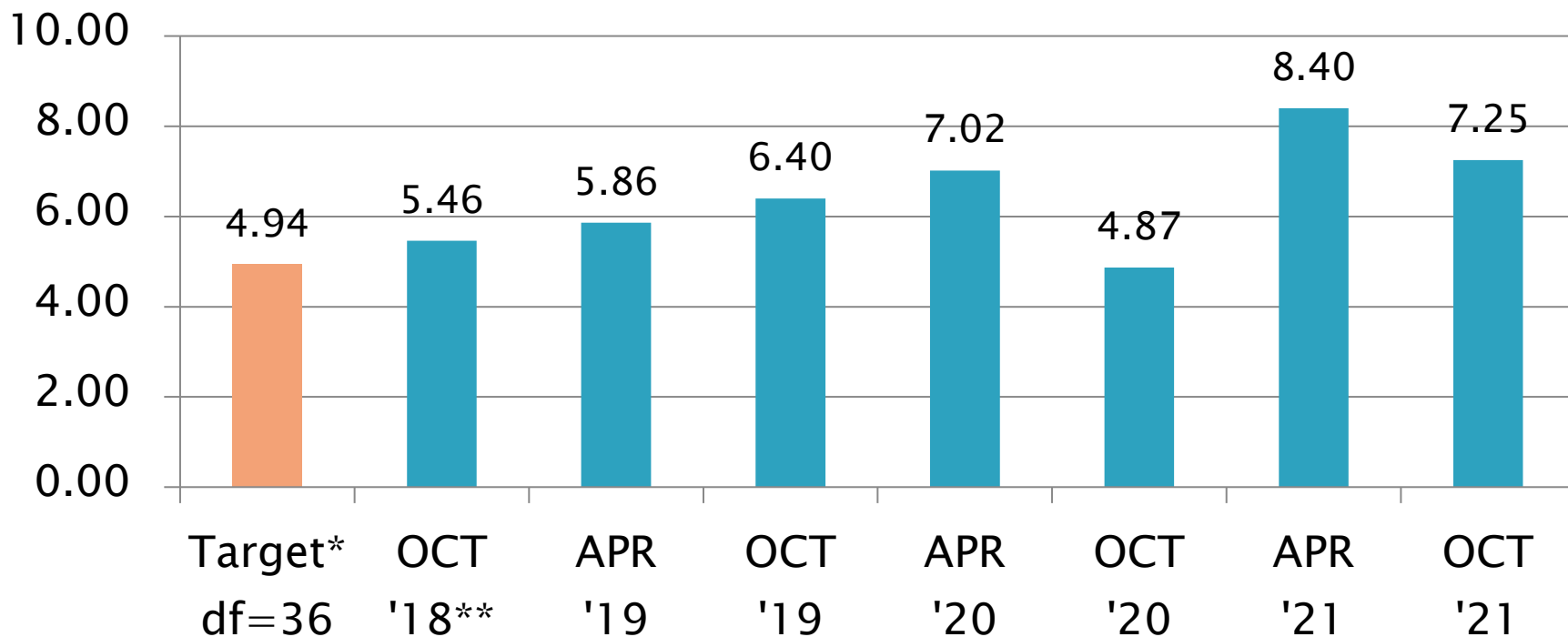
*Target precision updated to reference oils 432 and 434-3 preliminary
**One severe OC test from instrument G5 excluded (8.9 s)

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D7097 Severity Estimates

Total Deposits, mg

Mean Δ/s
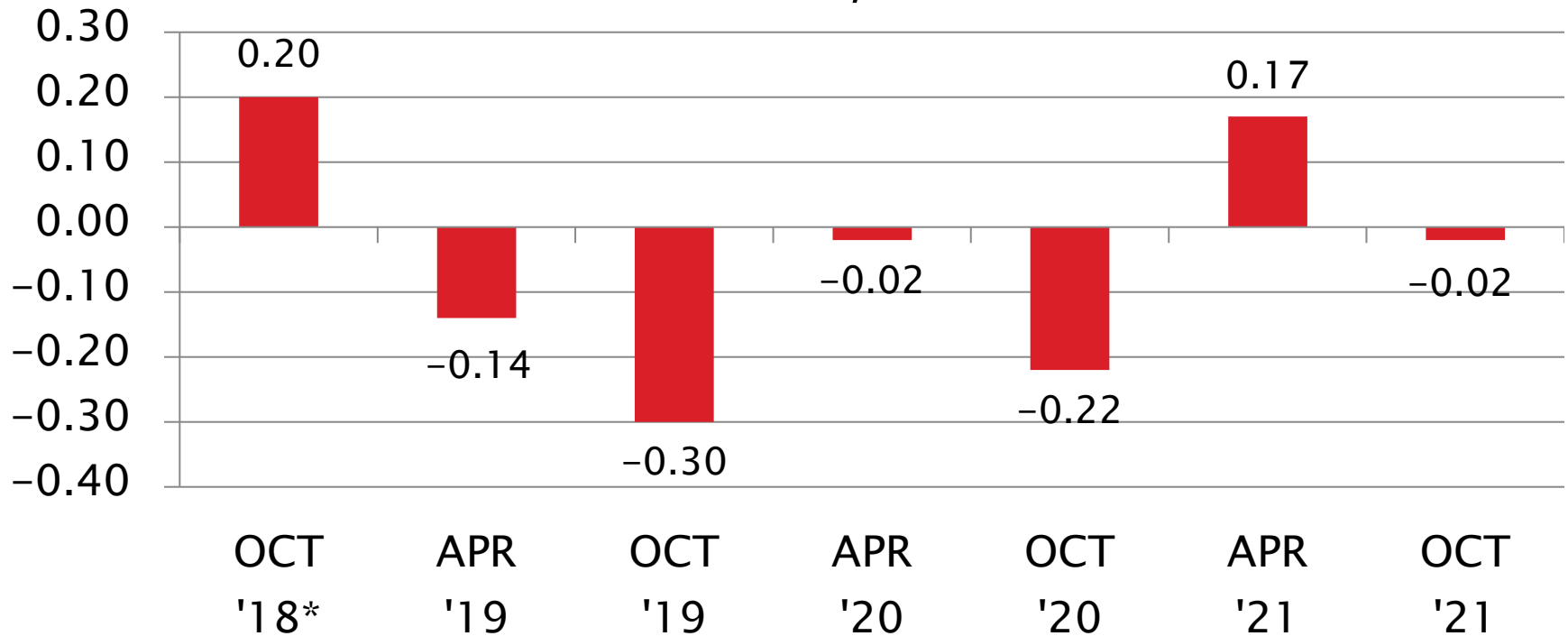
*One severe OC test from instrument G5 excluded (8.9 s)

D7097 Lab Severity Estimates

Total Deposits, mg

Mean Δ/s
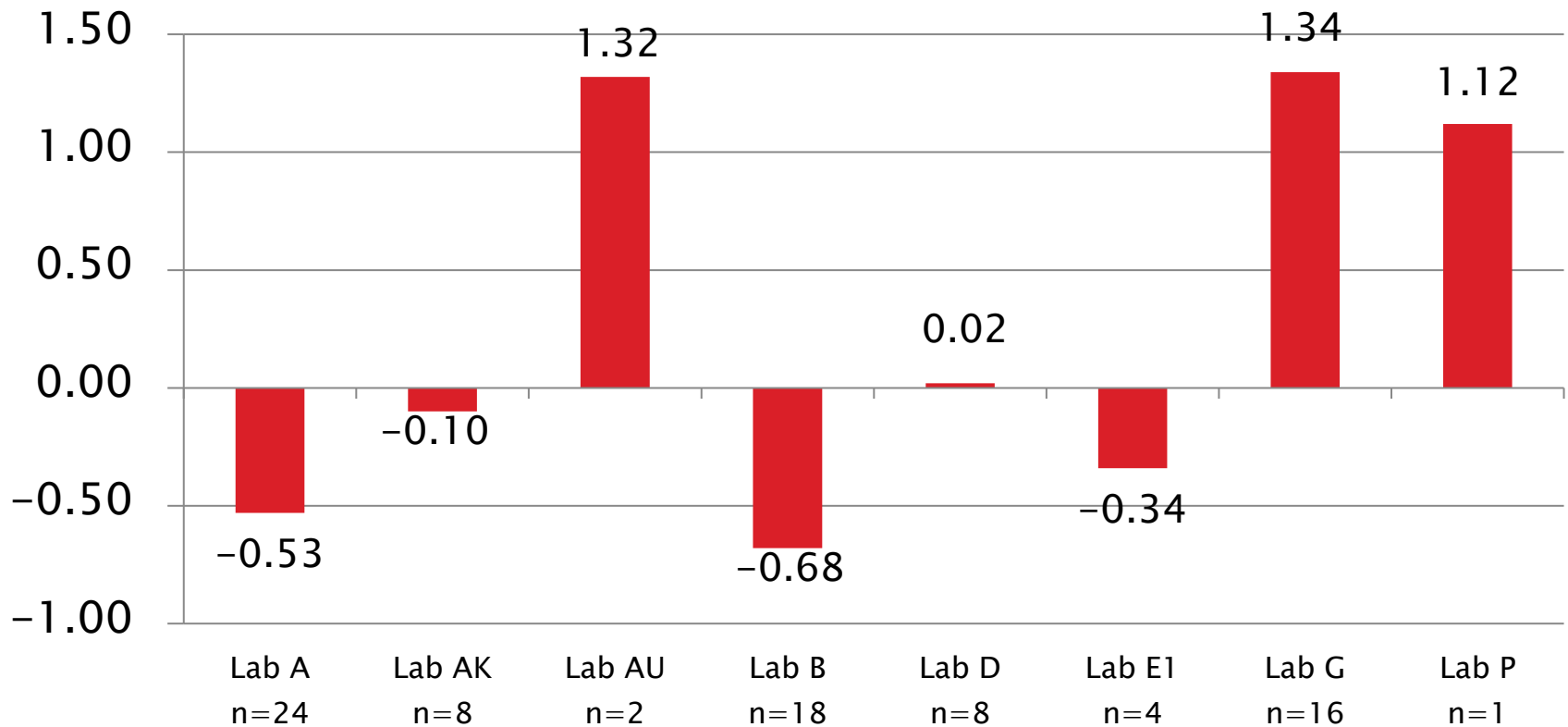
D7097: Deposits by MHT TEOST

Total Deposits, mg

Mean Δ/s Severity by CATBATCH and Period
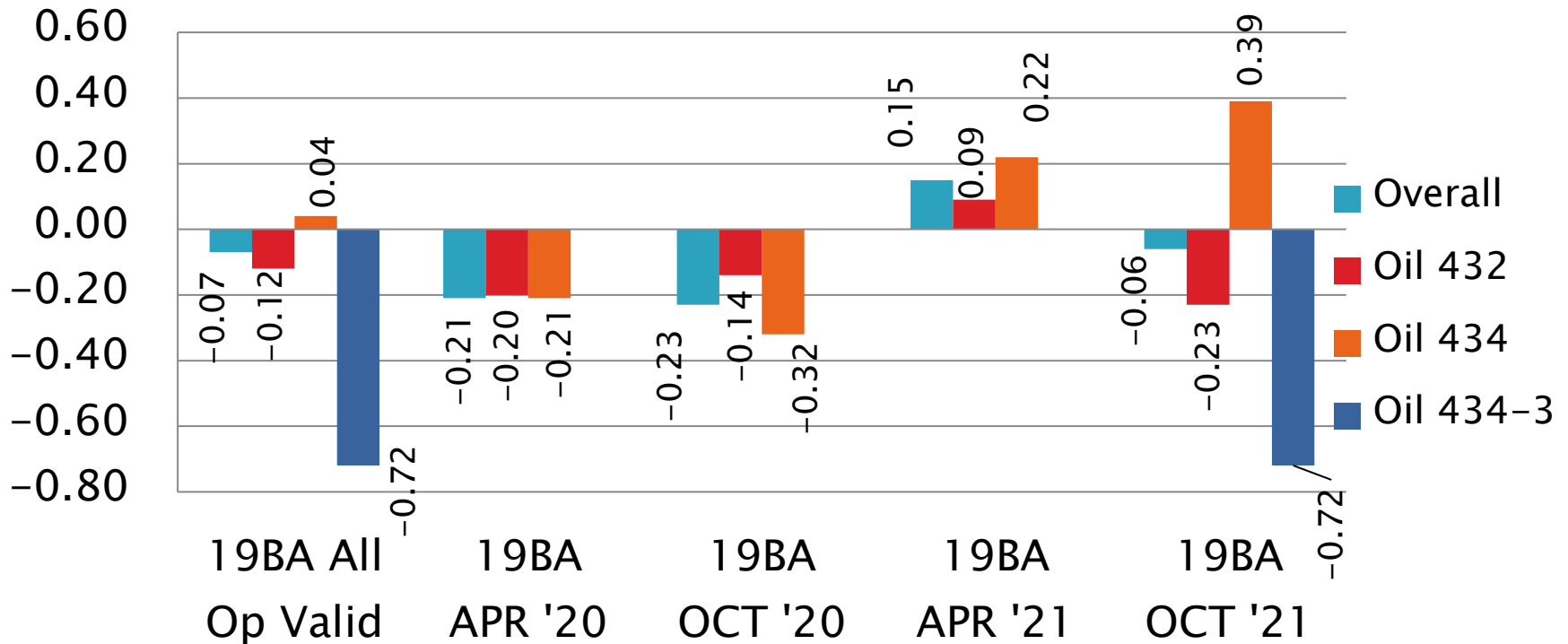
D7097: Deposits by MHT TEOST

- Precision (Pooled s) has been less precise for the past two report periods than for most prior report periods
  - Significantly less precise than prior or updated target precision

- Performance (Mean Δ/s) is on-target (−0.02 s)

- All operationally valid tests this period report using Rod Batches M or N (new).

- All operationally valid calibration tests this period report using Catalyst Batch 18AB (n=1) or 19BA (n=80)
  - Lab P continues to report using catalyst batch 18AB

- Overall severity on catalyst batch 19BA (n=217) appears to be on-target, and on target for oils 432 and 434.
  - Replacement oil 434-3 introduced this period, running −0.72 s mild (n=10).

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CUSUM Severity Analysis

Standard Deviation Units

COUNT IN COMPLETION DATE ORDER

21OCT21: 17:13

MHT-4 TEOST INDUSTRY OPERATIONALLY VALID DATA

TOTAL DEPOSITS MG

CUSUM Severity Analysis

Standard Deviation Units

Y-axis: -830, -720, -610, -500, -390, -280, -170, -60, 50, 160, 270, 380, 490, 600, 710

Annotations:
- DUAL METHOD CALS DISALLOWED
- NEW TARGETS FOR $Li_2B_4O_7$ (11/03)
- NEW RO TARGETS (01/05)
- NEW RO TARGETS (07/06)
- WORKSHOP
- RESET 432 RO BAND
- END CAP FALSK SEALS MONITORING PROBLEM INTRODUCED
- NEW RO 434-3 TARGETS

X-axis: 0, 230, 460, 690, 920, 1150, 1380, 1610, 1840, 2070, 2300, 2530, 2760, 2990, 3220, 3450, 3680, 3910

COUNT IN COMPLETION DATE ORDER

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26OCT21:11:35

MHT—4 TEOST INDUSTRY OPERATIONALLY VALID DATA

TOTAL DEPOSITS MG

fmc
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CUSUM Severity Analysis

Standard Deviation Units (y-axis)

-830
-720
-610
-500
-390
-280
-170
-60
50
160
270
380
490
600
710

CAT BATCH 0804 INTRODUCED
CAT BATCH 0902C INTRODUCED
CAT BATCH 0911 INTRODUCED
CAT BATCH 1011 INTRODUCED
CAT BATCH 1201 INTRODUCED
CAT BATCH 1208 INTRODUCED
CAT BATCH 1307 INTRODUCED
CAT BATCH 14AA INTRODUCED
CAT BATCH 15AA INTRODUCED
CAT BATCH 16DA INTRODUCED
CAT BATCH 18AB INTRODUCED
CAT BATCH 19BA INTRODUCED

COUNT IN COMPLETION DATE ORDER (x-axis)

0   230   460   690   920   1150   1380   1610   1840   2070   2300   2530   2760   2990   3220   3450   3680   3910

21OCT21: 17:24

D7097 Performance by Oil

Total Deposits, mg

Mean

D7097: Deposits by MHT TEOST
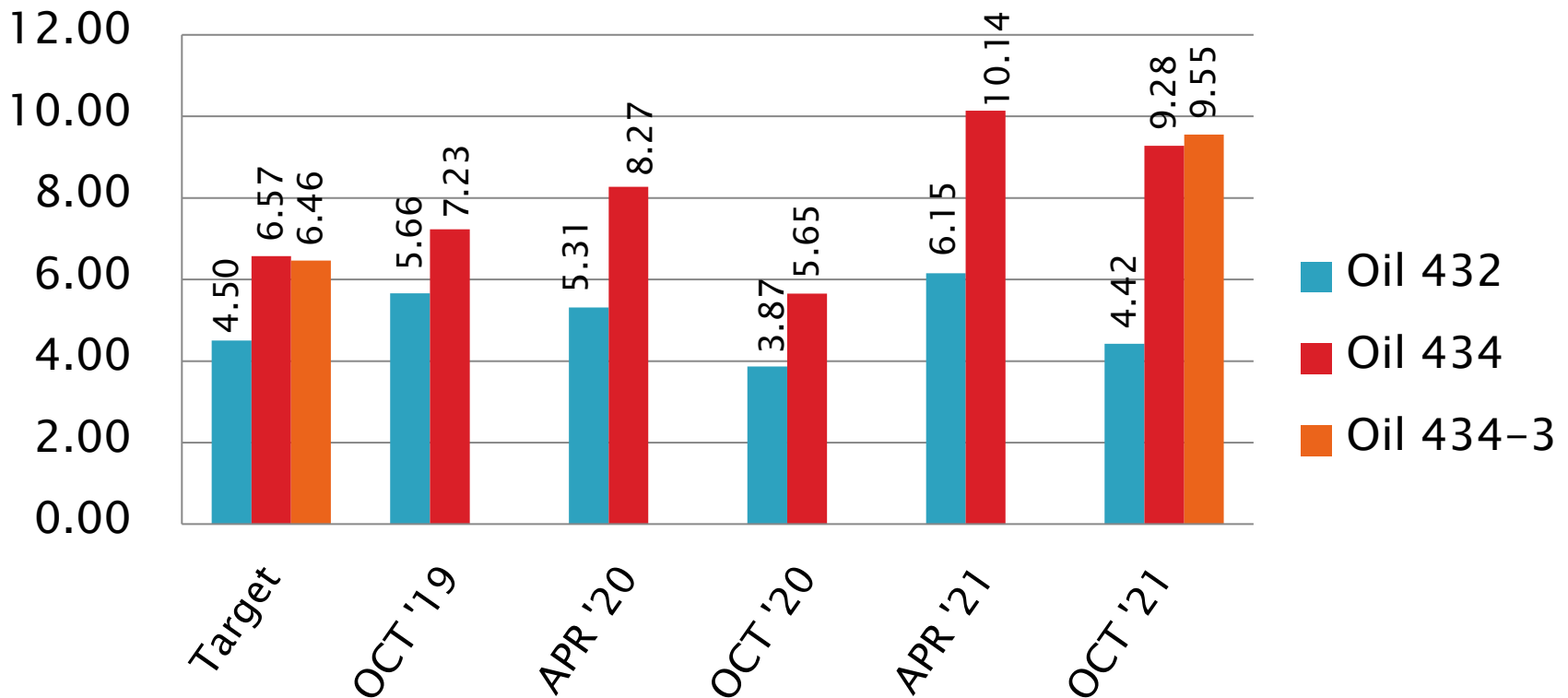
Total Deposits, mg

S_R

	Target	OCT '19	APR '20	OCT '20	APR '21	OCT '21
Oil 432	4.50	5.66	5.31	3.87	6.15	4.42
Oil 434	6.57	7.23	8.27	5.65	10.14	9.28
Oil 434-3	6.46					9.55

D7097: Deposits by MHT TEOST

Total Deposits, mg
Mean Δ/s

Oil 432
Oil 434
Oil 434-3
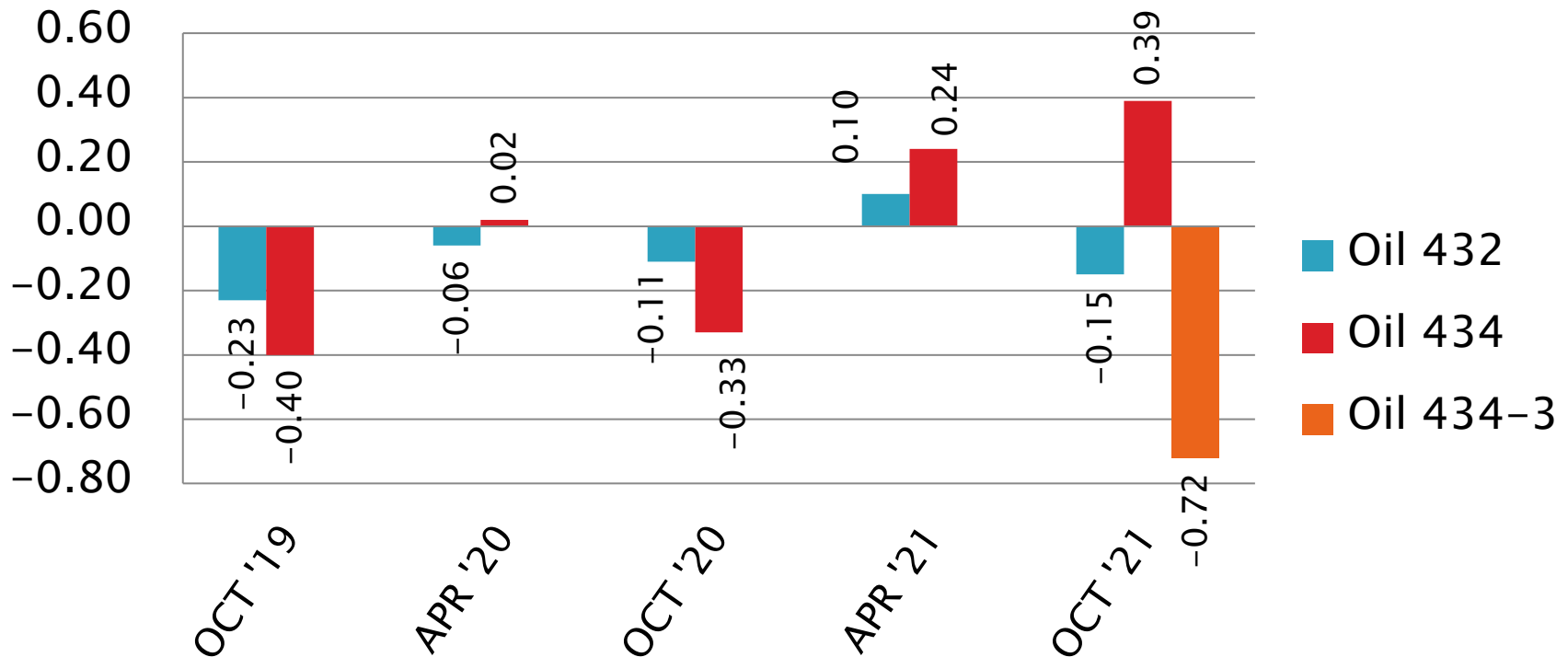
Return to Executive Summary

D6082: High Temperature Foam

Test Status	Validity Code	No. Tests
Acceptable Calibration Test	AC	14
Acceptable Discrimination Test	AS	6
Failed Statistically	OC	0
Operationally Invalidated by Lab	LC, XC	1
Total		21

Number of Labs Reporting Data: 6
Fail Rate of Operationally Valid Calibration Tests: 0%

D6082: High Temperature Foam

Statistically Unacceptable Tests (OC, OS)	No. Of Tests
Foam Tendency Mild	0
Foam Tendency Severe	0

- All severe oil discrimination runs (on TMC oil 66) reported this period demonstrated acceptable discrimination.
  - Discrimination runs are not evaluated for overall period precision or severity due to poor test precision above 100 ml foam tendency.

- One invalid runs this period.
  - Aborted due to broken seal (XC).

- There were no TMC technical updates issued this period for D6082.

- D6082 Calibration requirement updates are issued as LTMS document updates.

D6082: High Temperature Foam

Period Precision and Severity Estimates

Foam Tendency, ml	n	df	Pooled s	Mean Δ/s
Targets updated 20201001[1]	18	17	9	-----
10/1/17 through 3/31/18[2]	14	13	17	–0.02
10/1/17 through 3/31/18[2]	13	12	11	–0.19
4/1/18 through 9/30/18	14	13	9	–0.07
10/1/18 through 3/31/19	14	13	12	–0.07
4/1/19 through 9/30/19	14	12	12	–0.18
10/1/19 through 3/31/20	15	13	10	–0.23
4/1/20 through 9/30/20	13	11	8	–0.85
10/1/20 through 3/31/21	12	10	7	–0.48
4/1/21 through 9/30/21	14	13	7	–0.48

[1]Target precision updated to current reference oil FOAMB18
[2]Single OC result Yi=2.3 s severe included and excluded

D6082: High Temperature Foam

Period Precision and Severity Estimates

Foam Stability @ 1 min, ml	n	Mean	s
Current Targets	18	0.00	0.00
10/1/17 through 3/31/18	14	No non-zero occurrences	
4/1/18 through 9/30/18	14	No non-zero occurrences	
10/1/18 through 3/31/19	14	No non-zero occurrences	
4/1/19 through 9/30/19	14	No non-zero occurrences	
10/1/19 through 3/31/20	15	No non-zero occurrences	
4/1/20 through 9/30/20	13	No non-zero occurrences	
10/1/20 through 3/31/21	12	No non-zero occurrences	
4/1/20 through 9/30/20	14	No non-zero occurrences	

D6082 Performance by Oil

Foam Tendency, ml

Mean

Legend: ▇ Oil 1007 ▇ Oil FOAMB18

Data values:

Period	Oil 1007	Oil FOAMB18
Target	66	54
APR '18	66	
OCT '18	65	
APR '19	65	
OCT '19	66	50
APR '20	66	51
OCT '20	60	45
APR '21	70	49
OCT '21		50
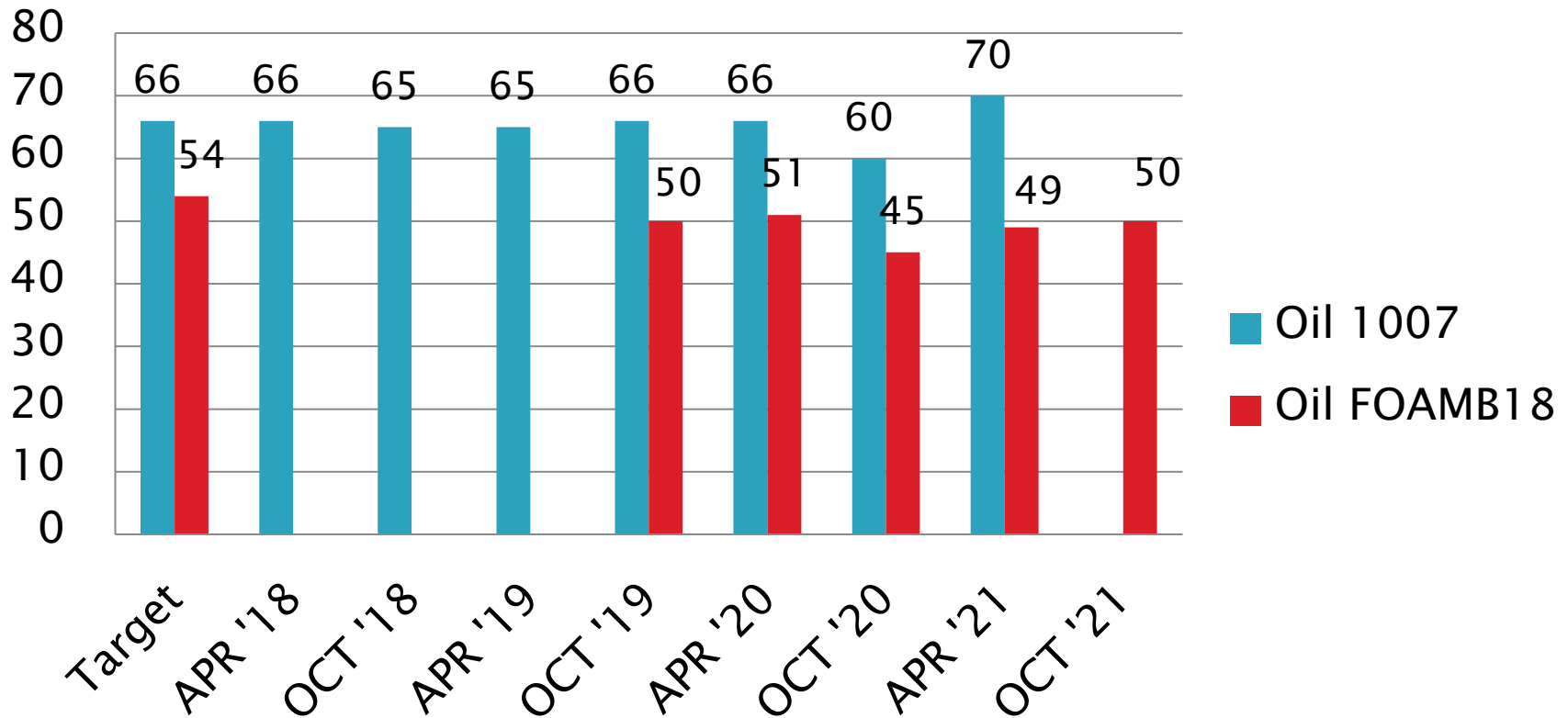
D6082: High Temperature Foam

Foam Tendency, ml
Pooled s

D6082: High Temperature Foam

Foam Tendency, ml
Mean Δ/s

	APR '18	OCT '18	APR '19	OCT '19	APR '20	OCT '20	APR '21	OCT '21
Mean Δ/s	−0.02	−0.07	−0.07	−0.18	−0.23	−0.85	−0.48	−0.48
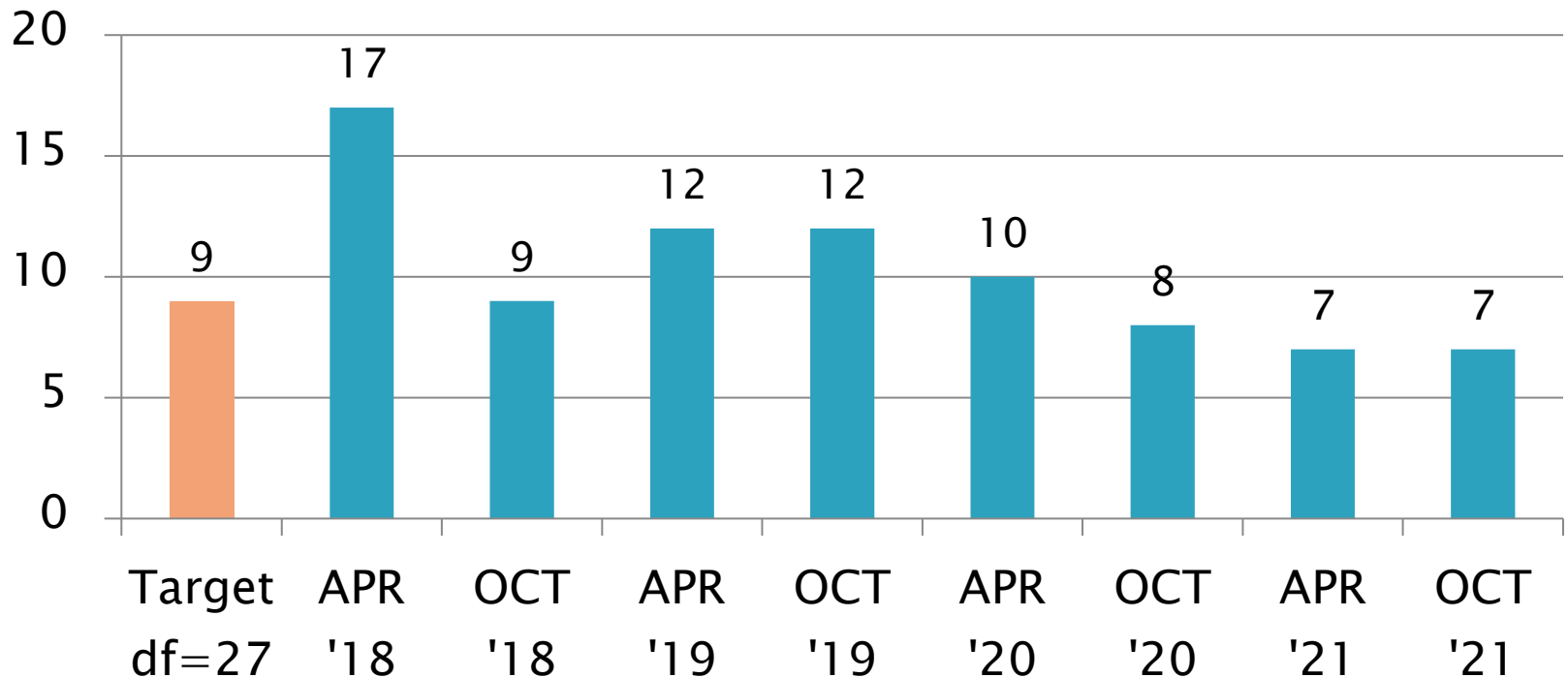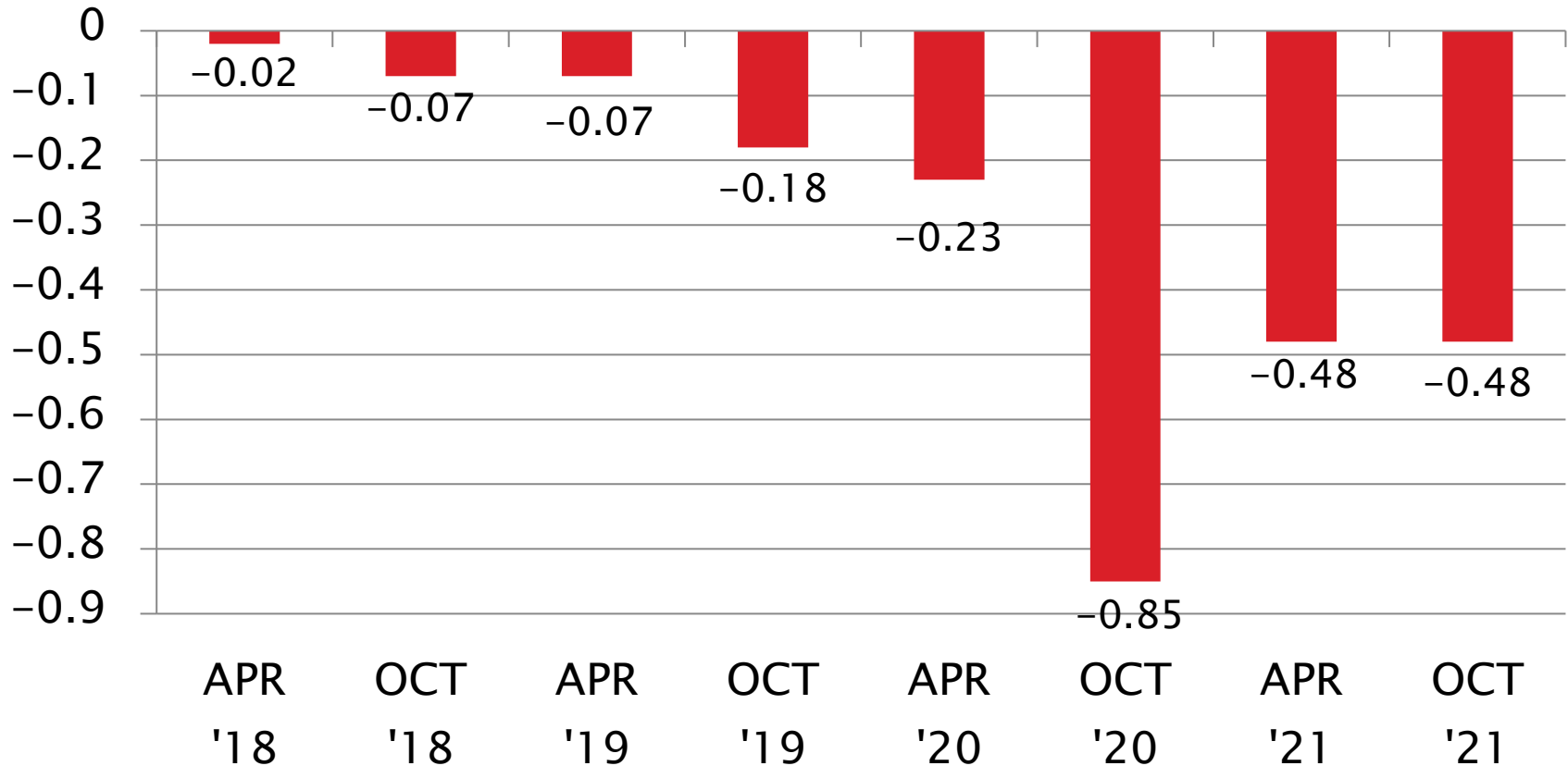
D6082: High Temperature Foam

Current Period Severity Estimates by Lab

Foam Tendency, ml

D6082: High Temperature Foam

- Foam Tendency Precision (Pooled s) is the same as last period
  - More precise than oil FOAMB18 target precision
    - Oil 1007 is entirely used up, first report period of all reference tests on replacement oil FOAMB18 only.

- Performance (Mean Δ/s) is -0.48 s mild
  - Fifth consecutive period of mild performance on FOAMB18.
    - Target performance, set on 18 runs in a RR, may need revisited.

- No non-zero occurrences of Foam Stability

- All six severe oil discrimination runs (on TMC oil 66) demonstrated acceptable discrimination on foam tendency (>100 ml).

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D6082 HIGH TEMPERATURE FOAM INDUSTRY OPERATIONALLY VALID DATA
IND in ('1007', 'FOAMB18')
FOAM TENDENCY

CUSUM Severity Analysis

Standard Deviation Units

COUNT IN COMPLETION DATE ORDER

05NOV21:17:07

D6082 HIGH TEMPERATURE FOAM INDUSTRY OPERATIONALLY VALID DATA
IND='FOAMB18'
FOAM TENDENCY

CUSUM Severity Analysis

Standard Deviation Units

COUNT IN COMPLETION DATE ORDER

26OCT21: 13:35

D6082 HIGH TEMPERATURE FOAM INDUSTRY OPERATIONALLY VALID DATA
IND='1007'
FOAM TENDENCY

CUSUM Severity Analysis

Standard Deviation Units

COUNT IN COMPLETION DATE ORDER

05NOV21:17:10
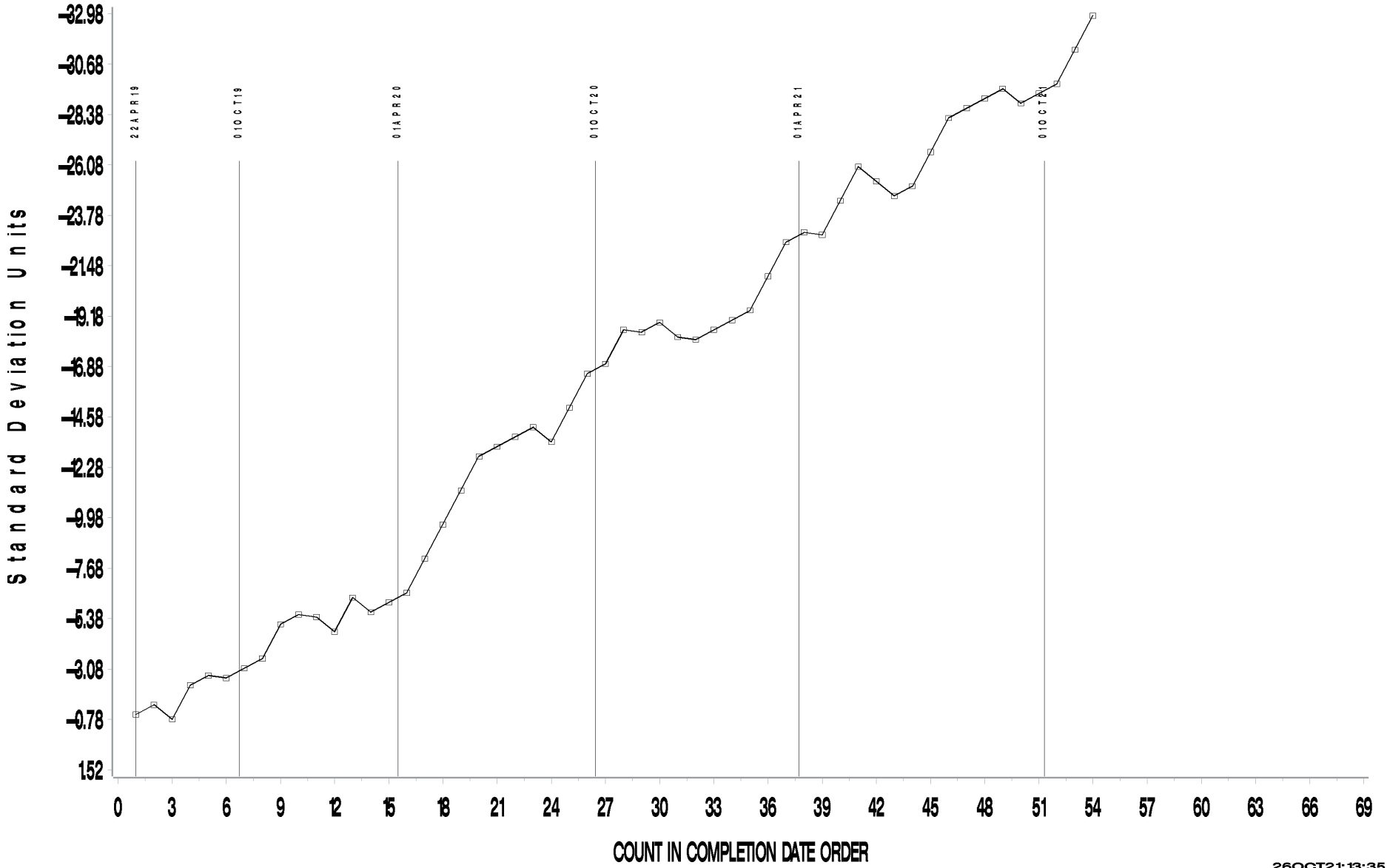
D874: Sulfated Ash

Test Status	Validity Code	No. Tests
Acceptable Calibration Test	AC	7
Failed Calibration Test	OC	3
Operationally Invalidated by Lab	LC, XC	0
Operationally Invalidated After Initially Reported as Valid	RC	0
Total		10

Number of Labs Reporting Data: 4
Fail Rate of Operationally Valid Tests: 30%

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D874: Sulfated Ash

Statistically Unacceptable Tests (OC)	No. Of Tests
Sulfated Ash Mild	1
Sulfated Ash Severe	2

- No operationally invalid tests reported this period.

- Three statistically invalid tests this period (OC)
  - Failing results ranged from -3.0 to +6.6 s, affecting period precision significantly

- No D874 TMC technical updates were issued this period

Test Monitoring Center
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D874: Sulfated Ash

Period Precision and Severity Estimates

Total Deposits, mg	n	df	Pooled s	Mean Δ/s
Current Targets	81	78	0.07	–––––
10/1/17 through 3/31/18	8	5	0.06	0.37
4/1/18 through 9/30/18	8	5	0.04	−0.22
10/1/18 through 3/31/19	8	5	0.04	−0.33
4/1/19 through 9/30/19	8	5	0.04	−0.18
10/1/19 through 3/31/20	7	4	0.04	−0.71
4/1/20 through 9/30/20	8	5	0.03	−0.30
10/1/20 through 3/31/21	8	5	0.02	−0.35
4/1/21 through 9/30/21	10	7	0.15	0.37

D874: Sulfated Ash

Sulfated Ash, mass%
Pooled s
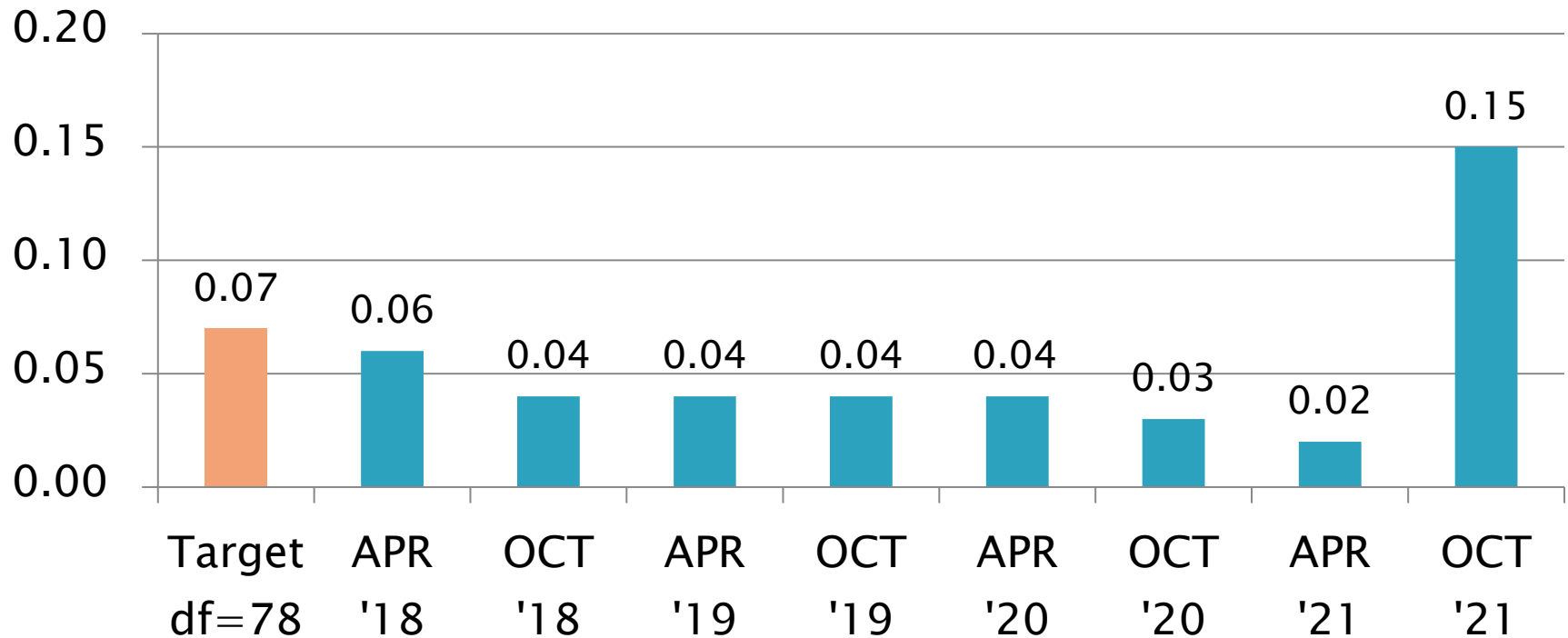
D874: Sulfated Ash
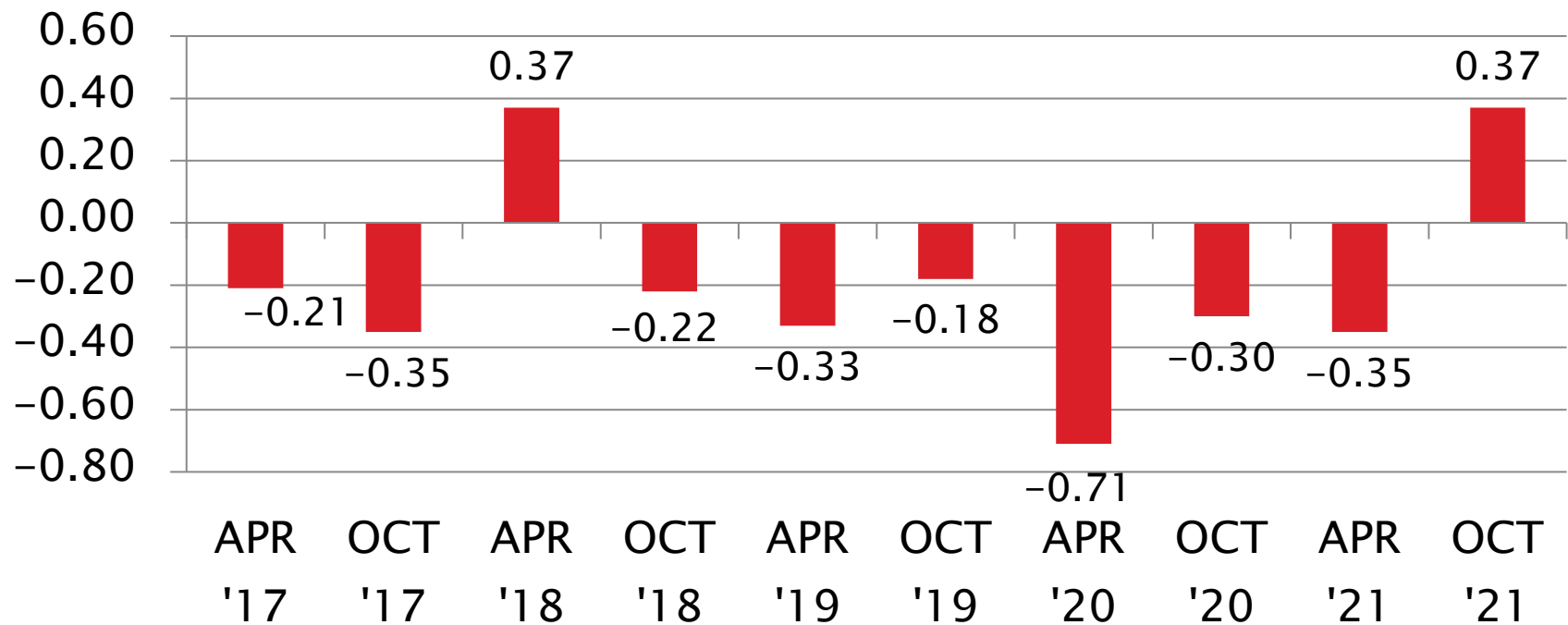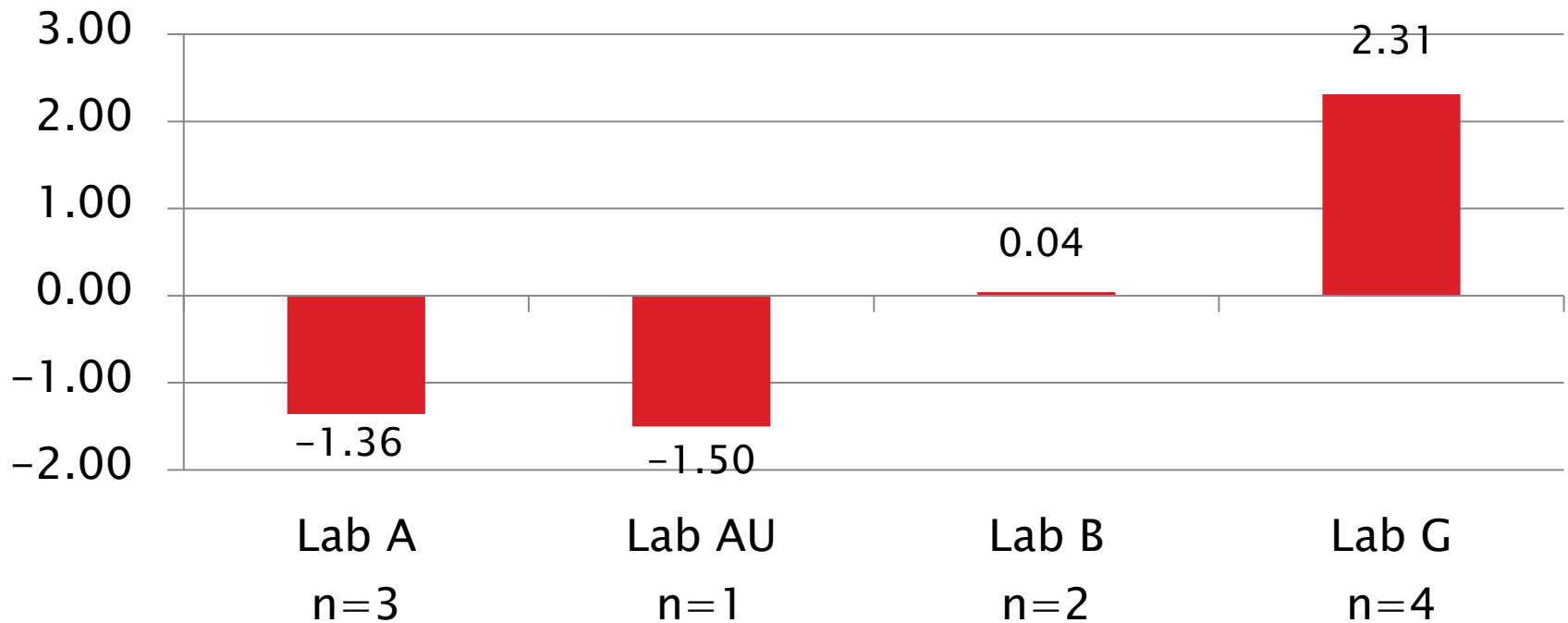
Sulfated Ash, mass%

Mean Δ/s

D874: Sulfated Ash

Sulfated Ash, mass%
Mean Δ/s

D874: Sulfated Ash

▸ Precision (Pooled s) is less precise than prior periods
  • Less precise than target precision

▸ Performance (Mean Δ/s) is 0.37 s severe

D874 INDUSTRY OPERATIONALLY VALID DATA

TEST SAMPLE PERCENT SULFATED ASH

CUSUM Severity Analysis

Standard Deviation Units (y-axis)

COUNT IN COMPLETION DATE ORDER (x-axis)

26OCT21:15:50
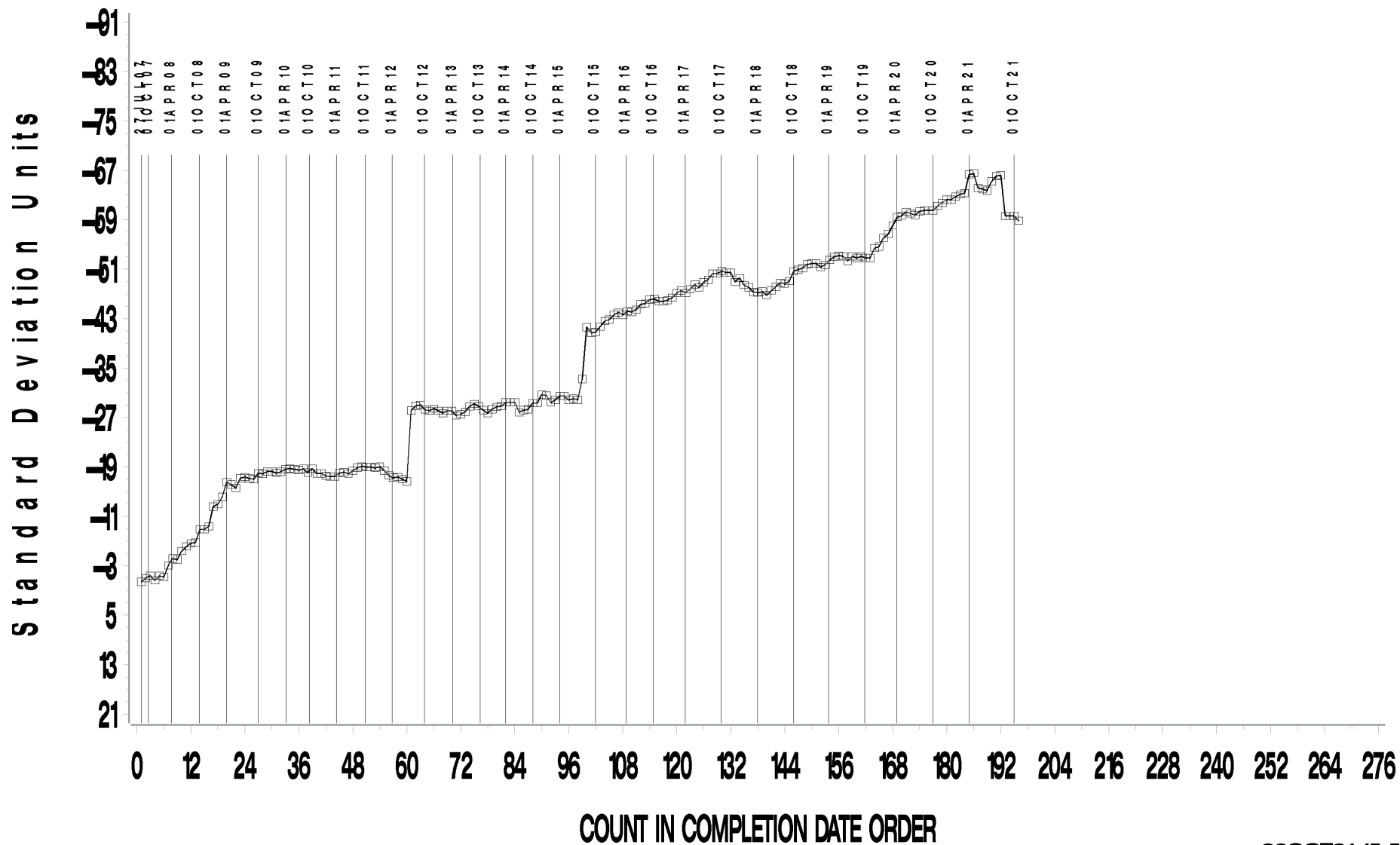
D874: Sulfated Ash

Sulfated Ash, mass%
Mean
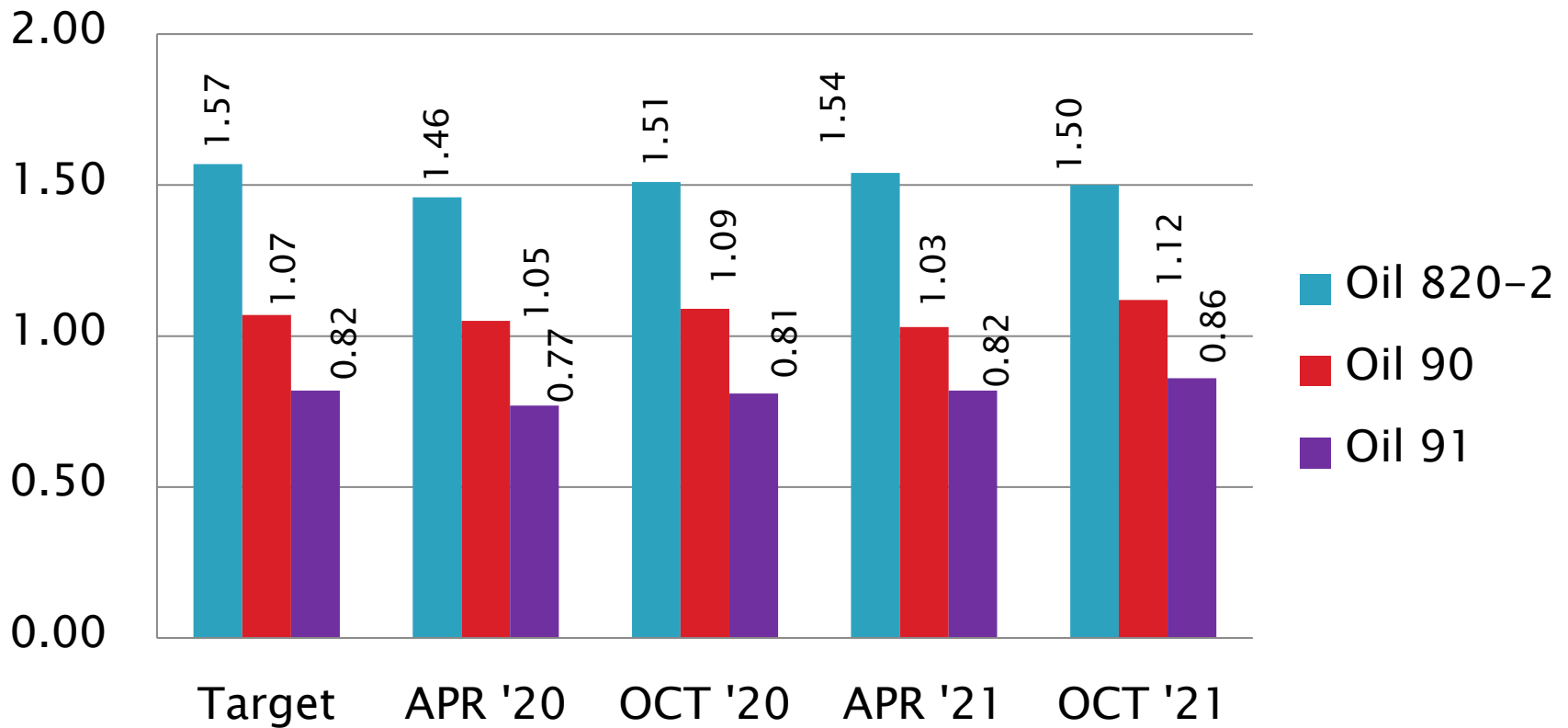
D874: Sulfated Ash

Sulfated Ash, mass%

S_R

D874: Sulfated Ash

Sulfated Ash, mass%

Mean Δ/s
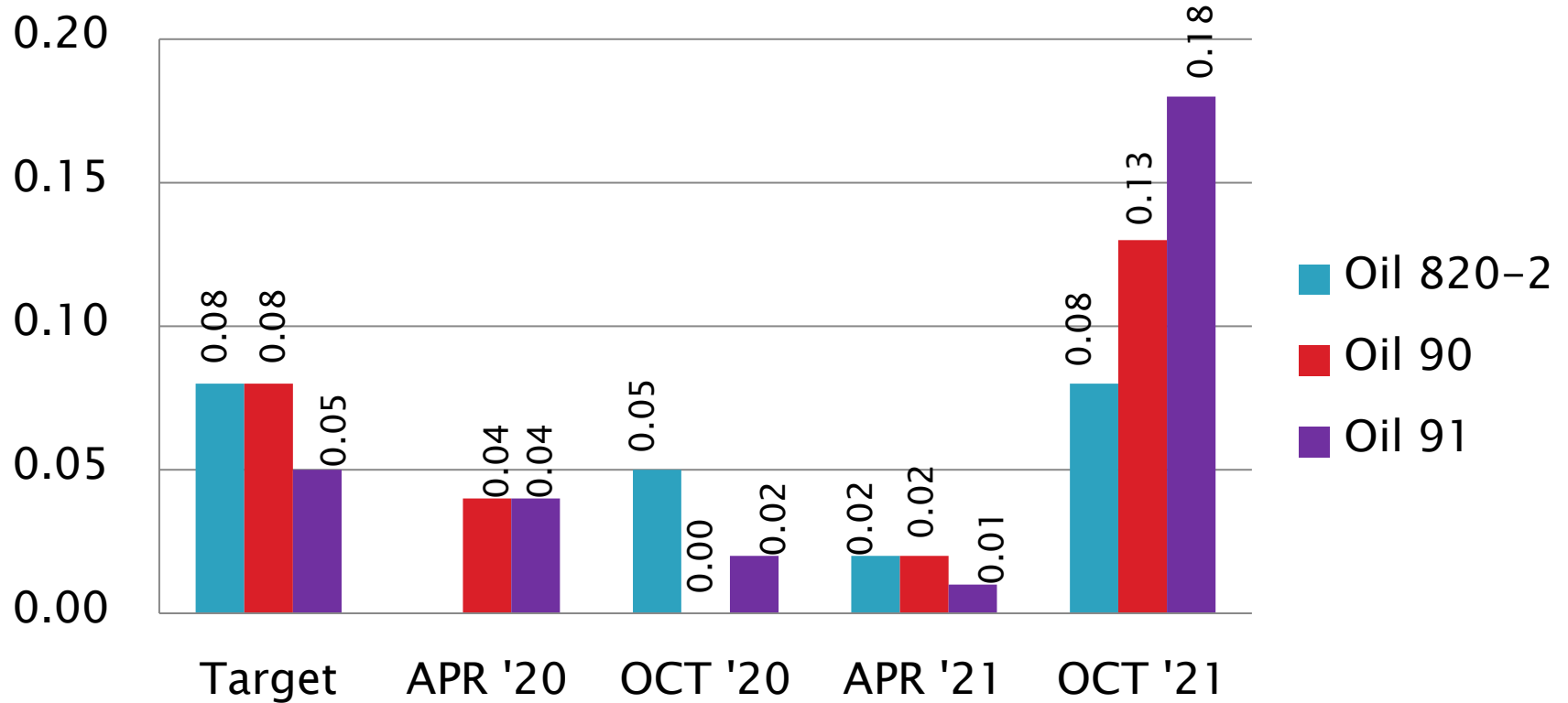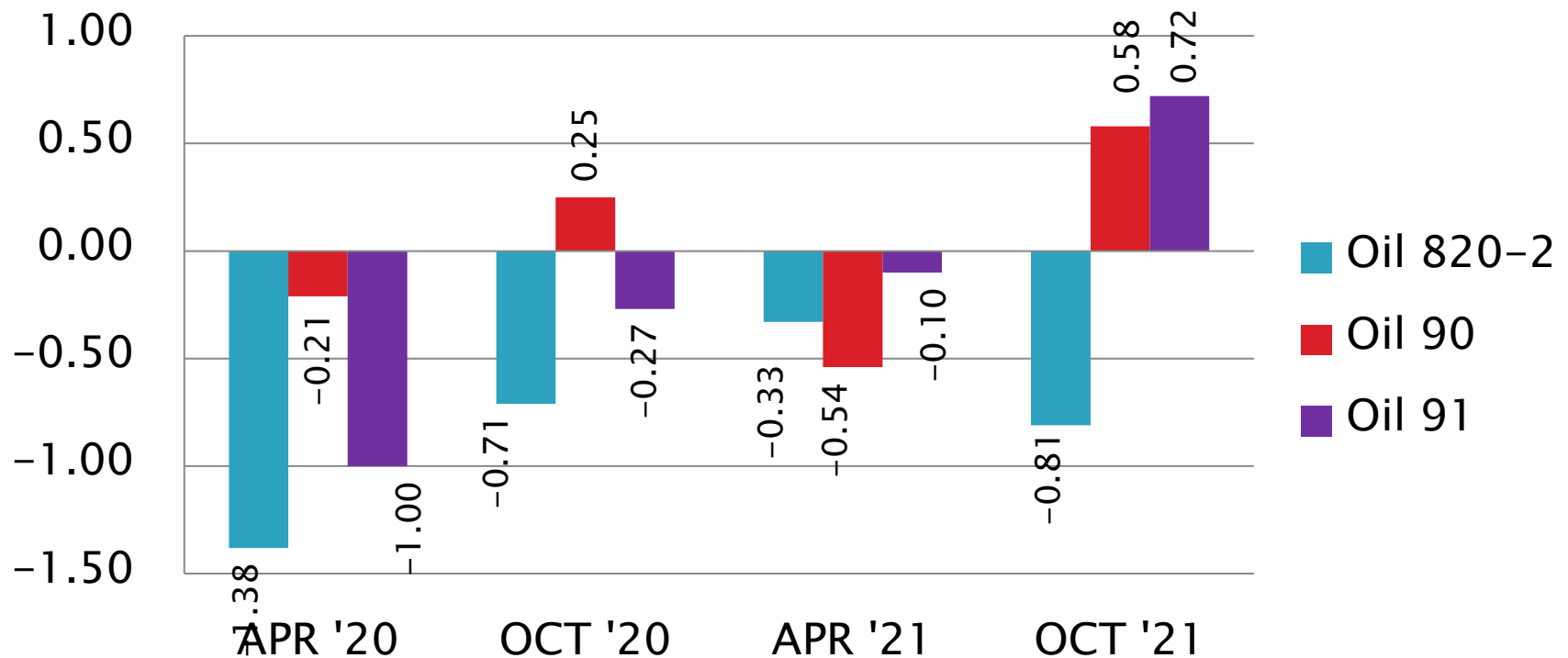
Return to Executive Summary

D7528: Oxidation by ROBO

Test Status	Validity Code	No. Tests
Acceptable Calibration Test	AC	103
Failed Calibration Test	OC	13
Operationally Invalidated by Lab	LC, XC	9
Operationally Invalidated After Initially Reported as Valid	RC	1
Total		126

Number of Labs Reporting Data: 7
Fail Rate of Operationally Valid Tests: 11%

D7528: Oxidation by ROBO

Statistically Unacceptable Tests (OC)	No. Of Tests
Natural Log (MRV Viscosity) Mild	11
Natural Log (MRV Viscosity) Severe	2

- There were no ROBO technical update issued this period

- ROBO Calibration requirement updates are issued as LTMS document updates

D7528: Oxidation by ROBO

Operationally Invalid Calibration Tests

- 2 tests NO_2 flow off-spec (LC)
- 1 tests vacuum leak or vacuum failure (LC)
- 2 tests stirrer failure (XC)
- 1 test VCV set position off-spec (RC)
  - Discovered after notification of failing calibration result
- 1 test voltage off-spec (LC)
- 2 tests heater failure (LC)
- 1 test power failure (XC)

D7528: Oxidation by ROBO

Period Precision and Severity Estimates

Natural Log (MRV Viscosity)	n	df	Pooled s	Mean Δ/s
Targets Updated 20211021[1]	80	77	0.1551	-----
4/1/18 through 9/30/18	126	122	0.2184	−0.49
10/1/18 through 3/31/19	100	96	0.2738	0.04
4/1/19 through 9/30/19	95	91	0.2492	−0.32
10/1/19 through 3/31/20	158	153	0.2723	−0.10
4/1/20 through 9/30/20	119	113	0.2264	−0.76
10/1/20 through 3/31/21	113	108	0.3188	−0.11
4/1/21 through 9/30/21	116	110	0.1992	−0.37

[1]Updated targets to include latest primary reference oils 434-3, 435-1 and 436

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D7528: Oxidation by ROBO

Natural Log (MRV Viscosity)
Pooled s
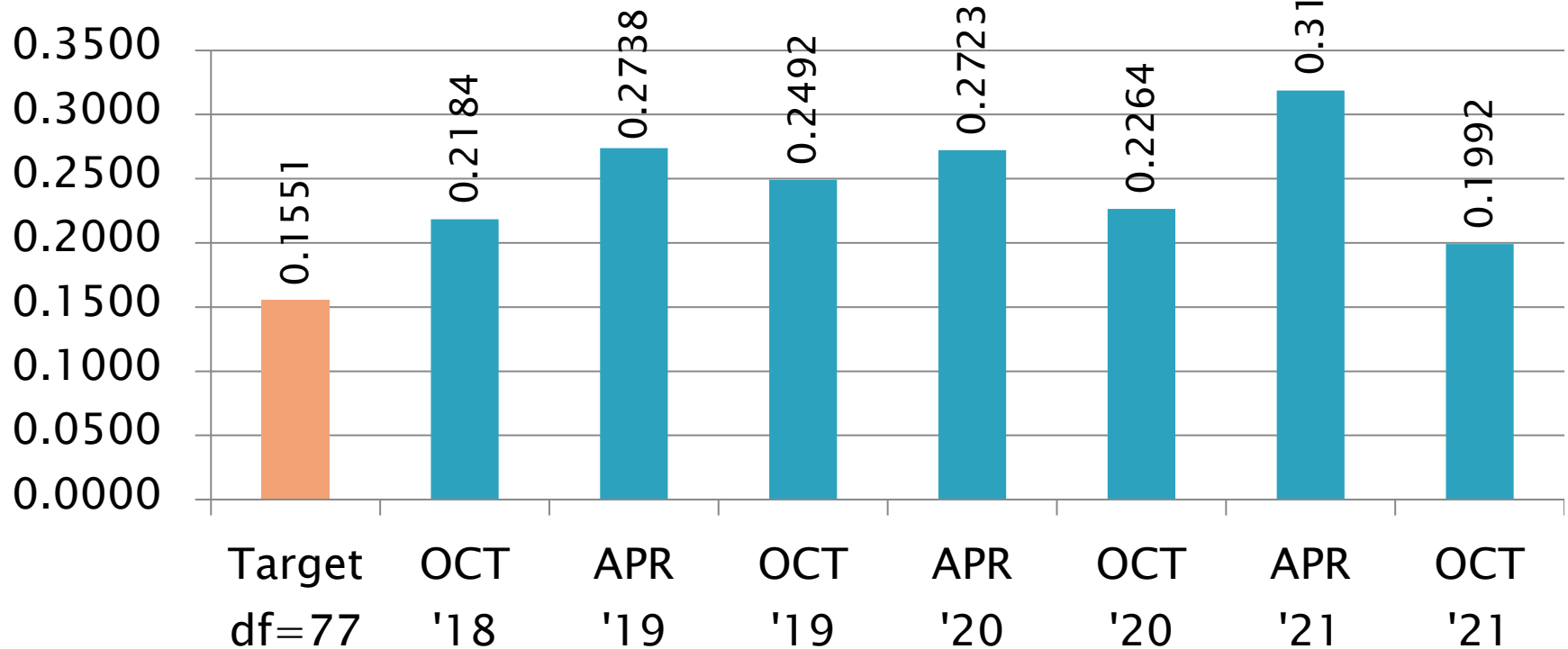
Category	Value
Target df=77	0.1551
OCT '18	0.2184
APR '19	0.2738
OCT '19	0.2492
APR '20	0.2723
OCT '20	0.2264
APR '21	0.3188
OCT '21	0.1992

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D7528: Oxidation by ROBO

Natural Log (MRV Viscosity)

Mean Δ/s

D7528: Oxidation by ROBO

Natural Log (MRV Viscosity)

Mean Δ/s

	Lab A	Lab AM	Lab AQ	Lab B	Lab BC	Lab E1	Lab G
Mean Δ/s	−0.55	−0.34	0.34	−1.10	−0.86	−1.52	−0.13
	n=42	n=10	n=6	n=5	n=2	n=4	n=58
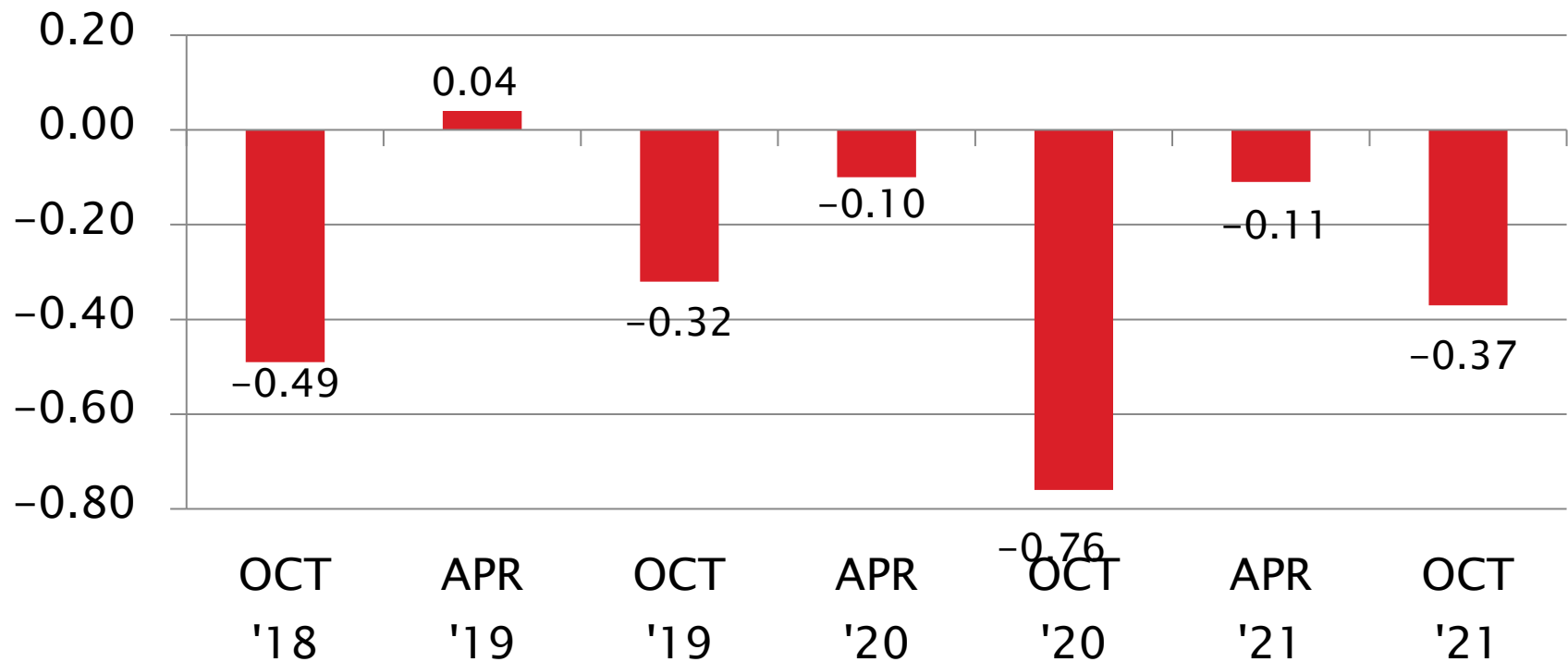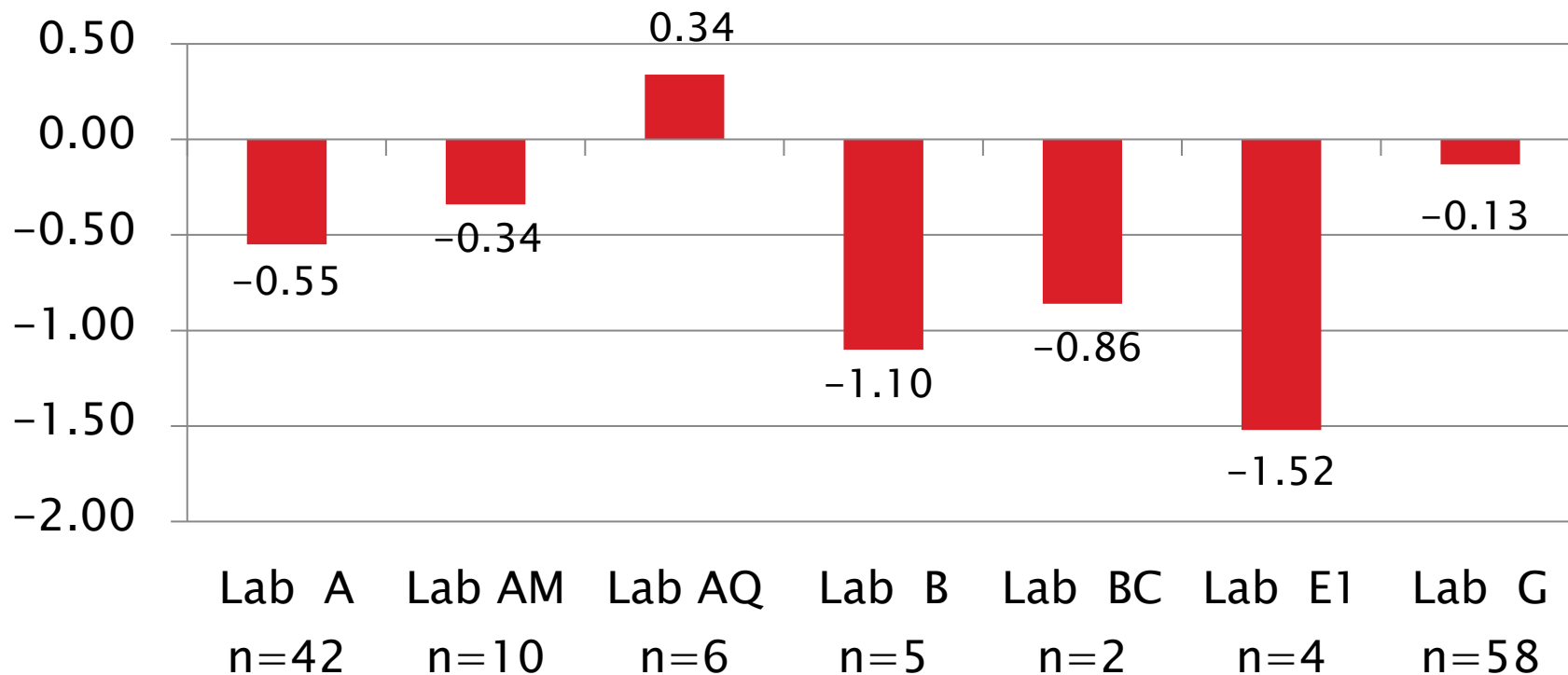
D7528: Oxidation by ROBO

- Precision (Pooled s) is more precise than prior periods
    - Significant improvement in precision
    - Likely due to new reference oil and targets
        - Dropped imprecise oil 438-2 mid-period, replaced by more precise oil 436
    - Continues to be less precise than target
    - Target precision updated to include current reference oils 434-3, 435-1 and 436
        - Dropped oils 438-2 and 434-2 from the pooled target precision for this period's statistics.

- Performance (Mean Δ/s) is -0.37 s mild for this report period

- CUSUM severity plot shows variable performance the past three report period

ROBO TEST INDUSTRY OPERATIONALLY VALID DATA

AGED OIL MRV APPARENT VISCOSITY

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CUSUM Severity Analysis

Standard Deviation Units (y-axis): -1300, -1200, -1100, -1000, -900, -800, -700, -600, -500, -400, -300, -200, -100, 0, 100

COUNT IN COMPLETION DATE ORDER (x-axis): 0, 210, 420, 630, 840, 1050, 1260, 1470, 1680, 1890, 2100, 2310, 2520, 2730, 2940, 3150, 3360, 3570

Date labels: 01APR10, 01OCT10, 01APR11, 01OCT11, 01APR12, 01OCT12, 01APR13, 01OCT13, 01APR14, 01OCT14, 01APR15, 01OCT15, 01APR16, 01OCT16, 01APR17, 01OCT17, 01APR18, 01OCT18, 01APR19, 01OCT19, 01APR20, 01OCT20, 01APR21, 01OCT21

28OCT21:13:14

ROBO TEST INDUSTRY OPERATIONALLY VALID DATA

AGED OIL MRV APPARENT VISCOSITY

CUSUM Severity Analysis

Standard Deviation Units

COUNT IN COMPLETION DATE ORDER

CAL PERIOD SHORTNED

435 – 1 REPLACES 435

ROBO WORKSHOP

ROBO WORKSHOP

IL 16 – 1 REVISIONS

434 – 2 REPLACES 434 – 1

434 – TARGETS UPDATED

438 – 2 REPLACES 438

434 – 3 & 43 – 2 NEW TARGETS

4 TARGETS

434 – 3 NEW ARGETS

436 NEW TARGETS, 38 – X END

28OCT21:15:35
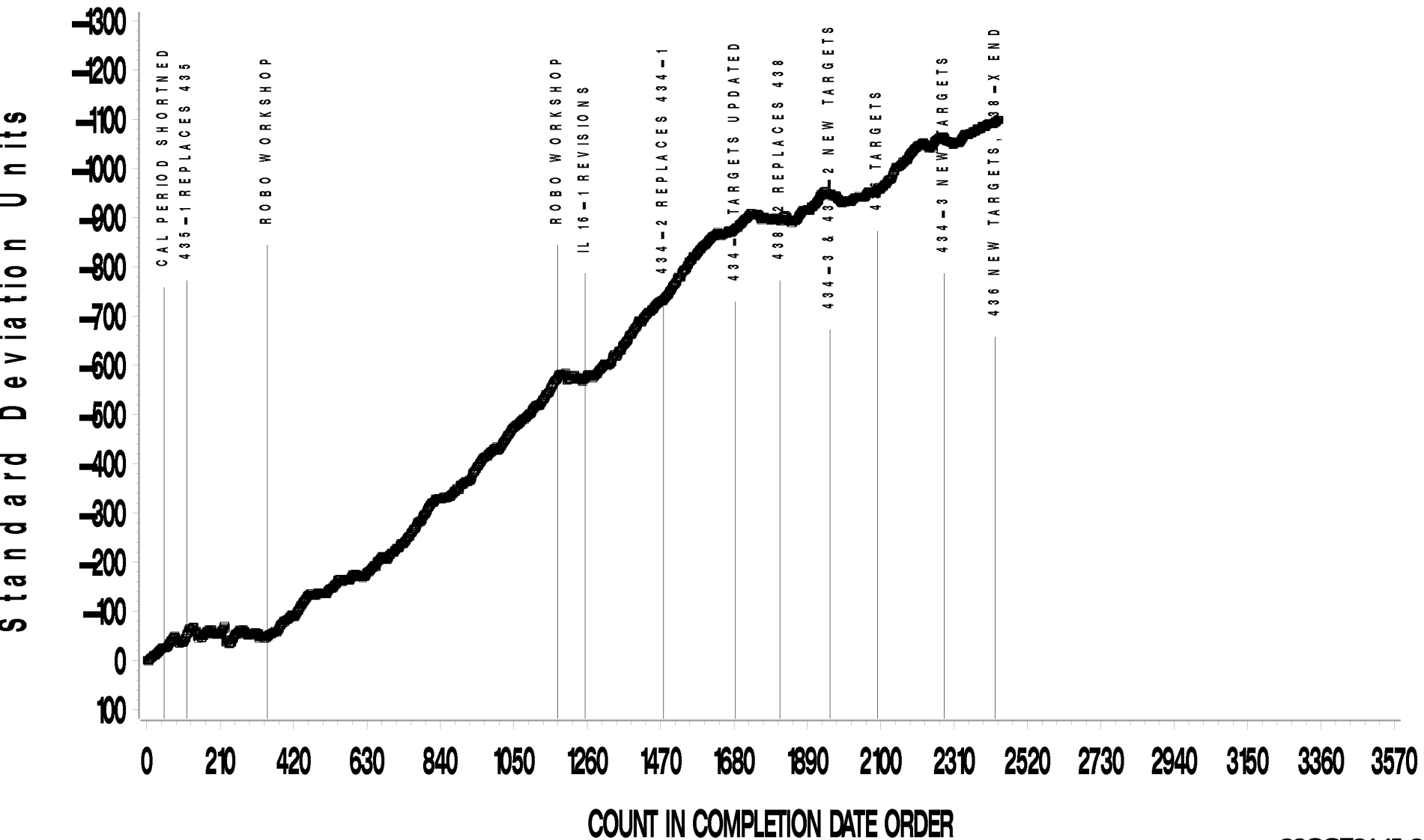
D7528: Oxidation by ROBO

Natural Log (MRV Viscosity) Mean
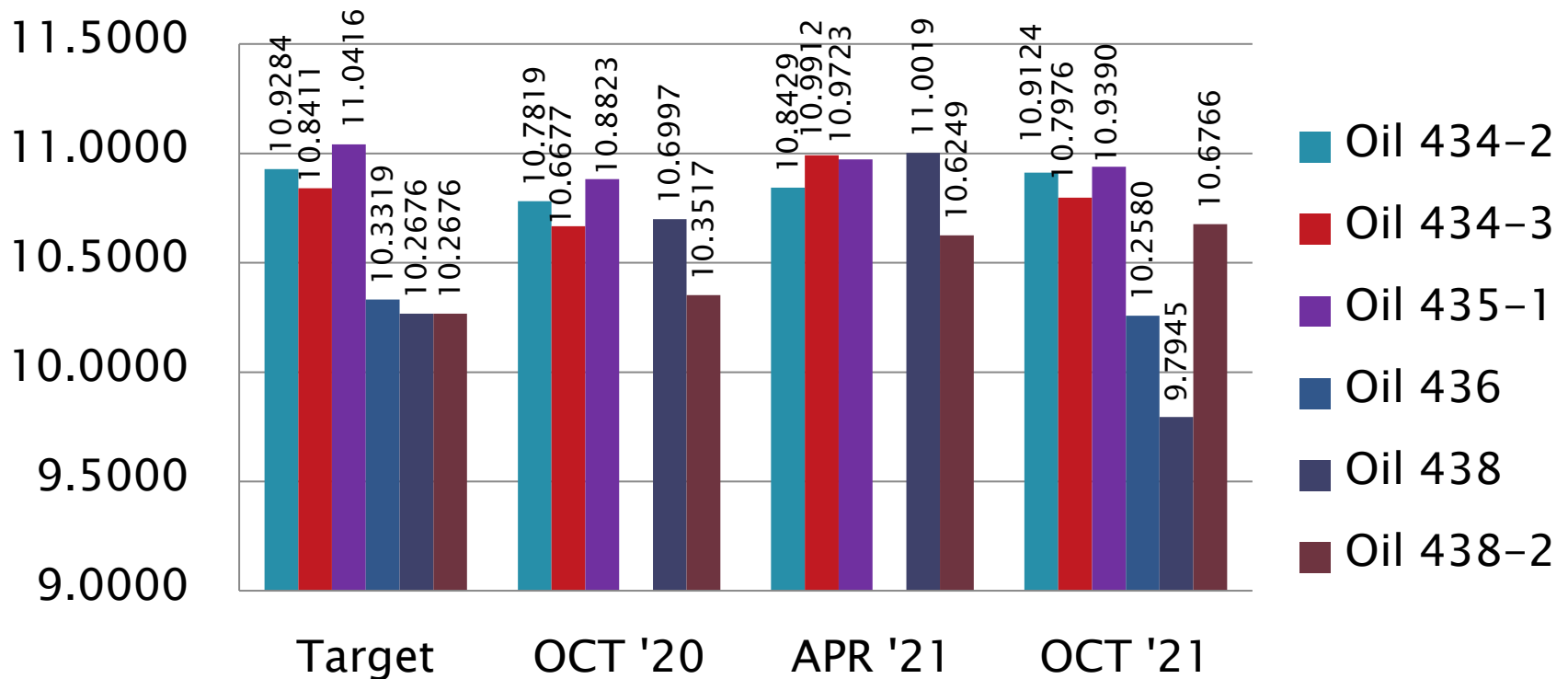
D7528: Oxidation by ROBO

Natural Log (MRV Viscosity)

S_R
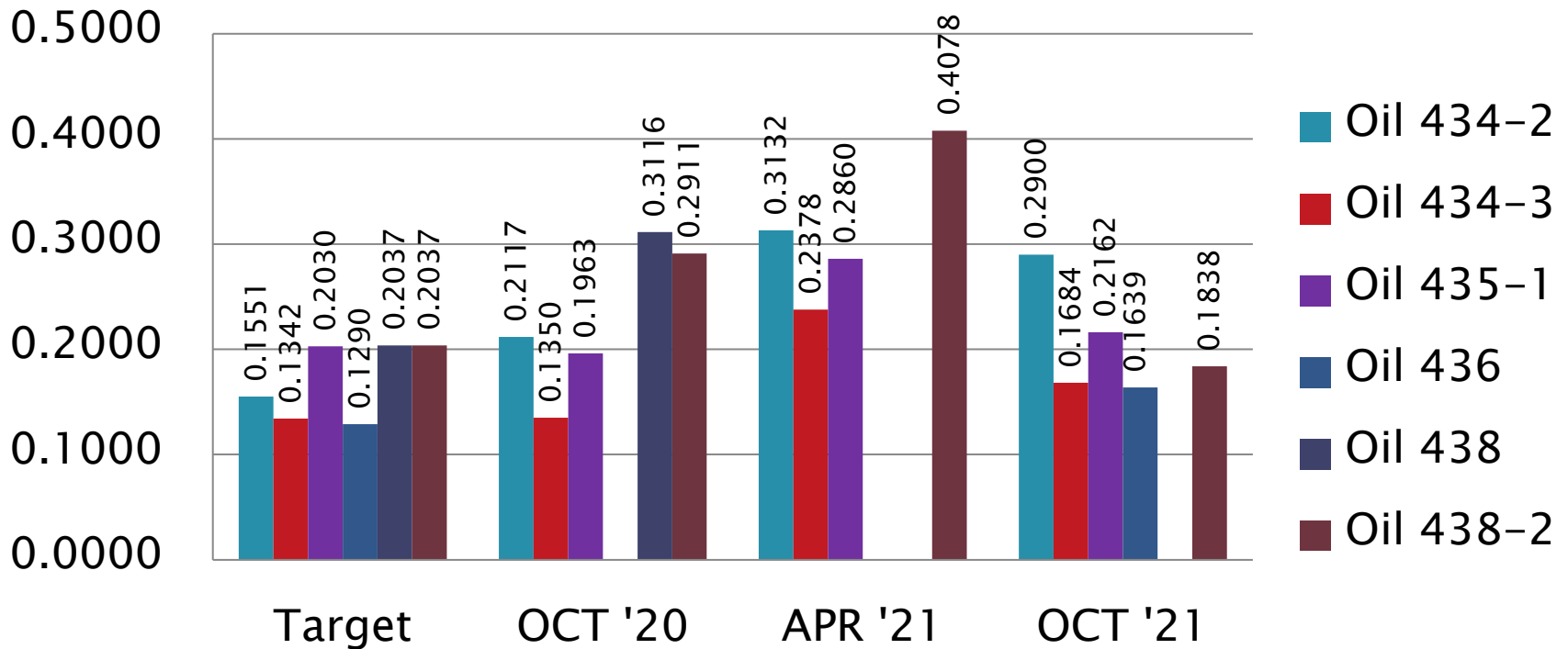
D7528: Oxidation by ROBO
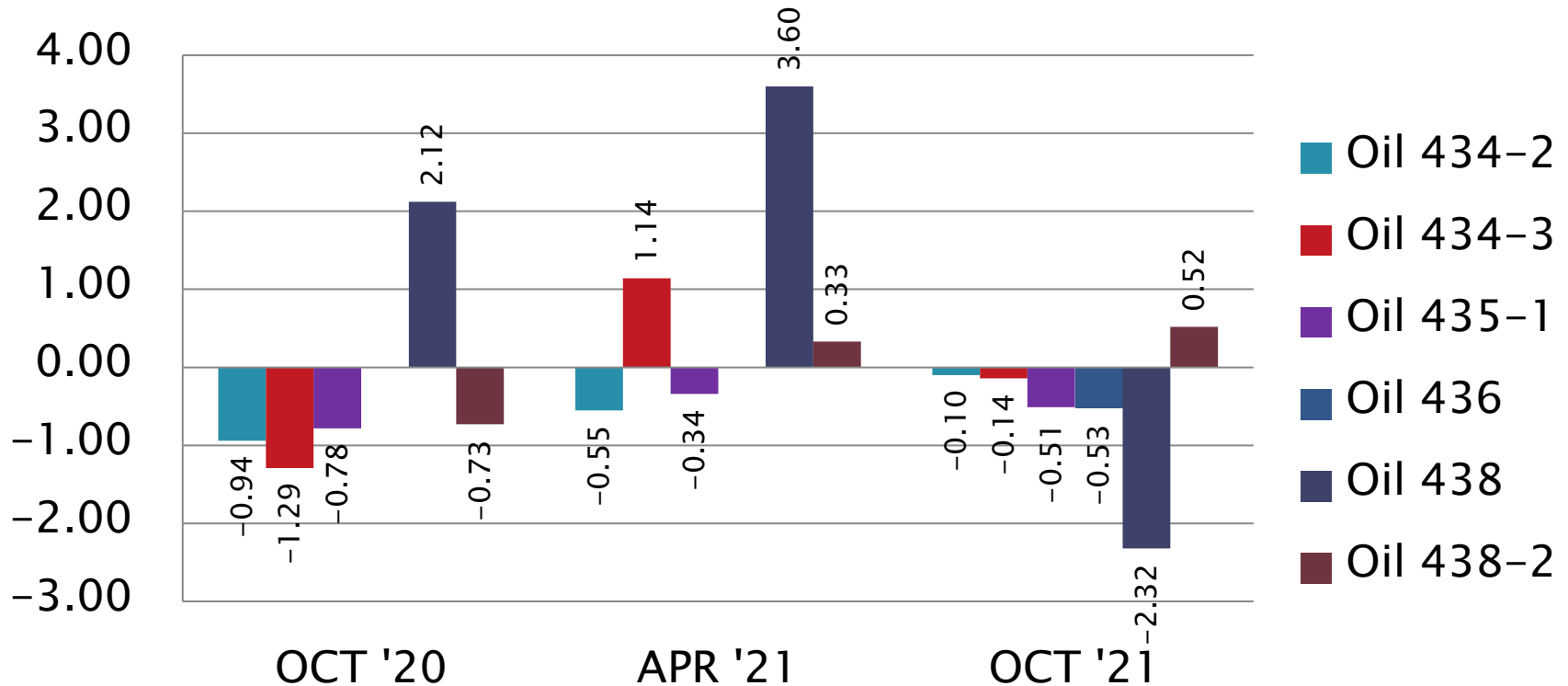
Natural Log (MRV Viscosity)

Mean Δ/s

Reference Oil Inventory

D5800

Oil	Year Rec'd By TMC[A]	Tests	TMC Inventory, gallons	Gallons Shipped last 12 months
VOLC12	2013	D5800	26.8	2.5
VOLD12	2013	D5800	25.2	2.6
VOLE12	2013	D5800	22.8	2.6
VOLD18	2018	D5800QC	832	82

[A] The integrity of TMC reference oils is confirmed annually by analytical QC testing of chemical and physical properties.

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Reference Oil Inventory

D6417, GI

Oil	Year Rec'd By TMC[A]	Tests	TMC Inventory, gallons	Gallons Shipped last 12 months
52	1995	D6417	59.4	0.01
55	1995	D6417	66.0	0.01
58	1998	D6417, D6417QC, GI	113.7	0.34
GIA17	2017	GI	8.3	0.7
GIC18	2018	GI	9.8	0.1
1009	2002	GI	36.6	0.4

[A] The integrity of TMC reference oils is confirmed annually by analytical QC testing of chemical and physical properties.

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Reference Oil Inventory

TEOST, MTEOS & ROBO

Oil	Year Rec'd By TMC[A]	Tests	TMC Inventory, gallons	Gallons Shipped last 12 months
432	1998	MTEOS	102.8	0.4
75–1	2016	TEOST	4.9	1.2
435–2[B]	2010	TEOST	39.4	0.4
434–3[B]	2017	ROBO/MTEOS	34.8	0.0
435–1	2008	ROBO	349	21.7
436[B]	2014	ROBO	44.2	3.7

[A]The integrity of TMC reference oils is confirmed annually by analytical QC testing of chemical and physical properties.

[B] Multi-test oil; estimated aliquot reserved for bench testing.

Reference Oil Inventory

D6082 & D874

Oil	Year Rec'd By TMC[A]	Tests	TMC Inventory, gallons	Gallons Shipped last 12 months
FOAMB18	2018	D6082	87.3	1.4
66	2002	D6082	75.1	0.3
820-2	2001	D874	8.8	0.1
90	2005	D874/D874QC	13.0	2.5
91	2006	D874	3.4	0.1

[A] The integrity of TMC reference oils is confirmed annually by analytical QC testing of chemical and physical properties.

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Additional Information

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Additional Information

▸ Available on the TMC's Website:
  ◦ Lubricant Test Monitoring System (LTMS) Document
  ◦ CUSUM Severity Plots
  ◦ Reference Data, Period Statistics and Timelines
  ◦ Information Letters and Technical Memos
  ◦ Report Forms & Data Dictionaries
  ◦ Online Store, and more…

▸ www.astmtmc.org

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