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

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

Spring 2020

B0.07 Bench Testing Executive Summary

- D6417 (Volatility by GC)
- Precision (Pooled s) is less precise than prior period
  - More precise than target precision
- Performance (Mean Δ/s) is 0.09 s severe (on-target)
- CUSUM severity plot shows overall slight severe performance with leveling to nearly on-target the past two report periods.

B0.07 Bench Testing Executive Summary

- D5800 (Volatility by Noack)
- Effective 20200207, TMC monitoring of Mass % Volatility is being done in natural log transformed units.
- Precision (Pooled s) is less precise than the updated target precision, now in natural log transformed units.
- Performance (Mean Δ/s) is 0.54 s severe.
- CUSUM severity plots shows a continuing overall severe trend with reference testing.

B0.07 Bench Testing Executive Summary

- D5133 (Gelation Index)
- Fail rate of operationally valid tests is 12% this period. Historic period fail rates have ranged between 6% and 26%.
- Precision (Pooled s) is less precise than recent report periods, but more precise than target precision.
- Performance (Mean Δ/s) is -0.24 s mild, comparable to last report period.

B0.07 Bench Testing Executive Summary

- D6335 (TEOST-33C)

- Precision (Pooled s) is more precise than prior period, and less precise than target precision.
- Performance (Mean Δ/s) is 0.28 s severe.
- Period Fail rate of 0% is remarkable
  - Fail rates last two periods have been 20% and 23%, and similarly high in prior periods

B0.07 Bench Testing Executive Summary

- D7097 (MHT-4 TEOST)

- Precision (Pooled s) is less precise than the prior report period and less precise than target precision
  - Increasingly poor precision trend noted for each period since at least October 2017

- Performance (Mean Δ/s) is on-target
  - Failing tests all trending severe, no mild fails,
    - Three on oil 432 and four on oil 434
    - Across four labs and four instruments
    - Four tests exceed 3 s severe, most severe was 4.6 s

- All operationally valid tests this period report using Rod Batch M

- All operationally valid calibration tests this period report using Catalyst Batches 15AA (n=2), 18AB (n=51) or 19BA (n=48)

- Overall severity on catalyst batch 19BA (n=51) appears to be about -0.20 s mild, and comparably mild on both reference oils.
  - Catalyst Batch 18AB is, overall, performing similarly mild (n=242)

B0.07 Bench Testing Executive Summary

- D6082 (High Temperature Foam)

- Foam Tendency Precision (Pooled s) is more precise than the prior report period
  - More precise than target precision

- Performance (Mean Δ/s) is -0.23 s mild

- No non-zero occurrences of Foam Stability

- All six severe oil discrimination runs (on TMC oil 66) demonstrated acceptable discrimination.

- Replacement oil FOAMB18 was introduced last period.
  - Period estimates are a combination of oils 1007 and FOAMB18.

B0.07 Bench Testing Executive Summary

- D874 (Sulfated Ash)
- Precision (Pooled s) is comparable to prior periods
  - More precise than target precision
- Performance (Mean Δ/s) is -0.71 s mild
  - Notably more mild than prior periods
    - Biased by two mild results from lab B
  - CUSUM severity plot shows a distinct mild slope for the report period

B0.07 Bench Testing Executive Summary

- D7528 (ROBO)
- Precision (Pooled s) is less precise than last period
  - Continues to be less precise than target
- Performance (Mean Δ/s) is -0.10 s mild for this report period
- CUSUM severity plot shows variable performance past three report period, but prior severe trend has improved

Calibrated Labs and Stands*

Test	Labs	Stands
D6417	6	7
D5800	8	21
D5133 (GI)	8	12
D6335 (TEOST)	8	12
D7097 (MTEOS)	11	43
D6082	6	7
D874	3	--
D7528 (ROBO)	6	25

*As of 3/31/2020

D02.B0.07
TMC Monitored Tests

- October 1, 2019 –
  March 31, 2020

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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

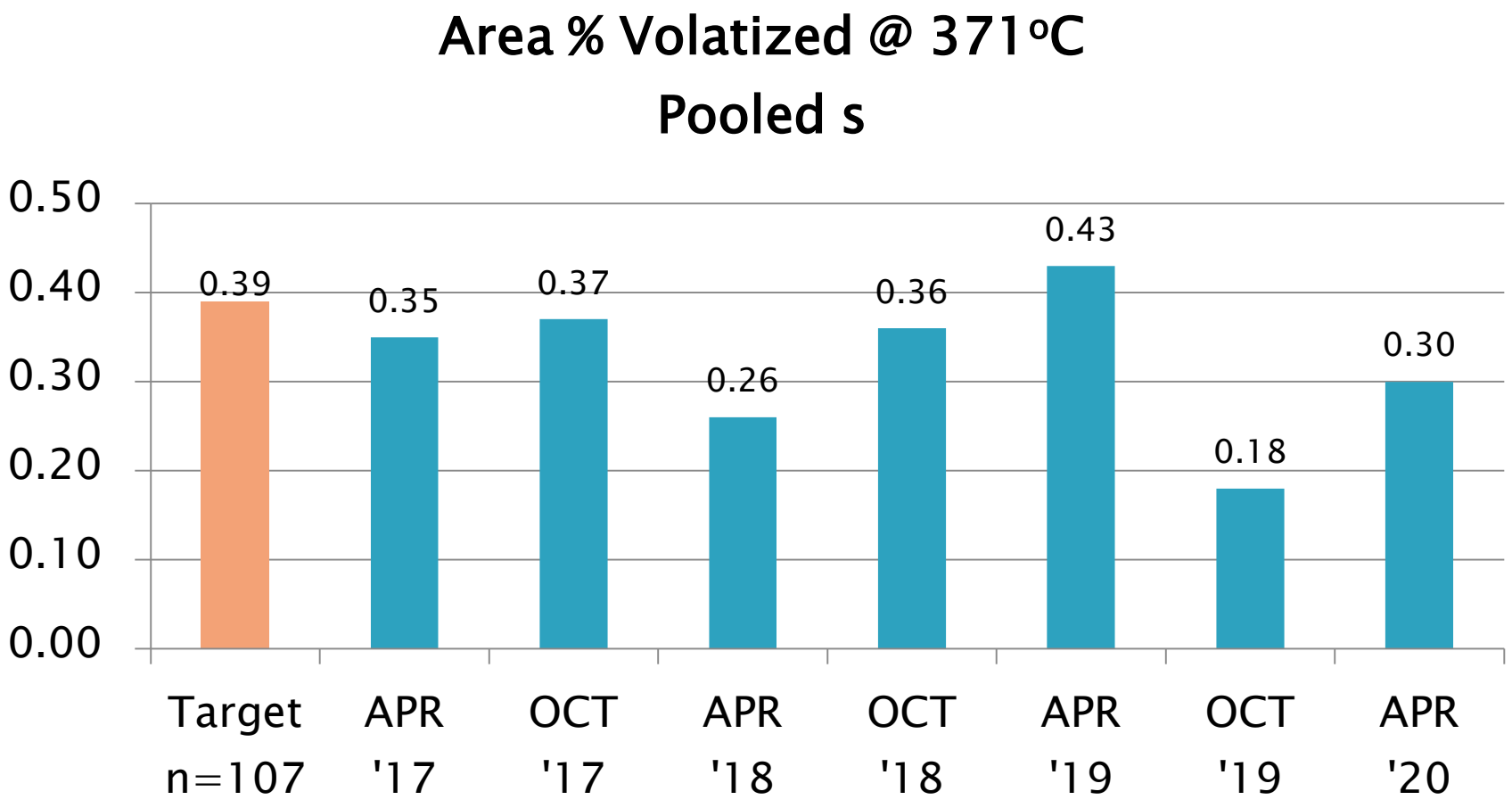
- There were no operationally or statistically invalid tests reported this period
  - All reported tests this period passed calibration (AC)
- No D6417 TMC technical updates were issued this report period.
- D6417 calibration requirement updates are issued as LTMS document updates

D6417: Estimation of Engine Oil Volatility by Capillary GC

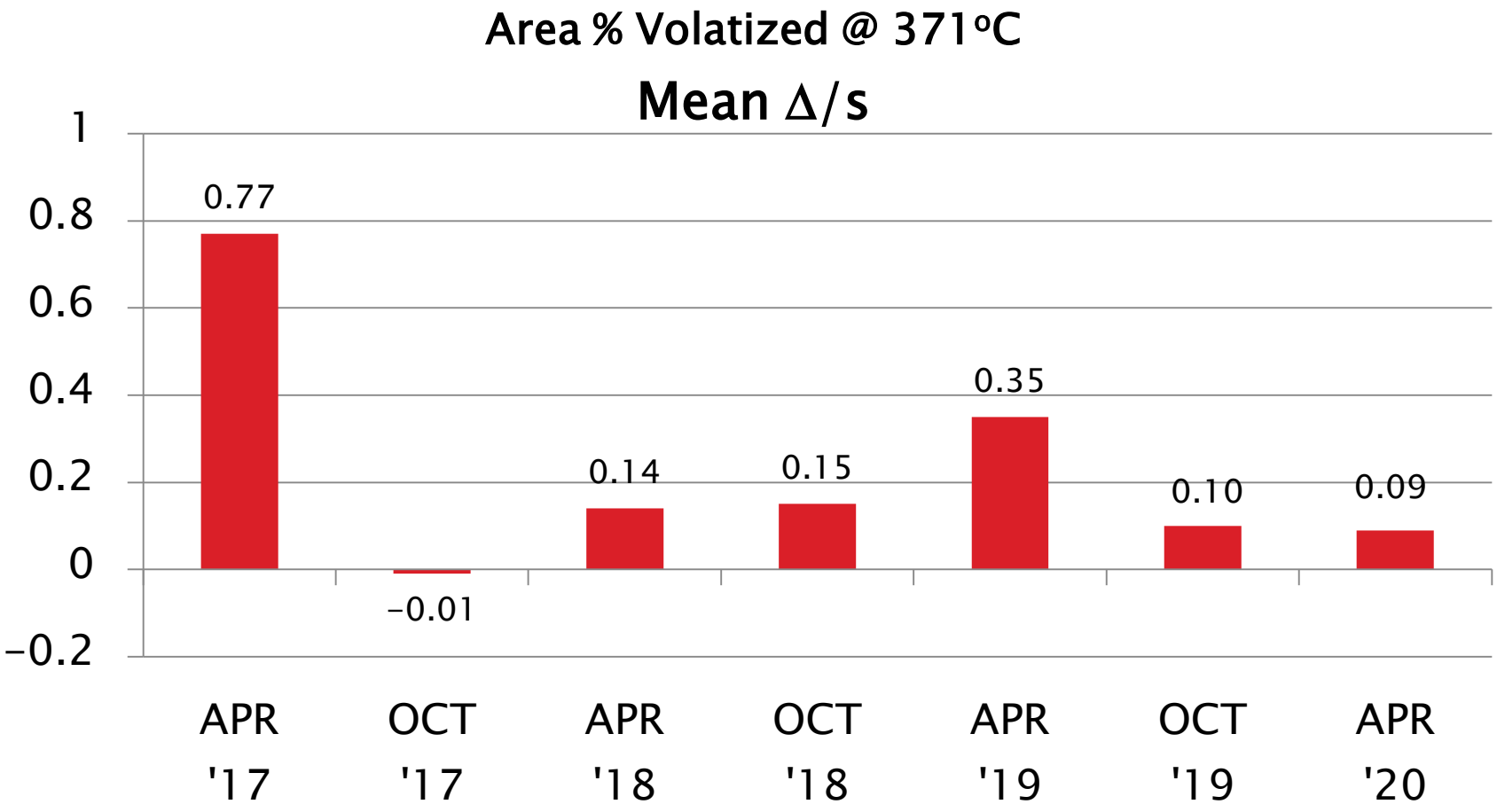
Period Precision and Severity Estimates

Area % Volatized @ 371°C	n	df	Pooled s	Mean Δ/s
Initial Selected Oils from RR	54	51	0.39	-----
10/1/16 through 3/31/17	13	10	0.35	0.77
4/1/17 through 9/30/17	15	12	0.37	-0.01
10/1/17 through 3/31/18	15	12	0.26	0.14
4/1/18 through 9/30/18	16	13	0.36	0.15
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

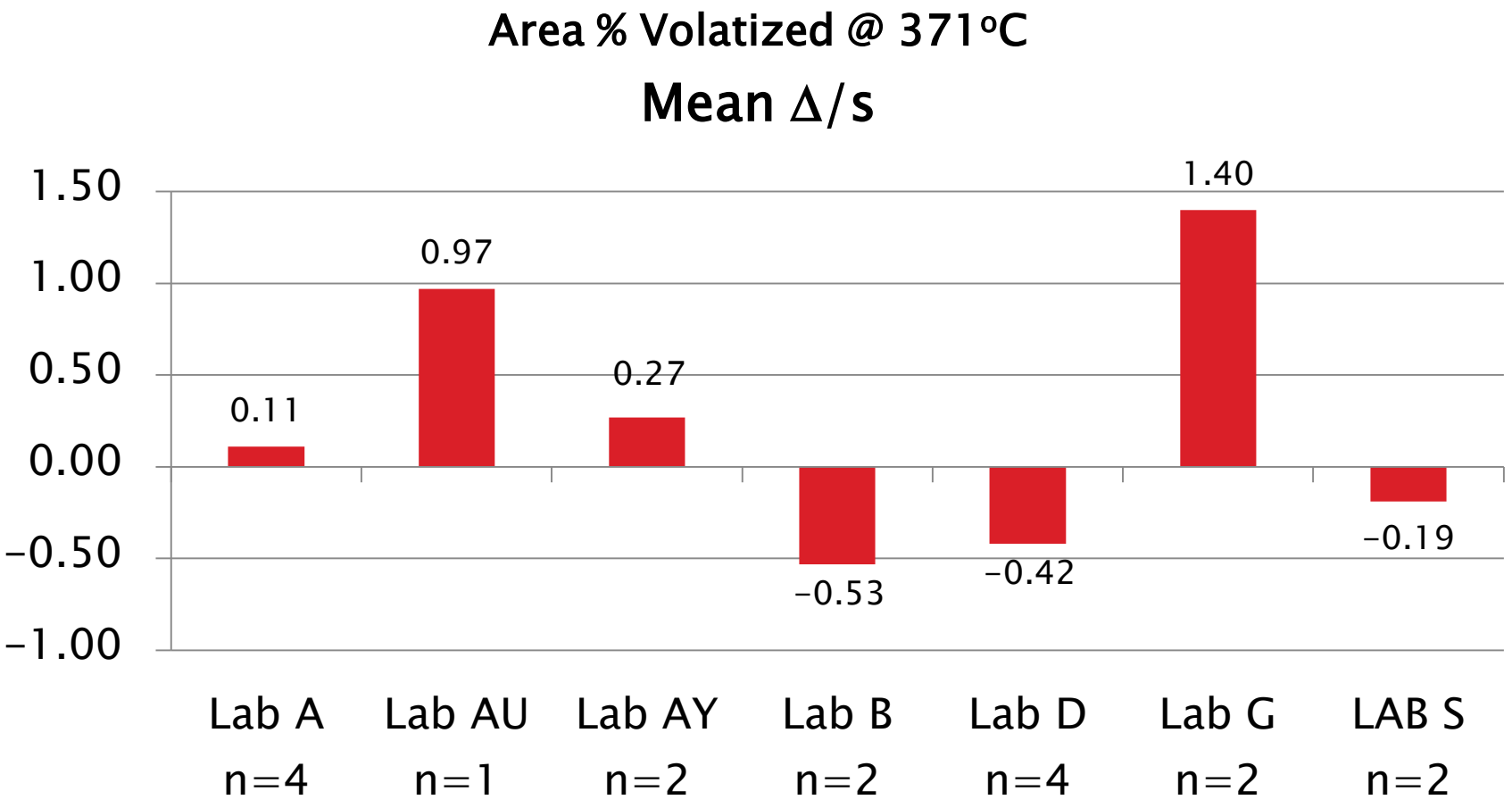
D6417 Precision Estimates



D6417 Severity Estimates



D6417 Lab Severity Estimates



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D6417: Estimation of Engine Oil Volatility by Capillary GC

- Precision (Pooled s) is less precise than prior period
  - More precise than target precision
- Performance (Mean Δ/s) is 0.09 s severe (on-target)
- CUSUM severity plot shows overall slight severe performance with leveling to nearly on-target the past two report periods.

D6417 VOLATILITY BY GC INDUSTRY OPERATIONALLY VALID DATA

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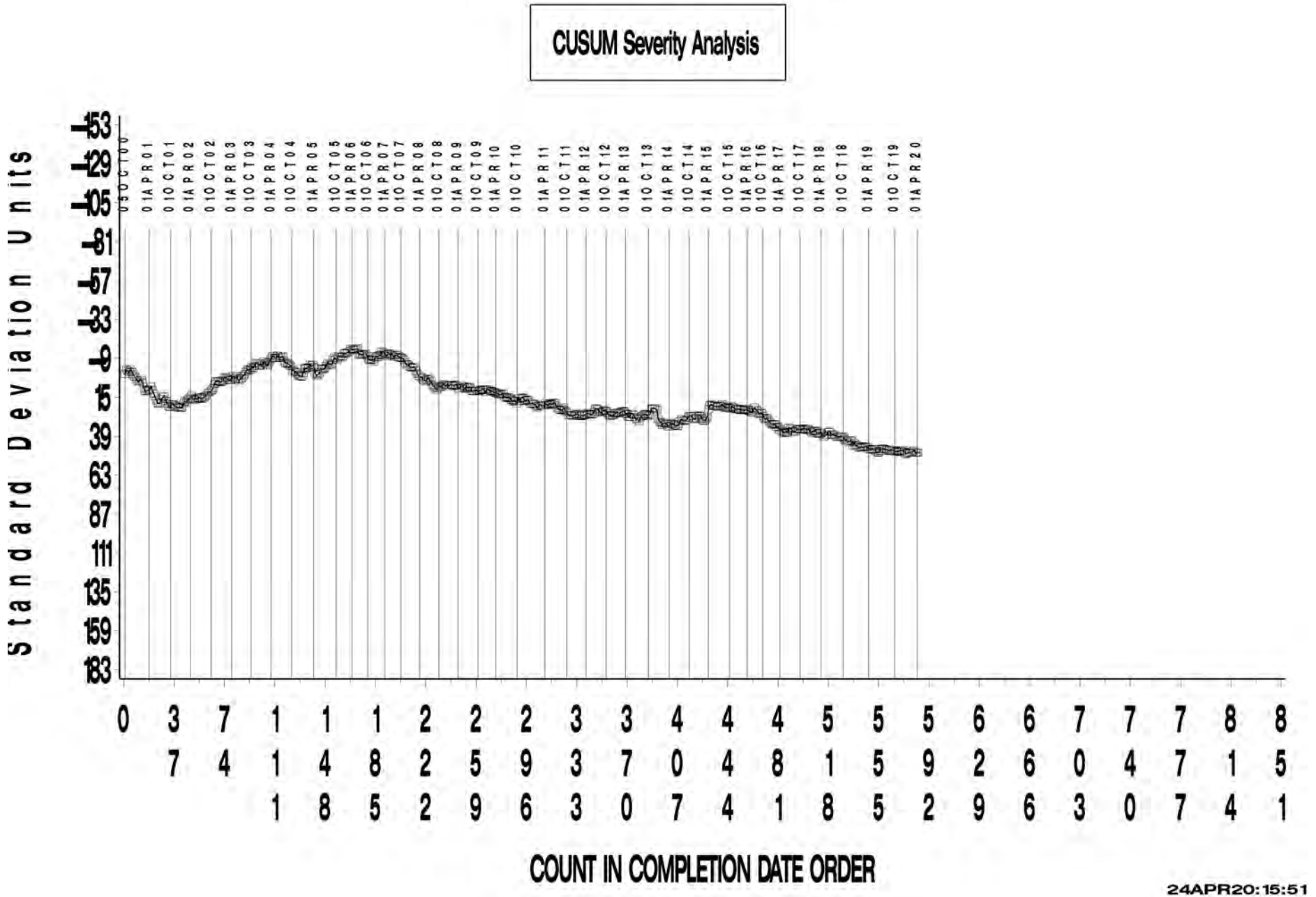
SAMPLE AREA % VOLATIZED



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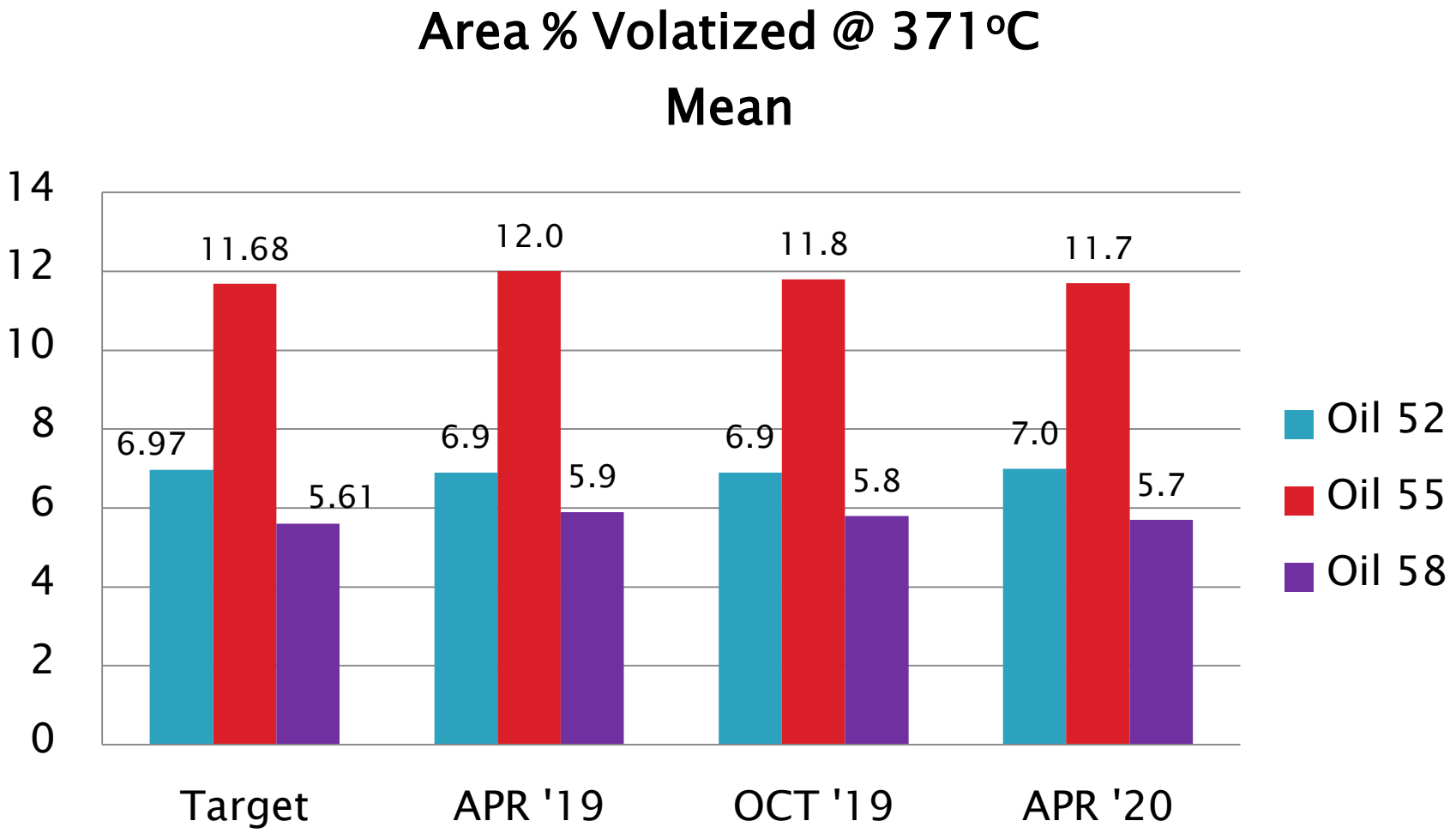
D6417 Performance by Oil



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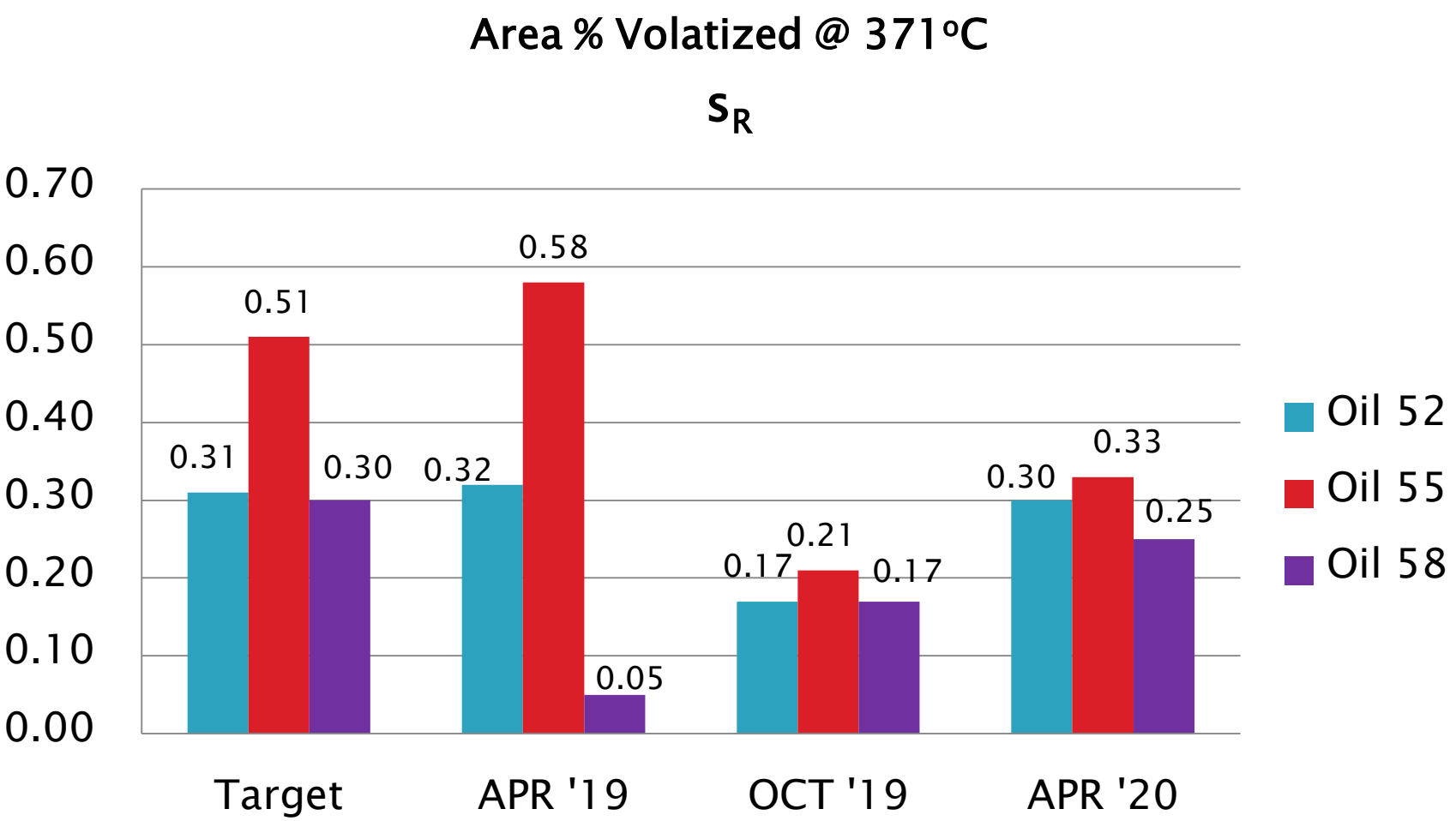
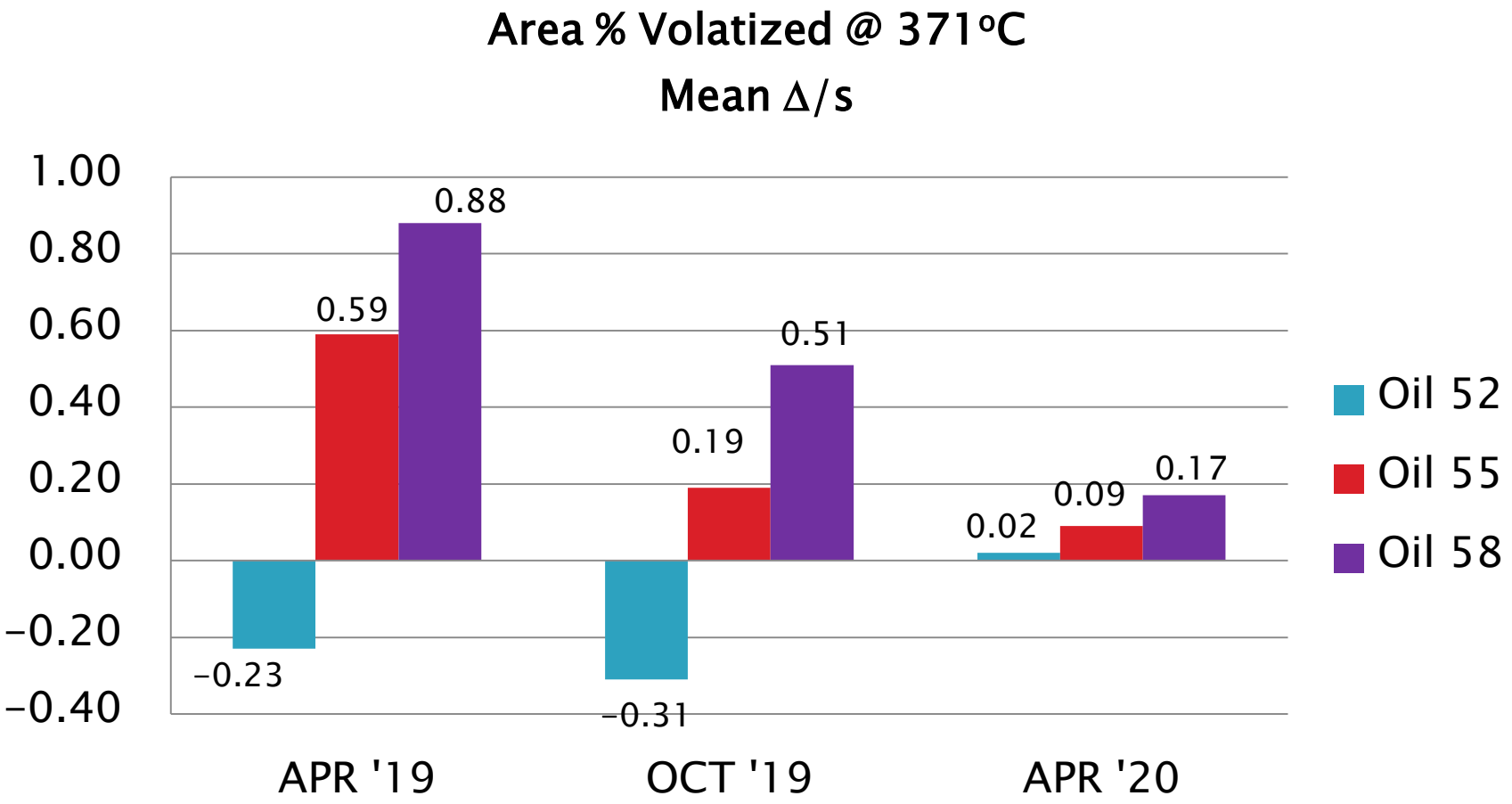
D6417 Performance by Oil



D6417 Performance by Oil



Return to Executive Summary

D5800: Evaporation Loss of Lubricating Oil by Noack Method

Test Status	Validity Code	No. Tests
Acceptable Calibration Test	AC	140
Failed Calibration Test	OC	6
Operationally Invalidated by Lab	LC, XC	0
Operationally Invalidated After Initially Reported as Valid	RC	6
Non-Blind Instrument Shakedown	NN	20
Held out of statistics (new rig, failed to calibrate)	MC	4
Total		**176**

Number of Labs Reporting Data: 12
Fail Rate of Operationally Valid Tests: 4%

D5800: Evaporation Loss of Lubricating Oil by Noack Method

Statistically Unacceptable Tests (OC)	No. Of Tests
Ei Level 3 Precision Alarm Mild	1
Ei Level 3 Precision Alarm Severe	3
Zi Level 2 Severity Severe	2
Zi Level 2 Severity Mild	0

- The 6 OC tests were on five different rigs at four labs.
  - No tests triggered both Ei L3 and Zi L2 alarms
  - Rig I6 had two consecutive Ei L3 alarms before alarm cleared on the third attempt.

- Six operationally invalid calibration runs reported this period:
  - All six reported off-spec QC results on the day of the calibration run, invalidated by the TMC (RC).
    - Four were on two new rigs at lab J.

D5800: Evaporation Loss of Lubricating Oil by Noack Method

- Non-calibration tests reported for the period:
  - Twenty non-blind shakedown runs to troubleshoot instrument performance (NN).
  - Four tests held out of statistics; new rigs that failed to demonstrate a passing initial calibration (MC; Lab J)

- LTMS update issued, effective 20200207, to transform test results to natural log before applying instrument severity adjustments.
  - TMC monitoring of mass% evaporation loss is now done on natural log transformed test results.
  - Report packet revision notice D5800-20191112 was issued to accommodate these changes.

- Technical memo 20-006 was issued on 20200204 advising of test method update to D5800-19a

- D5800 calibration requirement updates are issued as LTMS document updates

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	-----
4/1/17 through 9/30/17[2]	147	144	1.13	0.56
4/1/17 through 9/30/17[2]	146	143	0.84	0.47
10/1/17 through 3/31/18	133	130	0.81	0.15
4/1/18 through 9/30/18[2]	149	146	0.82	0.40
4/1/18 through 9/30/18[2]	148	145	0.76	0.44
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

[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.

[2]Extreme OC result included and excluded

D5800: Evaporation Loss of Lubricating Oil by Noack Method

Performance Comparison by Procedure & Model

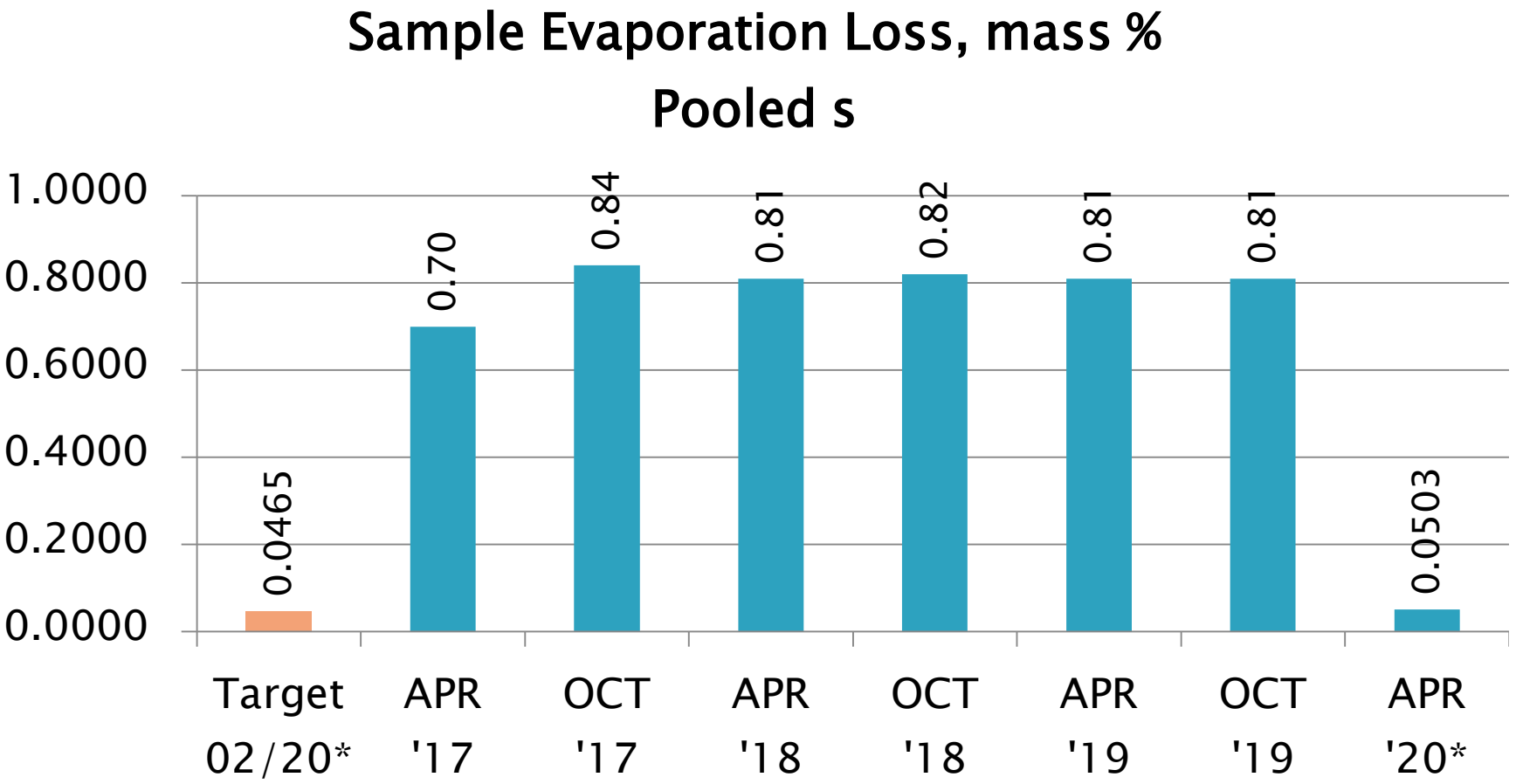
Sample Evaporation Loss, Mass %

Procedure	n	df	Pooled s	Mean Δ/s
Procedure B	108	105	0.04	0.83
Procedure C	No Procedure C tests reported this period.			
Procedure D	38	35	0.05	-0.27

Model	n	df	Pooled s	Mean Δ/s
NCK2	6	3	0.02	0.23
NCK25G	102	99	0.04	0.86
NS2	38	35	0.05	-0.27

1 Procedure B NCK2 Rig
24 Procedure B NCK25G Rigs
7 Procedure D NS2 Rigs

D5800 Precision Estimates



*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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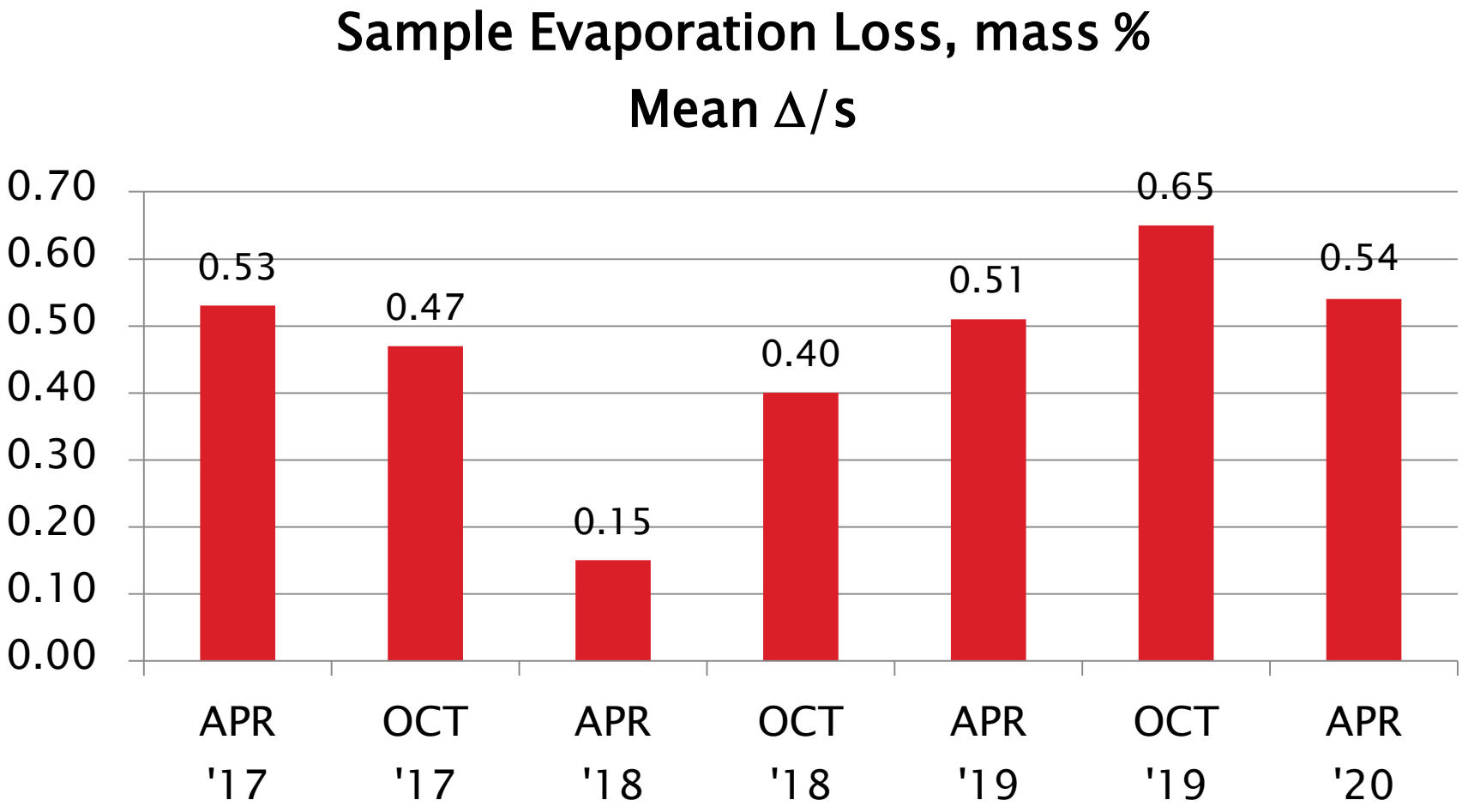
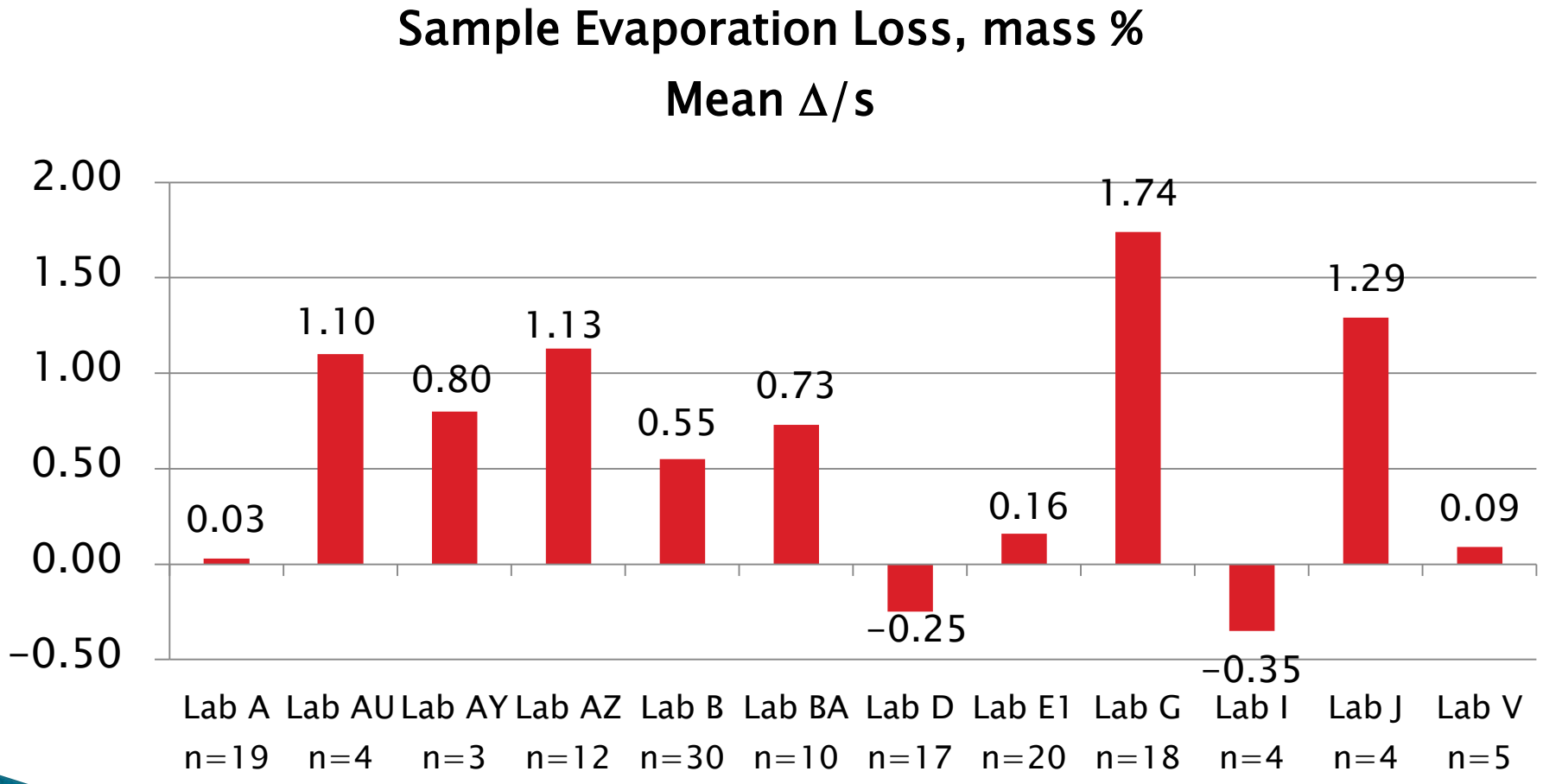
D5800 Severity Estimates



D5800 Lab Severity Estimates



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D5800: Evaporation Loss of Lubricating Oil by Noack Method

- Precision (Pooled s) is less precise than the updated target precision, now in natural log transformed units.
- Performance (Mean Δ/s) is 0.54 s severe.
- Two tests exceeded 3 s from targets this period
  - Both on rig G8, +3.4 s and +3.0 s
- CUSUM severity plots shows a continuing overall severe trend with reference testing.

D5800 VOLATILITY BY NOACK INDUSTRY OPERATIONALLY VALID DATA

EVAPORATION LOSS, MASS%

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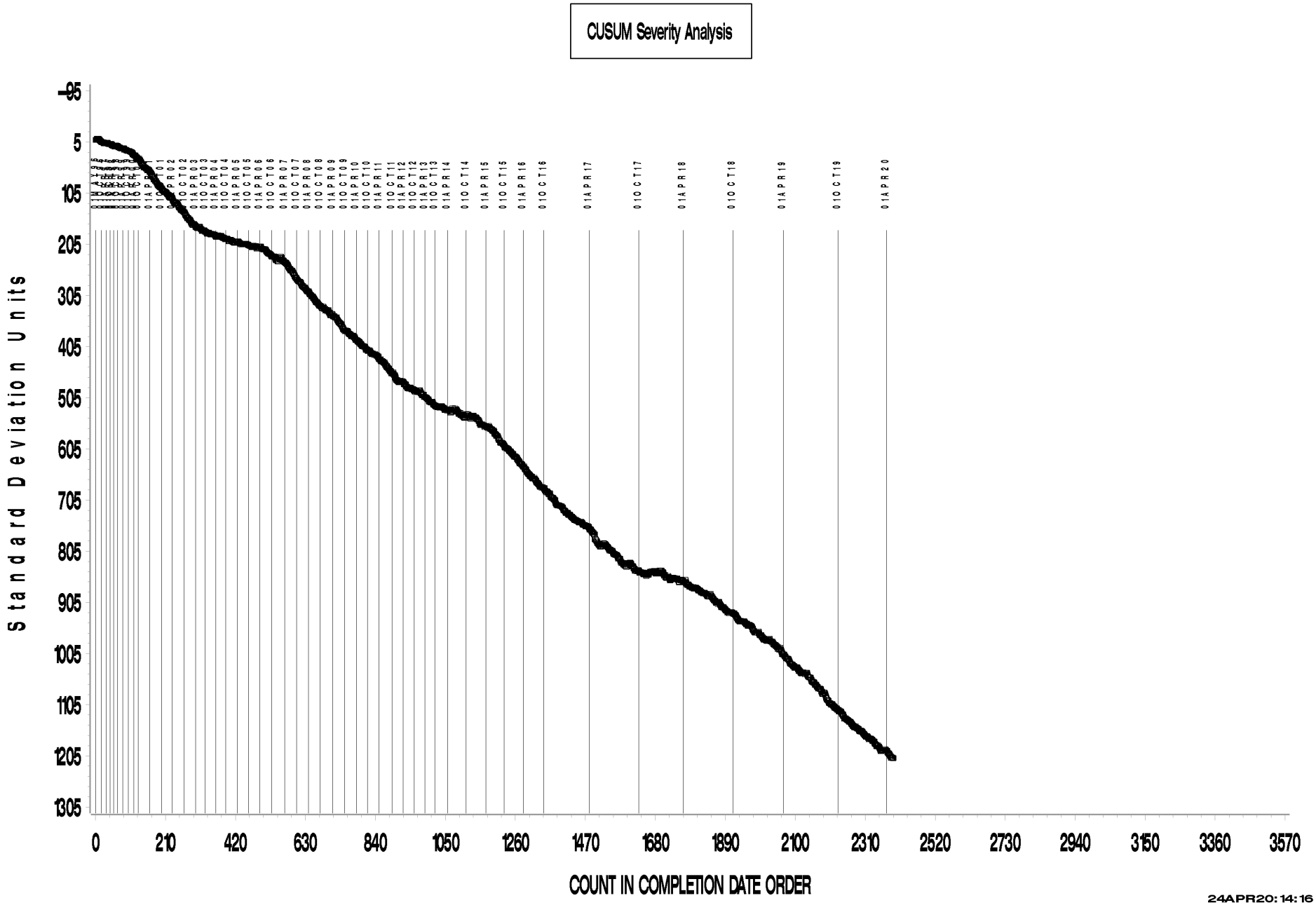

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D5800 VOLATILITY BY NOACK INDUSTRY OPERATIONALLY VALID DATA

EVAPORATION LOSS, MASS%

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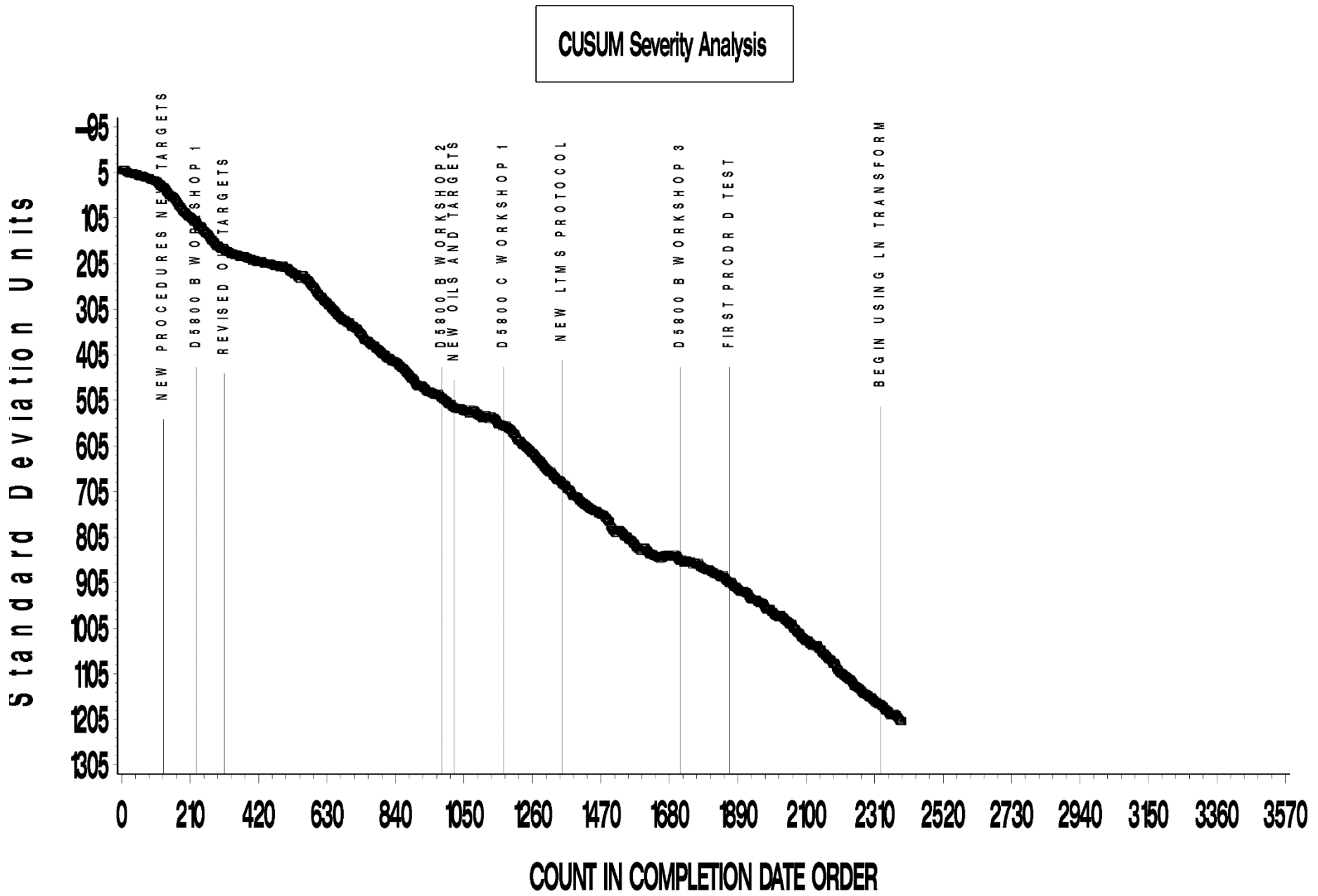

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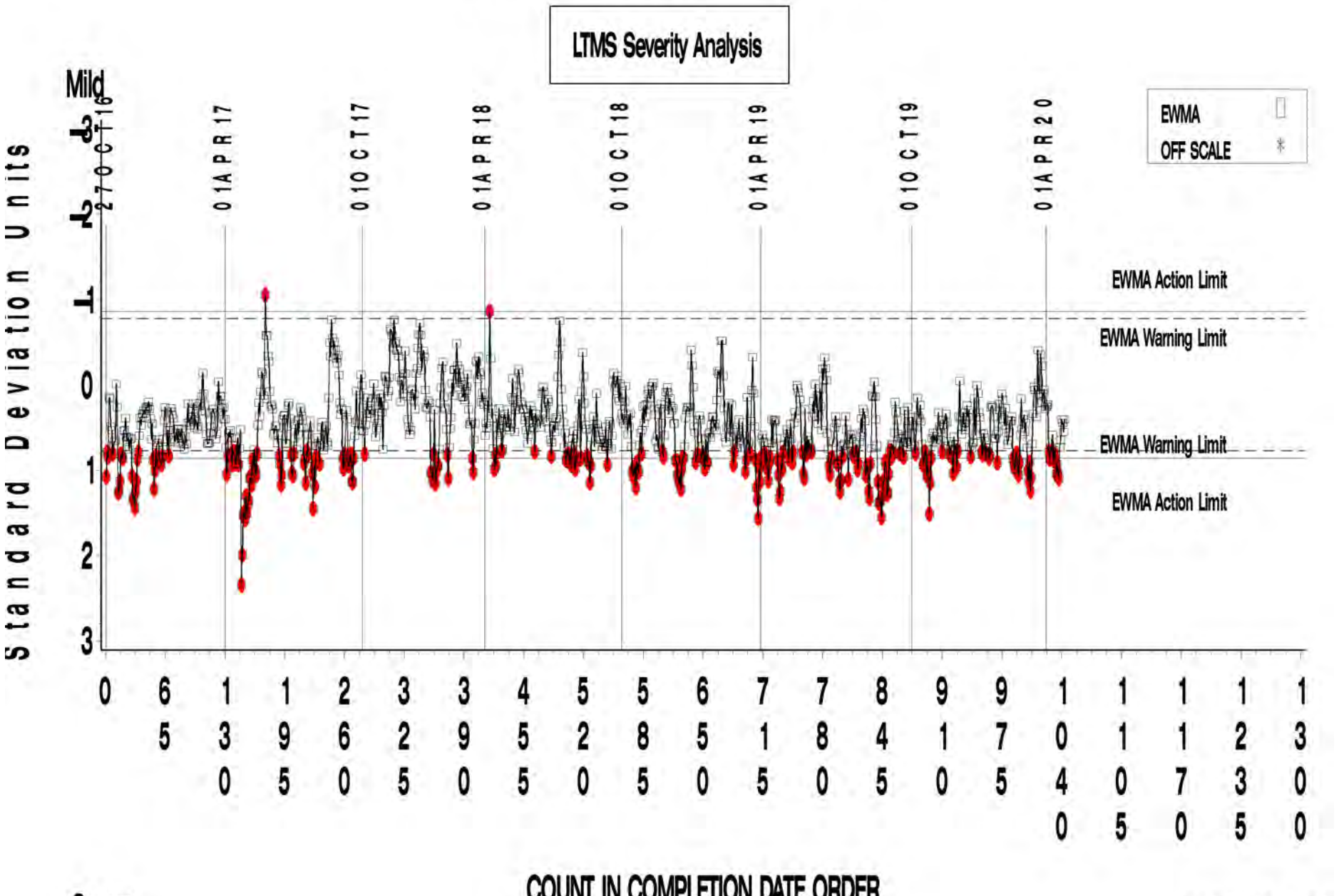
D5800 VOLATILITY BY NOACK INDUSTRY OPERATIONALLY VALID DATA

DTCOMP> = '20161019'

EVAPORATION LOSS, MASS%



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D5800 VOLATILITY BY NOACK INDUSTRY OPERATIONALLY VALID DATA
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EVAPORATION LOSS, MASS%

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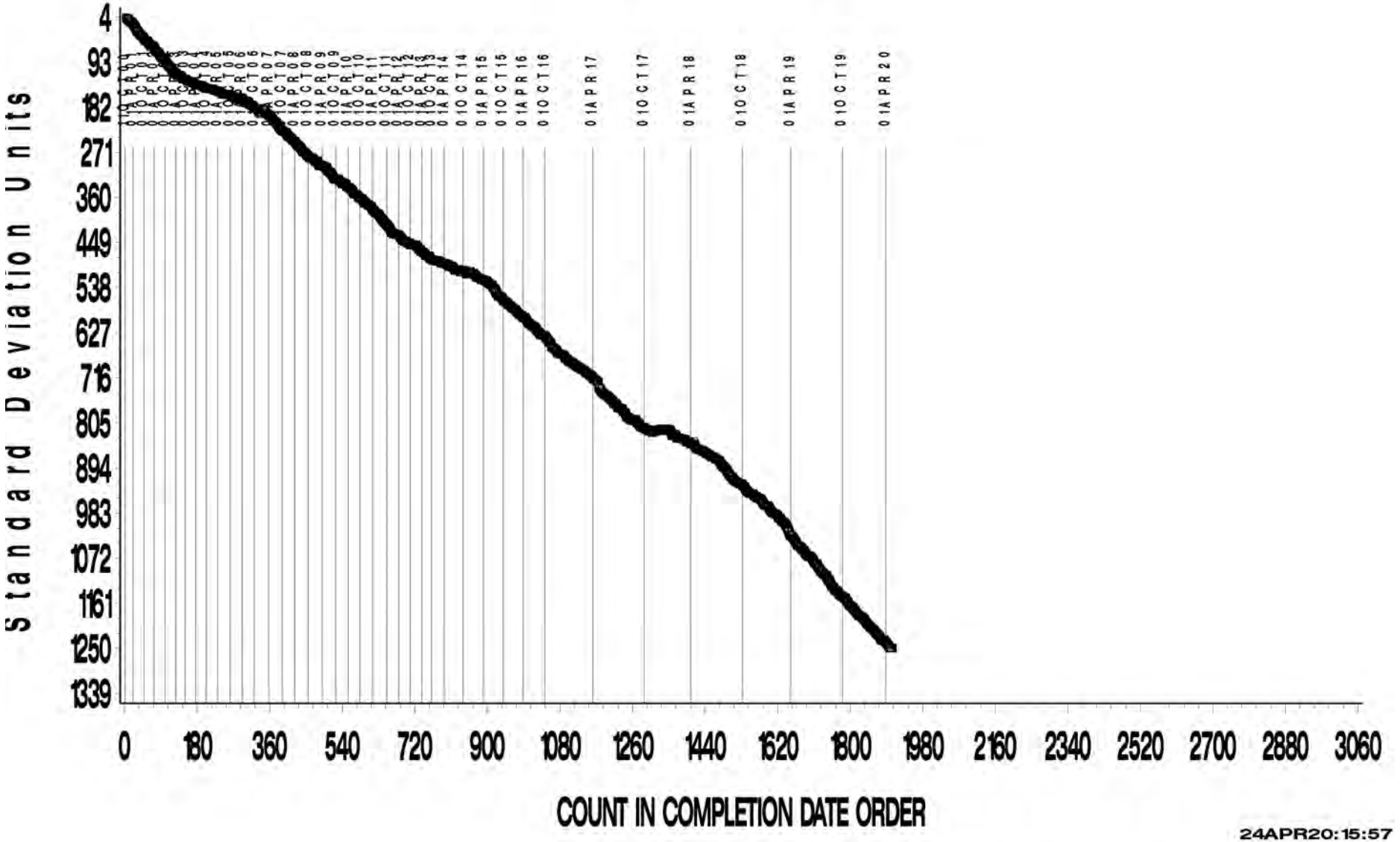
CUSUM Severity Analysis



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D5800 VOLATILITY BY NOACK INDUSTRY OPERATIONALLY VALID DATA
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EVAPORATION LOSS, MASS%

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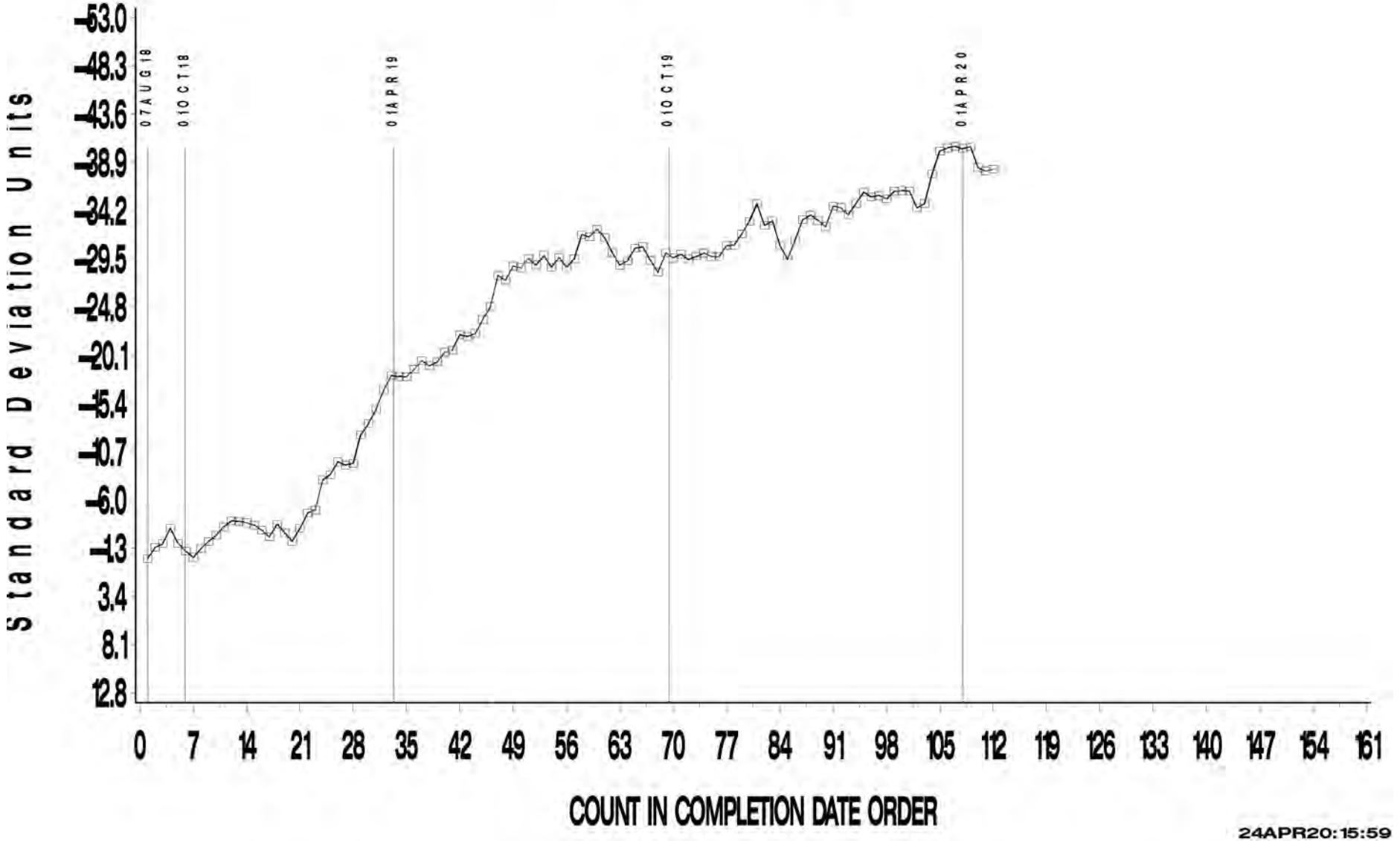
CUSUM Severity Analysis



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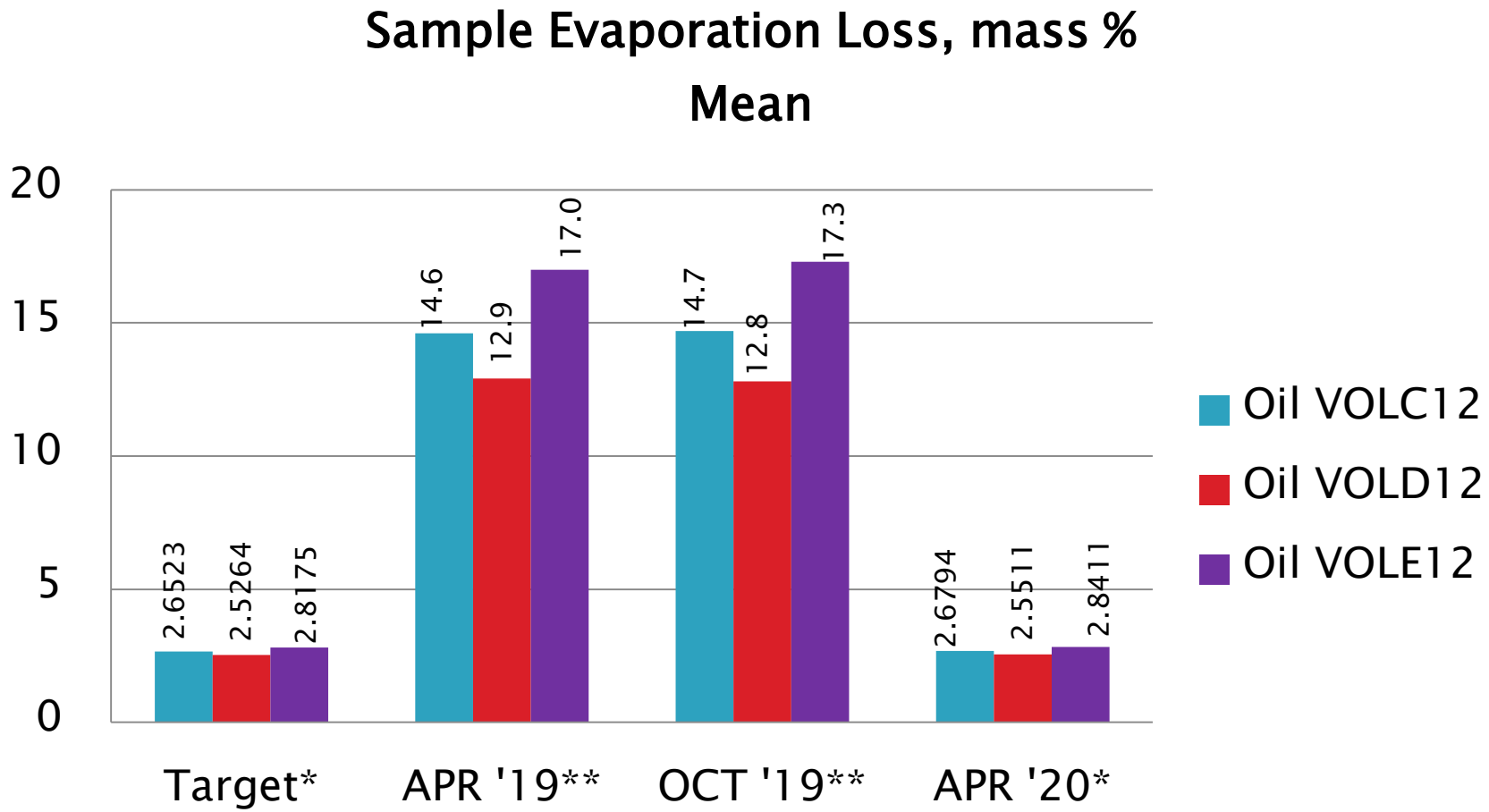
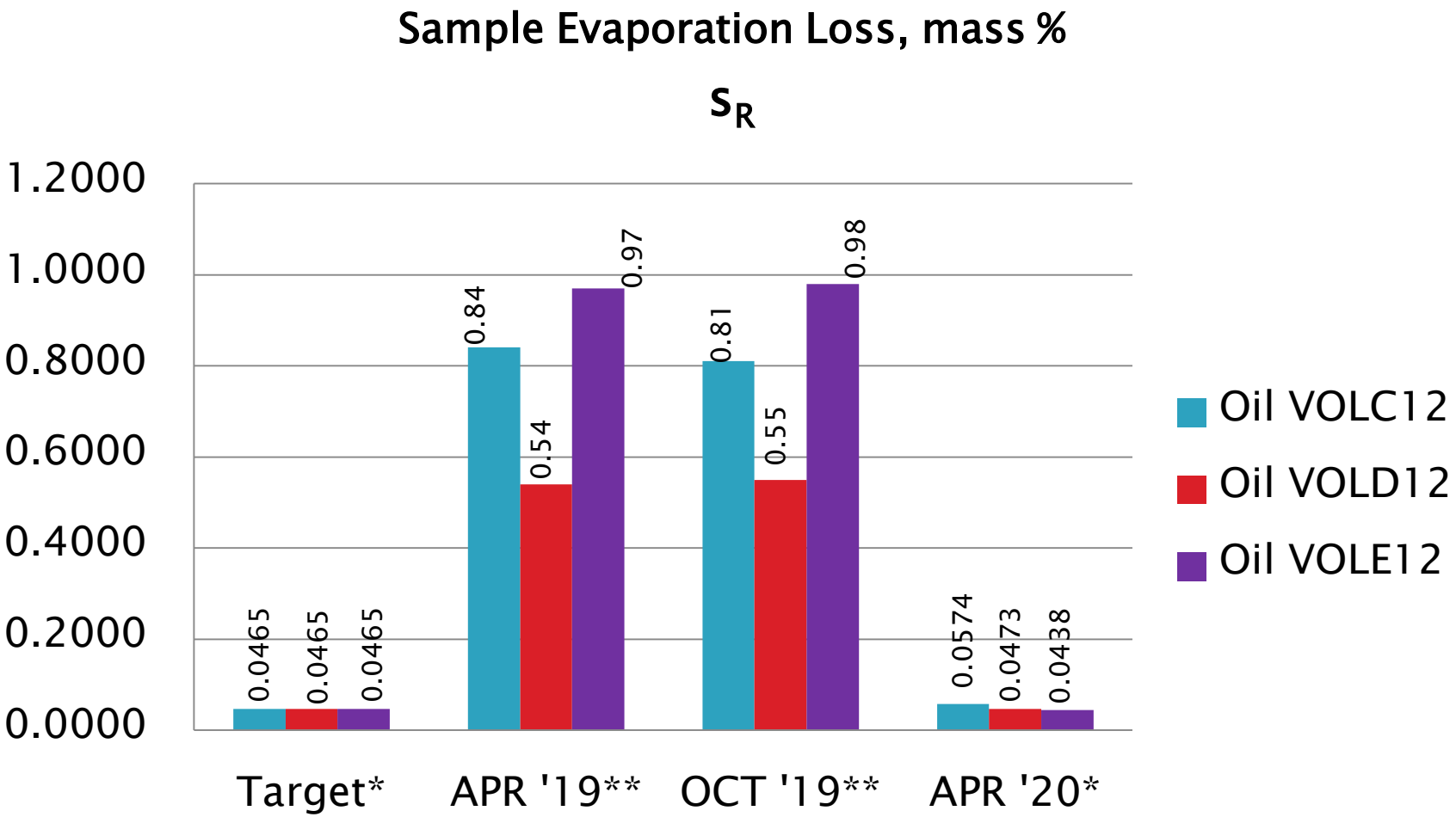
D5800 Performance by Oil



*Results transformed to natural log per updated LTMS 20200207
**Results in original units as monitored at the time

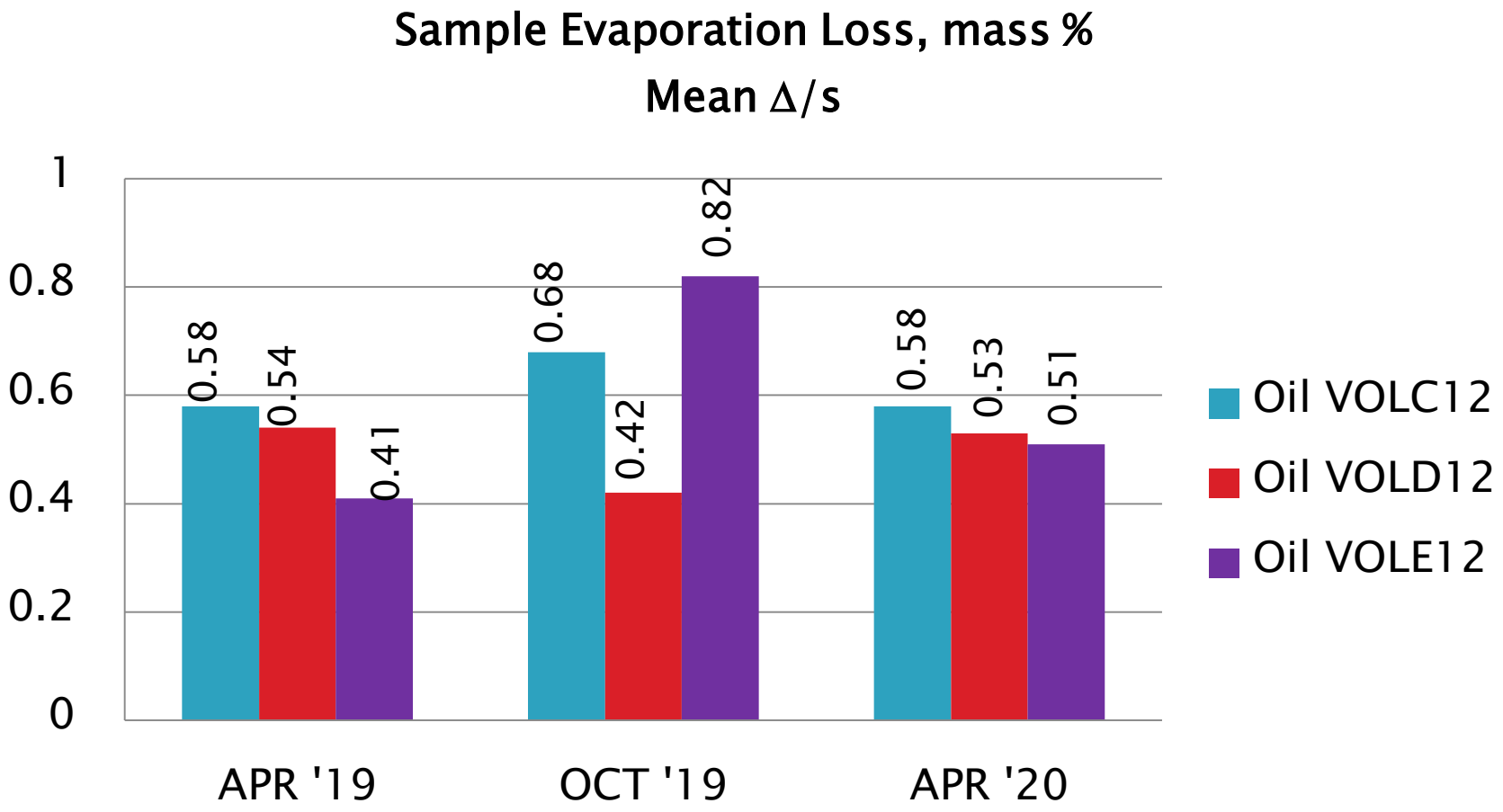
D5800 Performance by Oil



*Results transformed to natural log per updated LTMS 20200207

**Results in original units as monitored at the time

D5800 Performance by Oil



Return to Executive Summary

D5133: Gelation Index

Test Status	Validity Code	No. Tests
Acceptable Calibration Test	AC	36
Failed Calibration Test	OC	5
Operationally Invalidated by Lab	LC, XC	0
Operationally Invalidated After Initially Reported as Valid	RC	0
Total		**41**

Number of Labs Reporting Data: 10
Fail Rate of Operationally Valid Tests: 12%

D5133: Gelation Index

Statistically Unacceptable Tests (OC)	No. Of Tests
Gelation Index Mild	4
Gelation Index Severe	1

- No operationally invalid calibration runs reported this period.
- There was one GI technical update issued this report period:
  - TMC Memo 19-061, November 27, 2019, Updated Test Method D5133-19

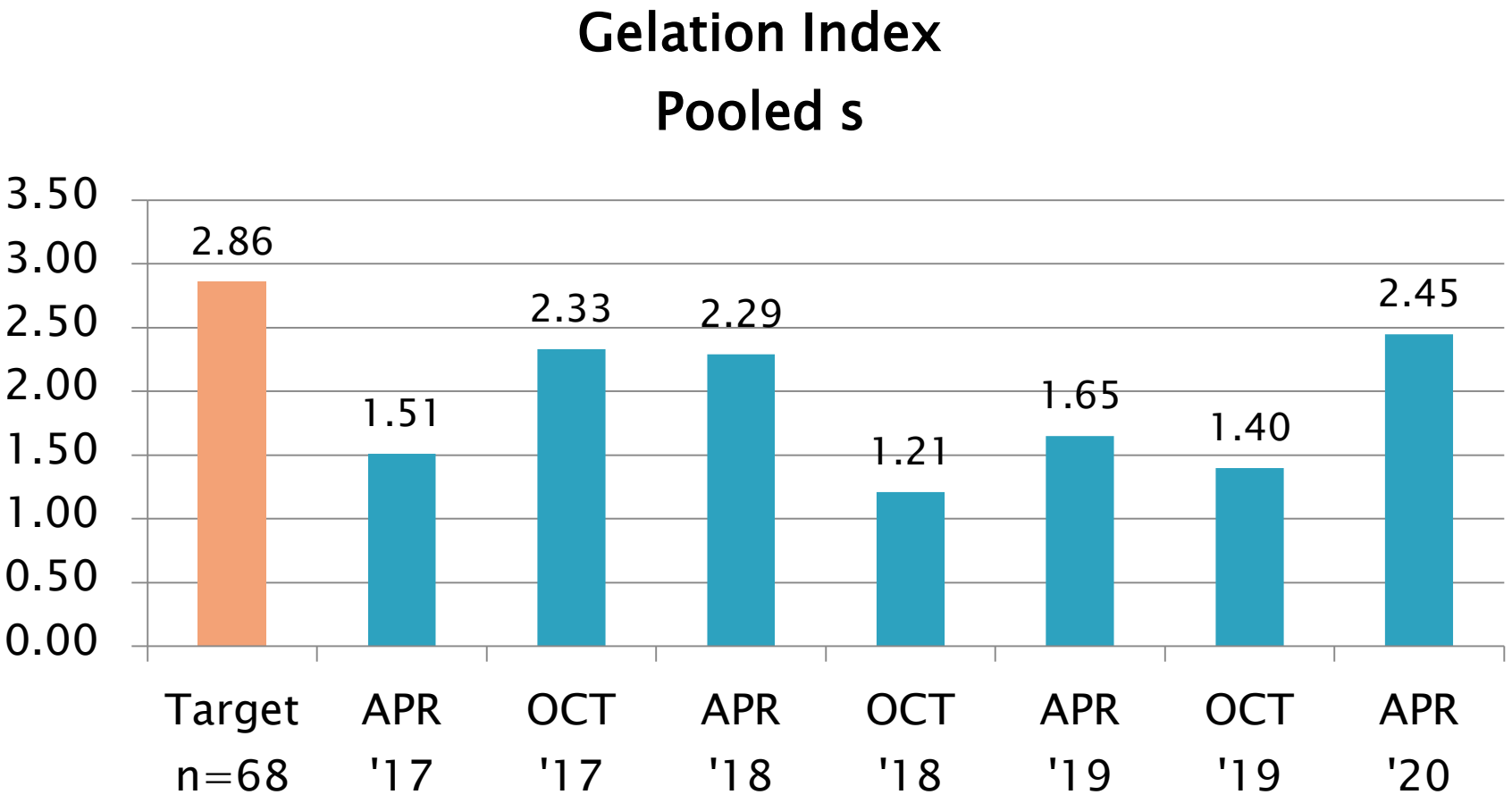
D5133: Gelation Index

Period Precision and Severity Estimates

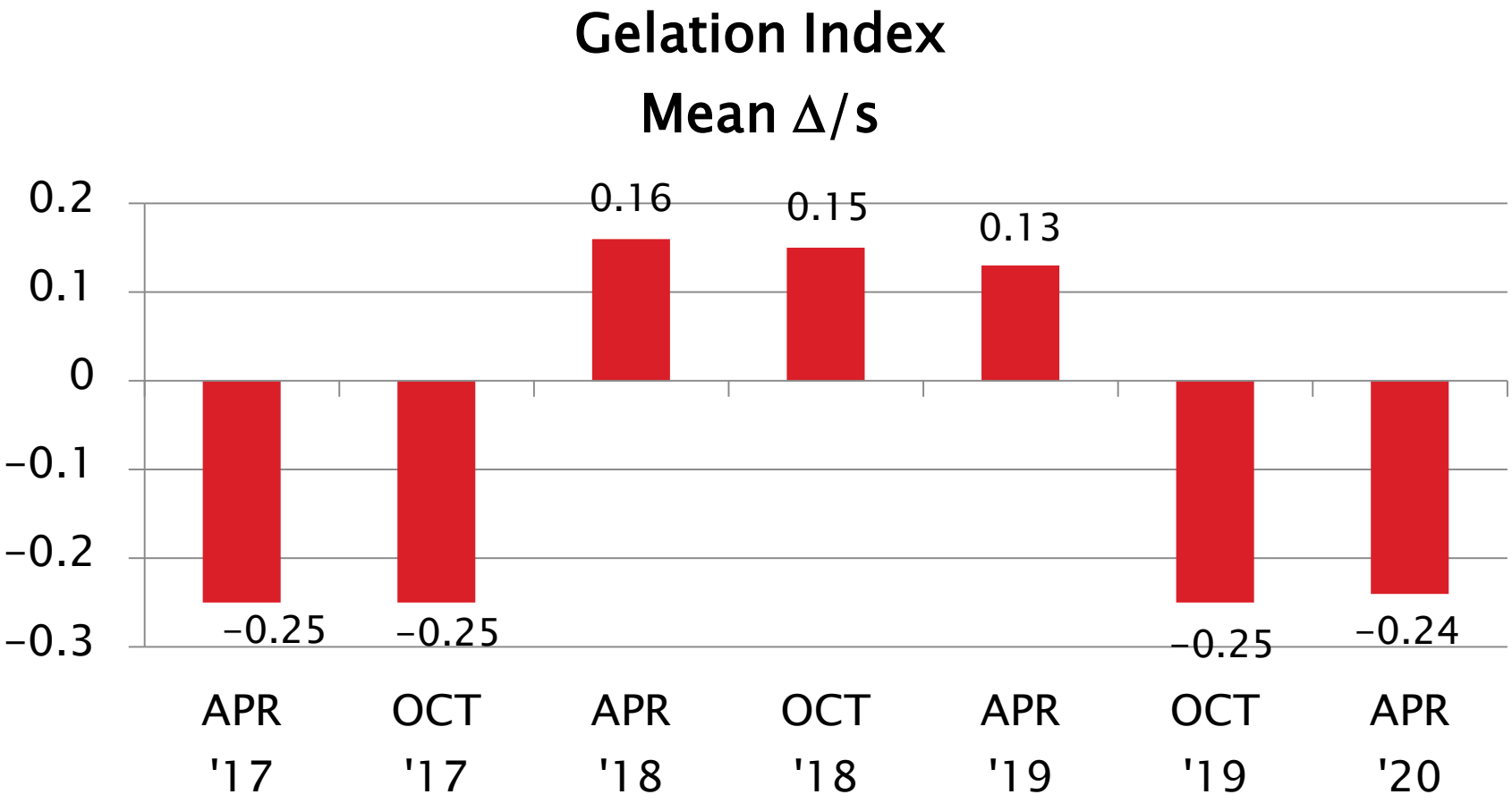
Gelation Index	n	df	Pooled s	Mean Δ/s
Current Targets 7/15/2003	68	65	2.86	-----
4/1/17 through 9/30/17*	30	27	4.69	-0.08
4/1/17 through 9/30/17*	29	26	2.33	-0.25
10/1/17 through 3/31/18	36	33	2.29	0.16
4/1/18 through 9/30/18*	32	29	1.21	0.15
4/1/18 through 9/30/18*	31	28	1.03	-0.02
10/1/18 through 3/31/19	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

*Extreme OC results included and excluded

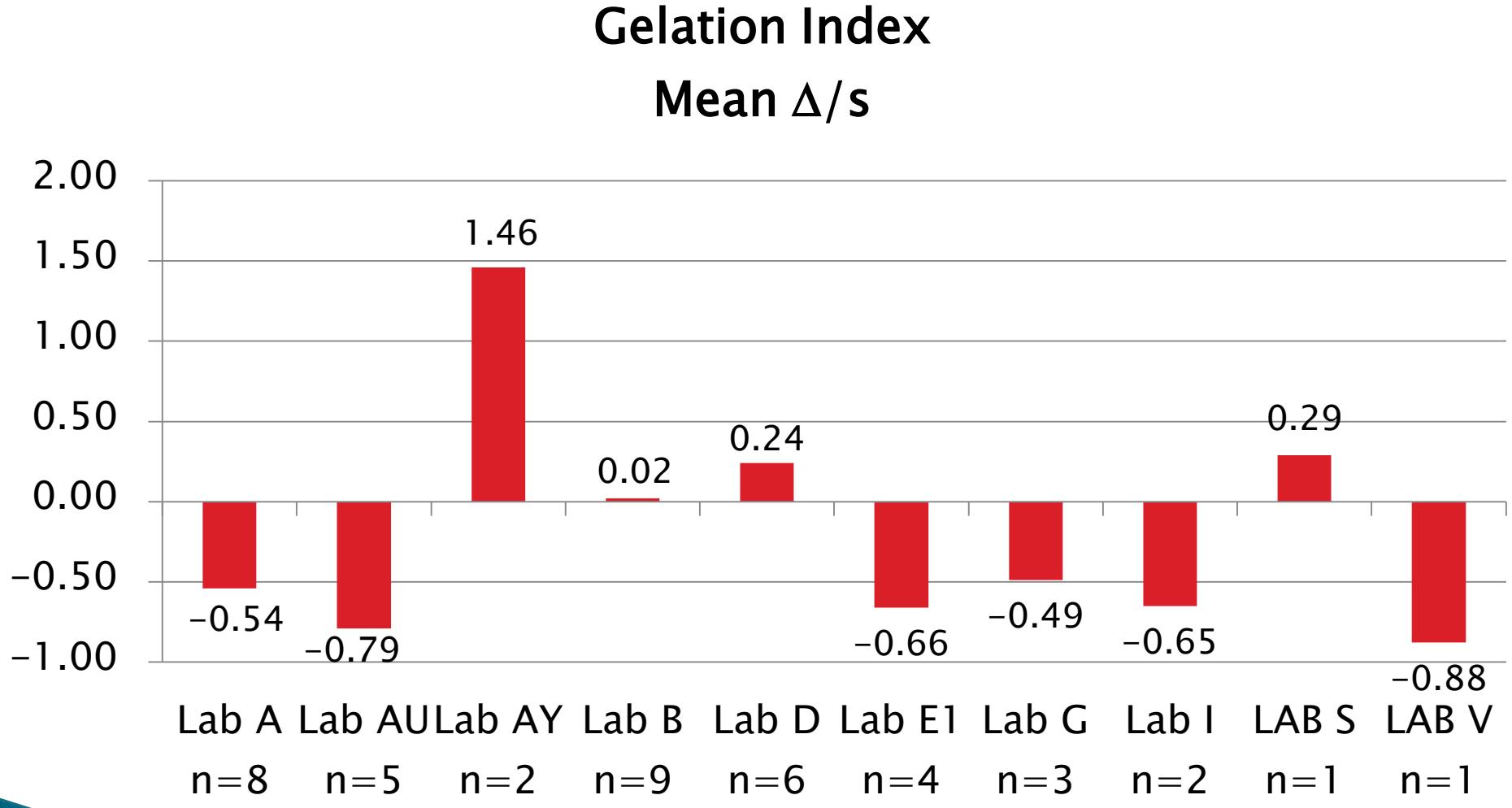
D5133 Precision Estimates



D5133 Severity Estimates



D5133 Lab Severity Estimates



D5133: Gelation Index

- Fail rate of operationally valid tests is 12% this period. Historic period fail rates have ranged between 6% and 26%.
- Precision (Pooled s) is less precise than recent report periods, but more precise than target precision.
- Performance (Mean Δ/s) is -0.24 s mild, comparable to last report period.
- Only one of the five statistically invalid results this period was on low/non-gelling oil 58, the others were on oils with expected measurable gelation index performance.
- Only one result this period was on severe reference oil GIA17 (replacing nearly depleted oil 62), -1.98 s mild.

D5133 GELATION INDEX INDUSTRY OPERATIONALLY VALID DATA

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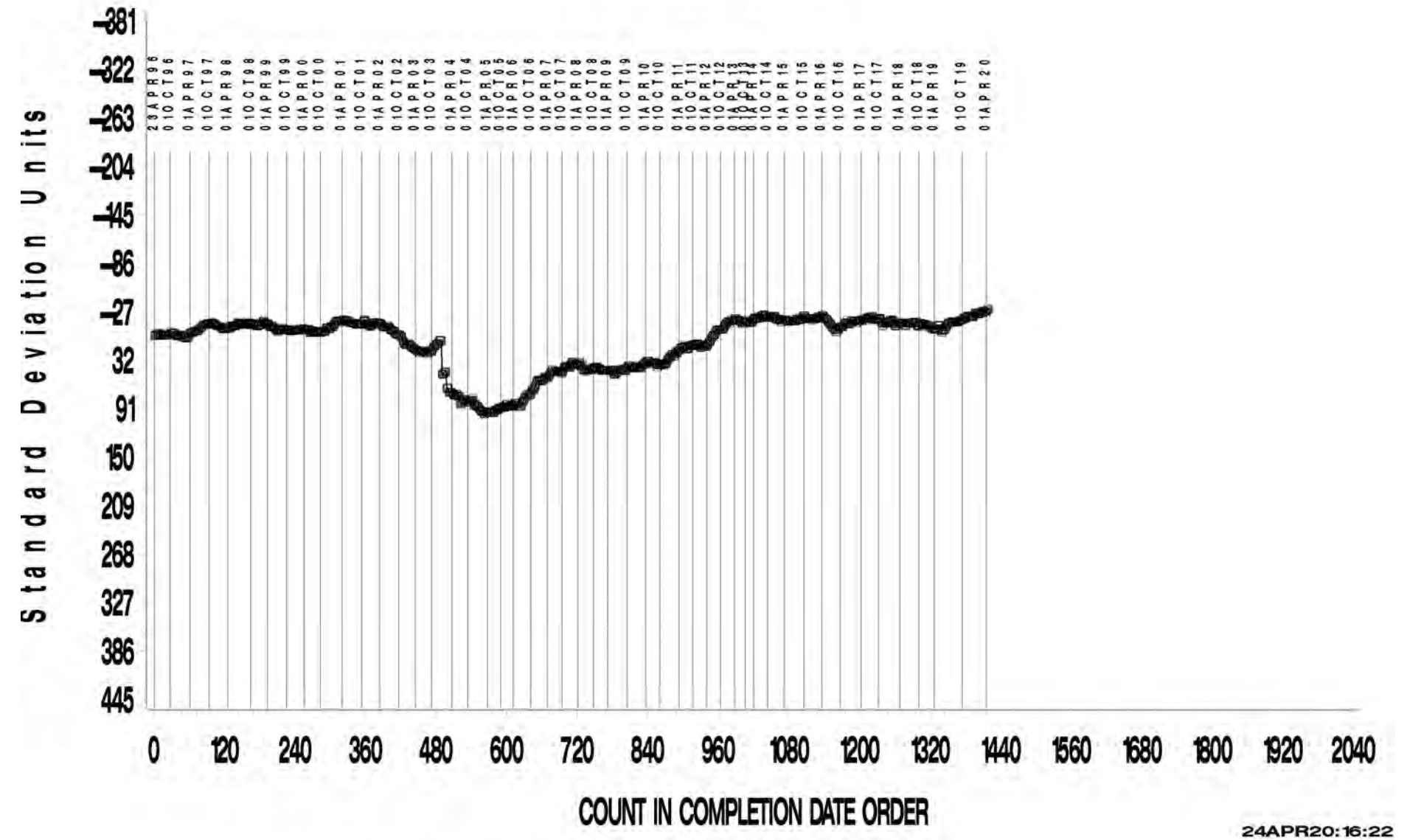
GELATION INDEX

CUSUM Severity Analysis



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D5133 GELATION INDEX INDUSTRY OPERATIONALLY VALID DATA

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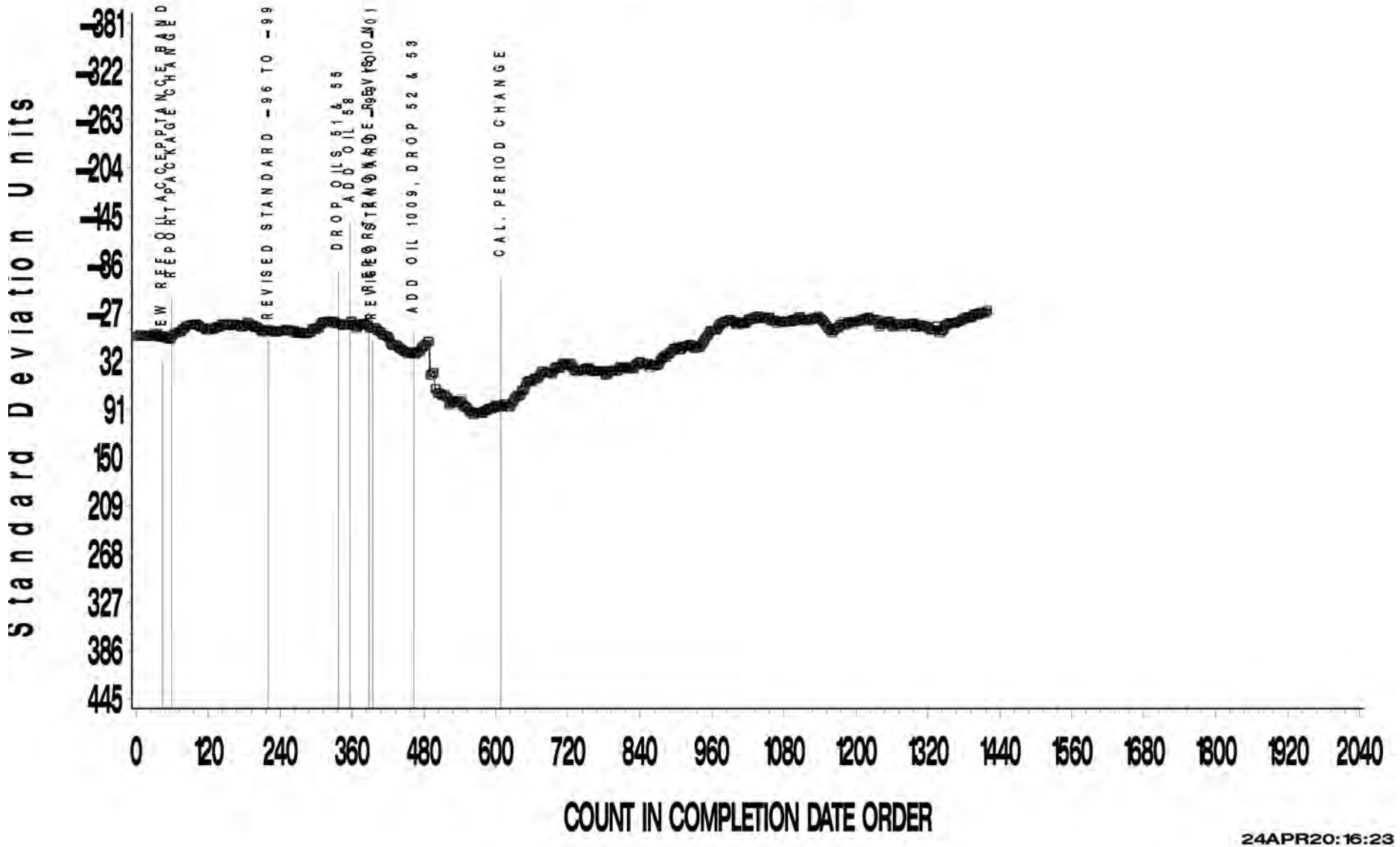
GELATION INDEX

CUSUM Severity Analysis



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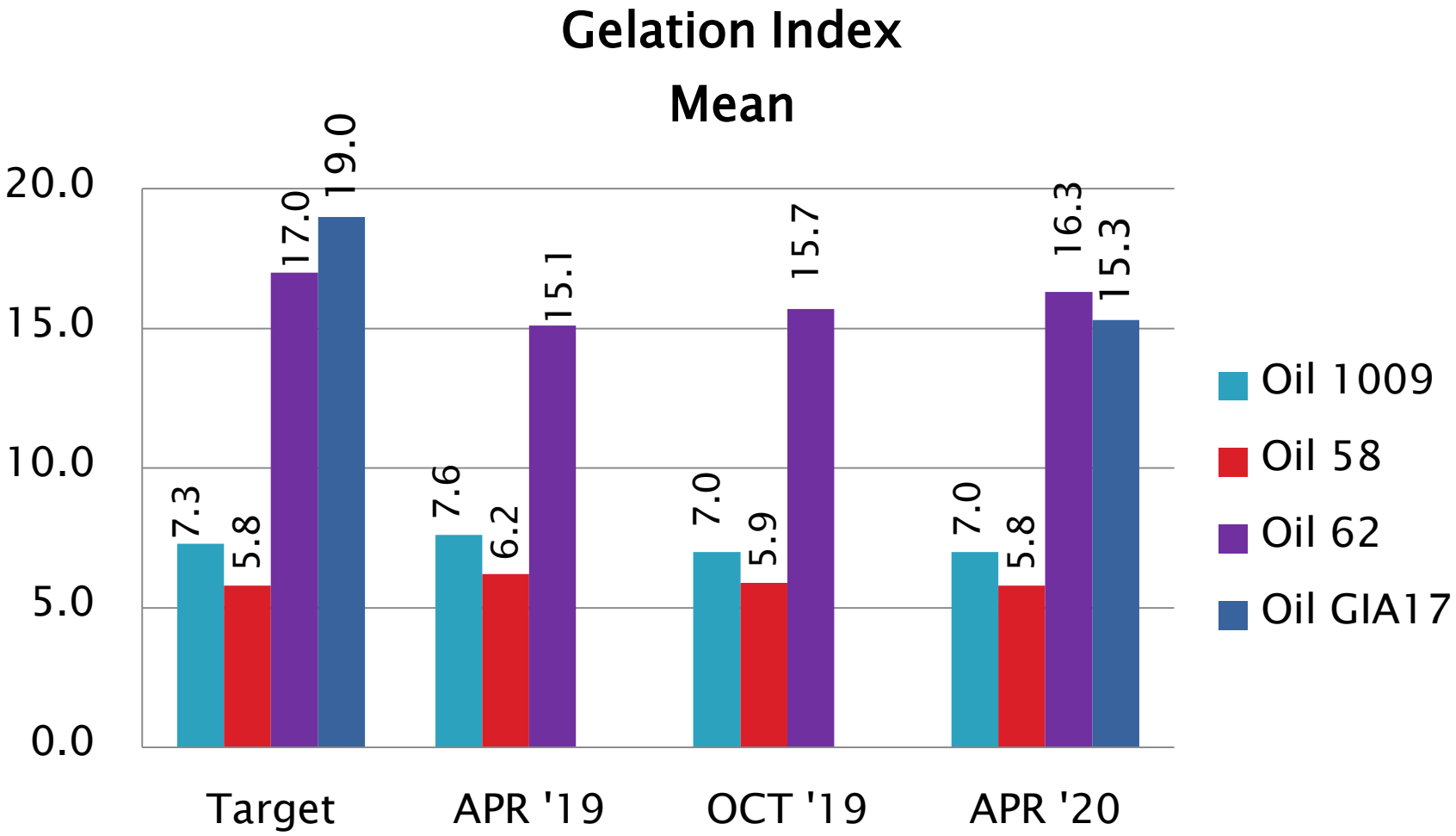
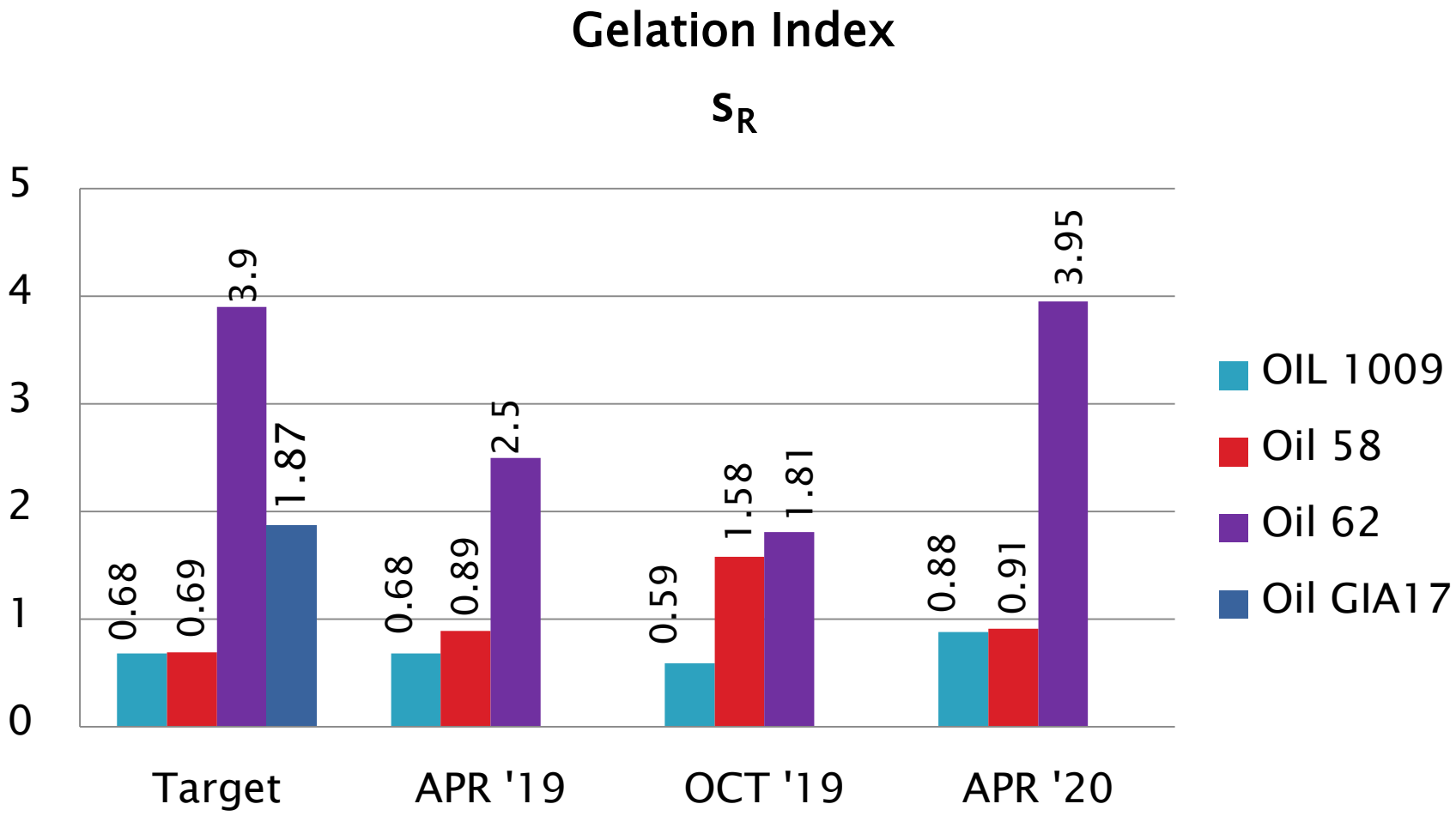
D5133 Performance by Oil



D5133 Performance by Oil



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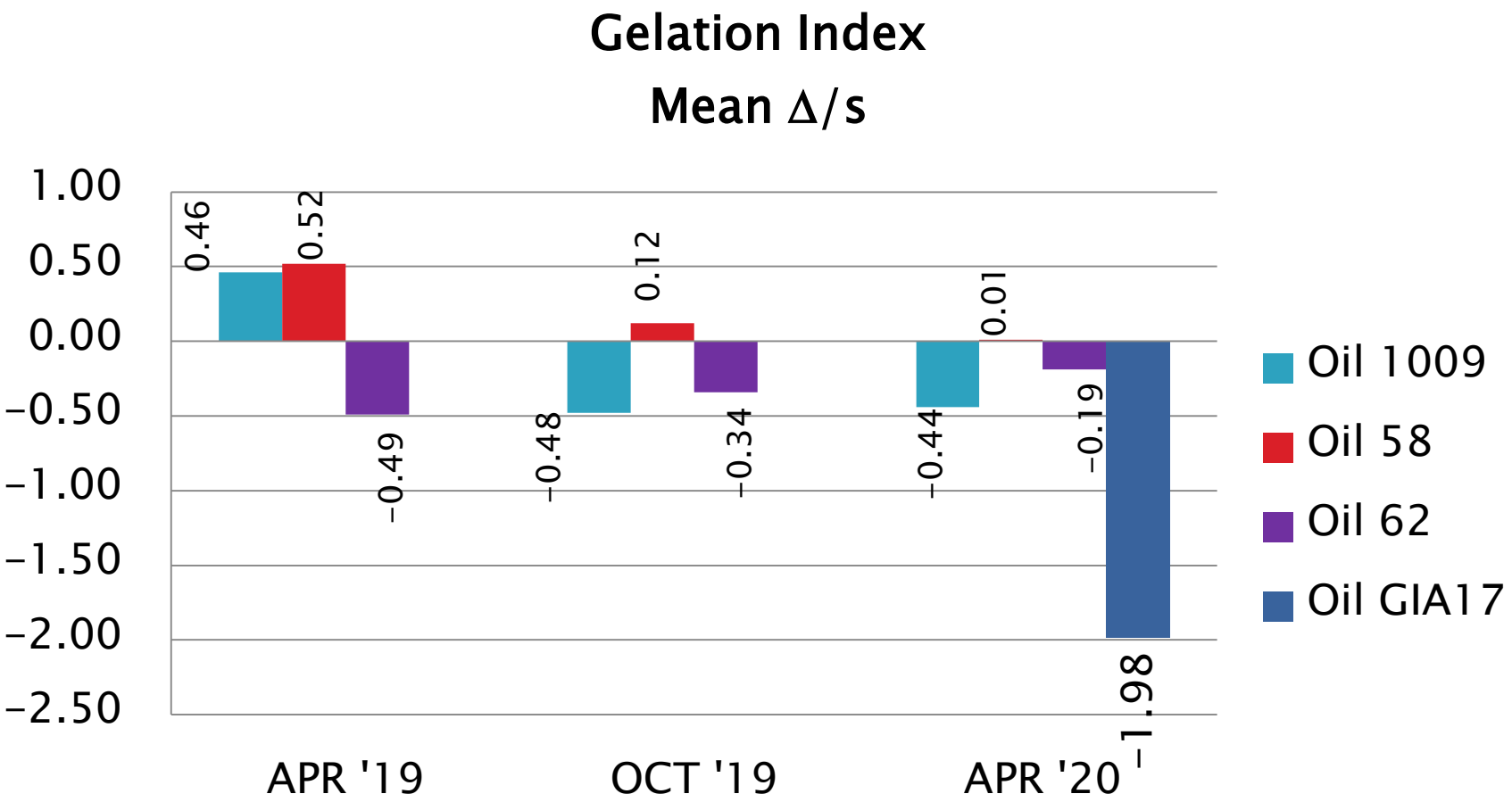
D5133 Performance by Oil



Return to Executive Summary

D6335: Deposits by TEOST-33C

Test Status	Validity Code	No. Tests
Acceptable Calibration Test	AC	32
Failed Calibration Test	OC	0
Operationally Invalidated by Lab	LC, XC	0
Operationally Invalidated After Initially Reported as Valid	RC	0
Total		**32**

Number of Labs Reporting Data: 8
Fail Rate of Operationally Valid Tests: 0%

D6335: Deposits by TEOST-33C

Statistically Unacceptable Tests (OC)	No. Of Tests
Total Deposits Mild	0
Total Deposits Severe	0

- There were no operationally or statistically invalid tests reported this period
  - All reported tests this period passed calibration (AC)

- There was one TEOST technical update issued this report period:
  - TMC Memo 20-002, January 14, 2020, Updated Test Method D6335-19

- Calibration requirement updates are issued as LTMS document updates.

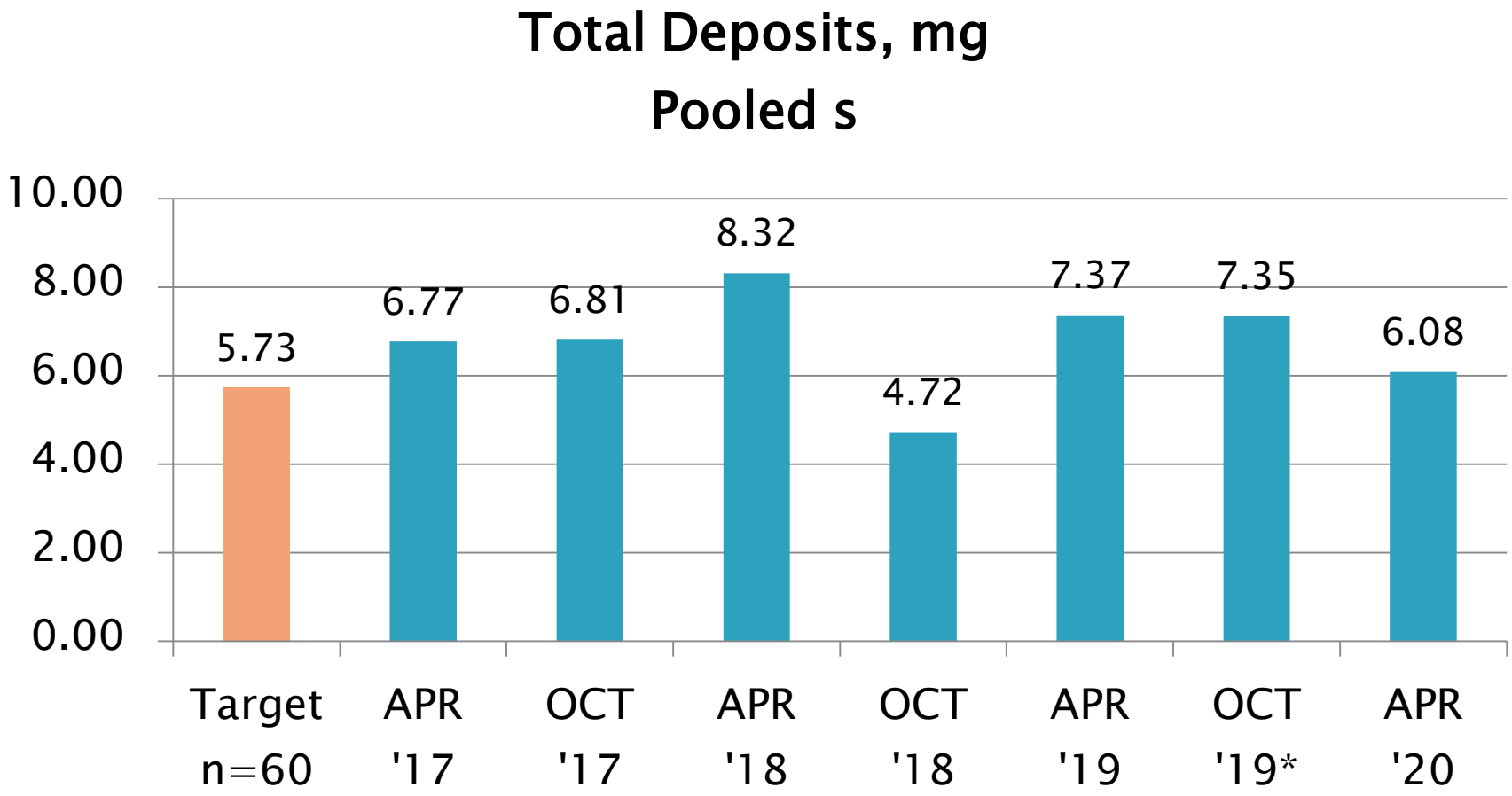
D6335: Deposits by TEOST-33C

Period Precision and Severity Estimates

Total Deposits, mg	n	df	Pooled s	Mean Δ/s
Updated Targets 20130415	60	58	5.73	-----
4/1/17 through 9/30/17*	26	24	6.81	0.00
4/1/17 through 9/30/17*	23	21	5.19	-0.28
10/1/17 through 3/31/18**	27	25	8.32	-0.61
10/1/17 through 3/31/18**	26	24	6.43	-0.45
4/1/18 through 9/30/18	21	19	4.72	-0.33
10/1/18 through 3/31/19	25	23	7.37	0.11
4/1/17 through 9/30/17***	30	28	12.66	0.47
4/1/17 through 9/30/17***	26	24	7.35	-0.23
10/1/19 through 3/31/20	32	30	6.08	0.28

*Three consecutive OC results on same rig included and excluded.
**Single result of -4.6 s mild included and excluded
*** Four consecutive OC results on same rig included and excluded.

D6335 Precision Estimates



* Four consecutive OC results on same rig excluded.

Test Monitoring Center
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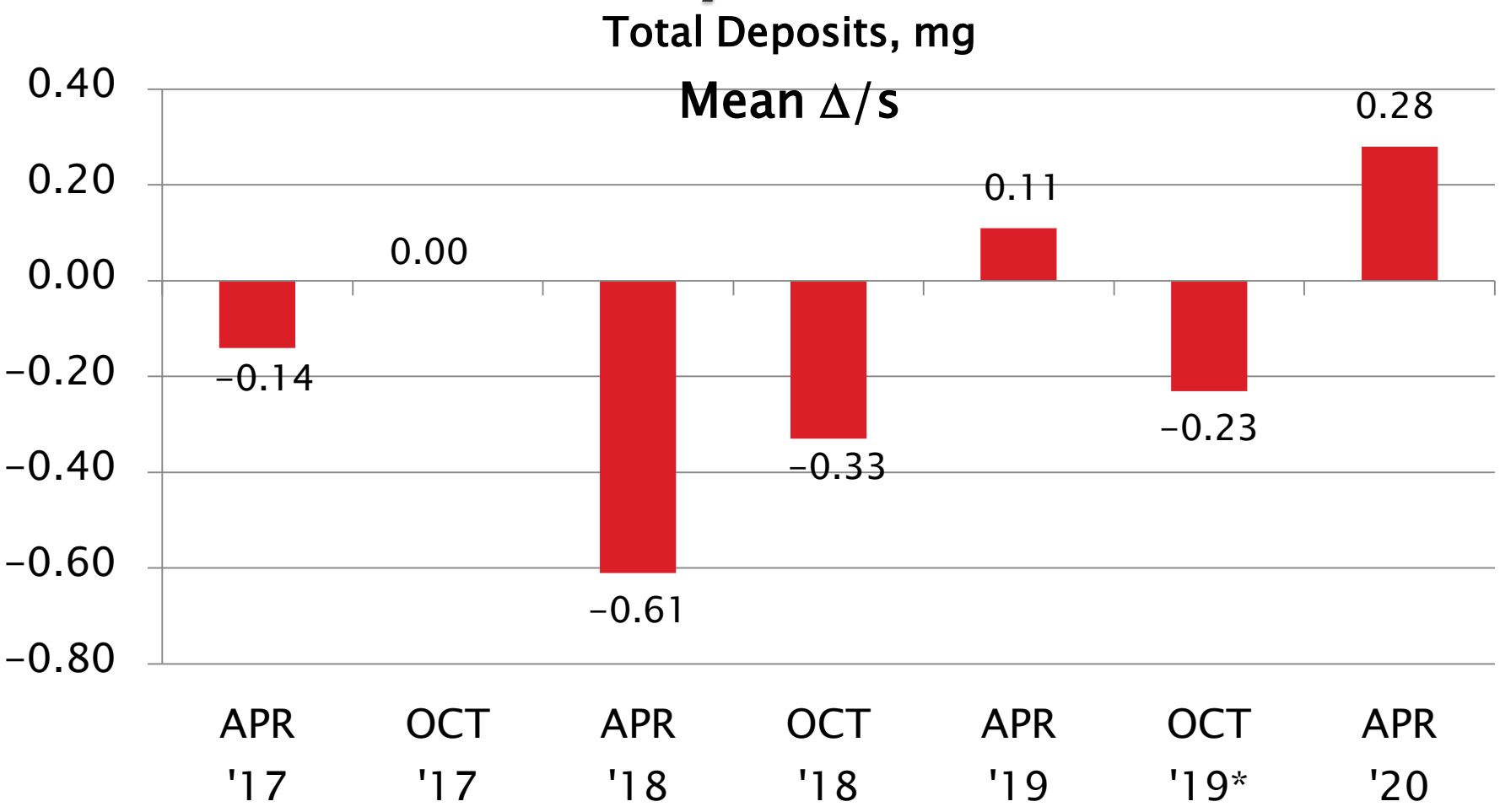
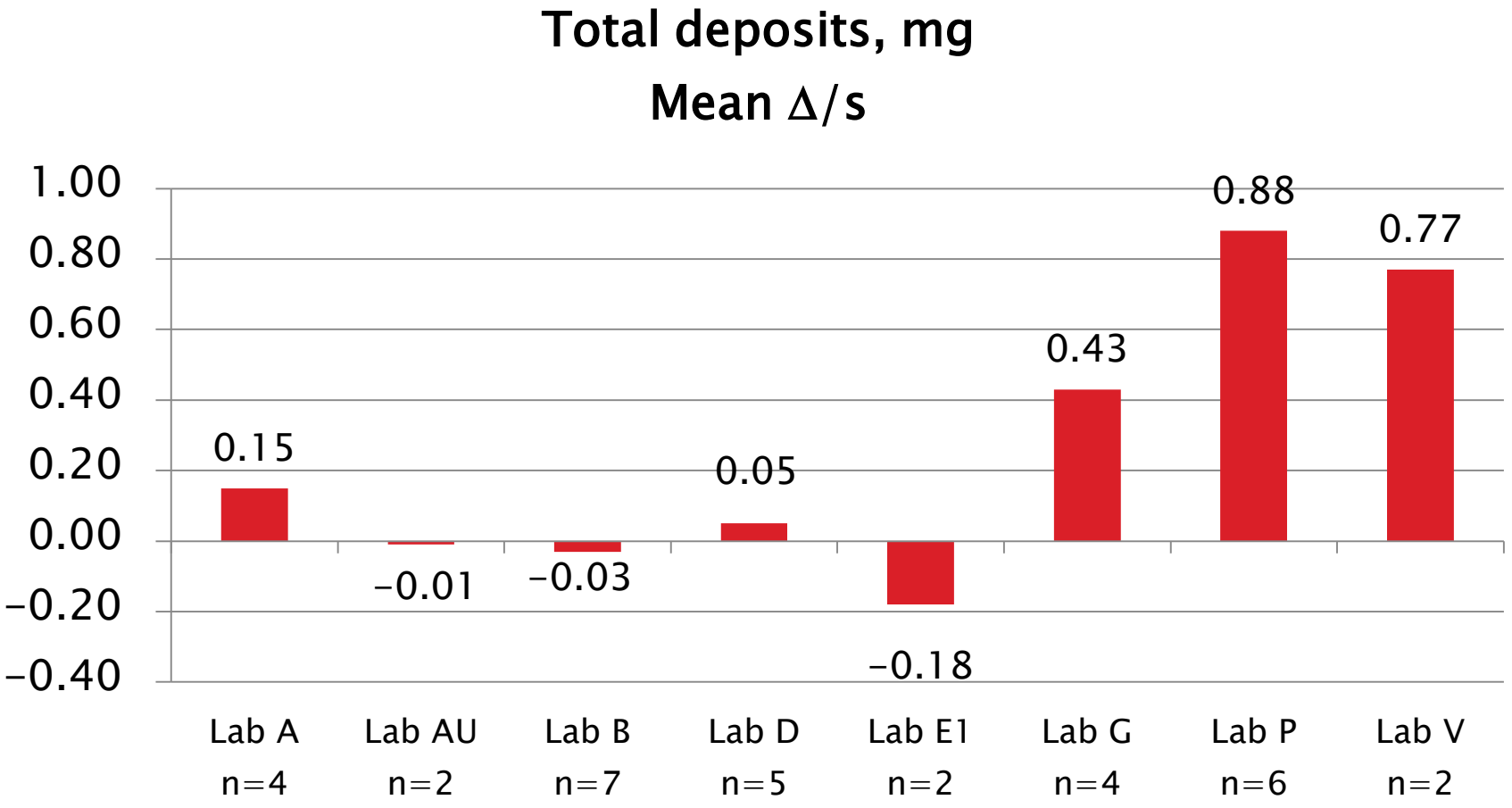
D6335 Severity Estimates



* Four consecutive OC results on same rig excluded.

D6335 Lab Severity Estimates



D6335: Deposits by TEOST-33C

- Precision (Pooled s) is more precise than prior period, and less precise than target precision.
- Performance (Mean Δ/s) is 0.28 s severe.
- Period Fail rate of 0% is remarkable
  - Fail rates last two periods have been 20% and 23%, and similarly high in prior periods
- All tests this period report using Rod Batch M.
- Oil 75-1 (reblend) was approved on 20190404 to replace severe performing reference oil 75, which is depleted at the TMC
  - Still assigning oil 75 out of lab inventories until gone.
  - There were no calibrations on oil 75-1 this period.

TEOST—33C INDUSTRY OPERATIONALLY VALID DATA

TOTAL DEPOSITS MG

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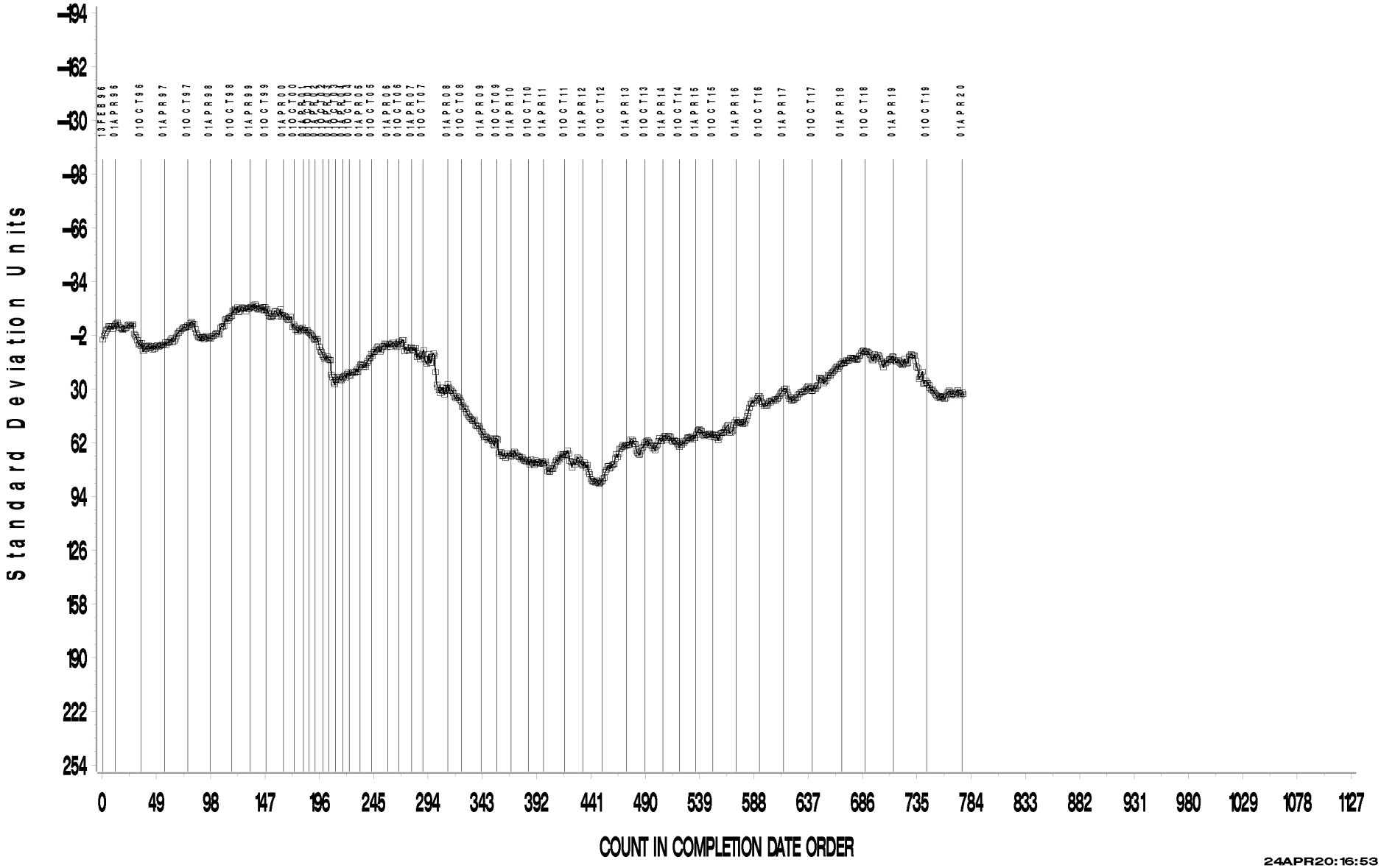
CUSUM Severity Analysis



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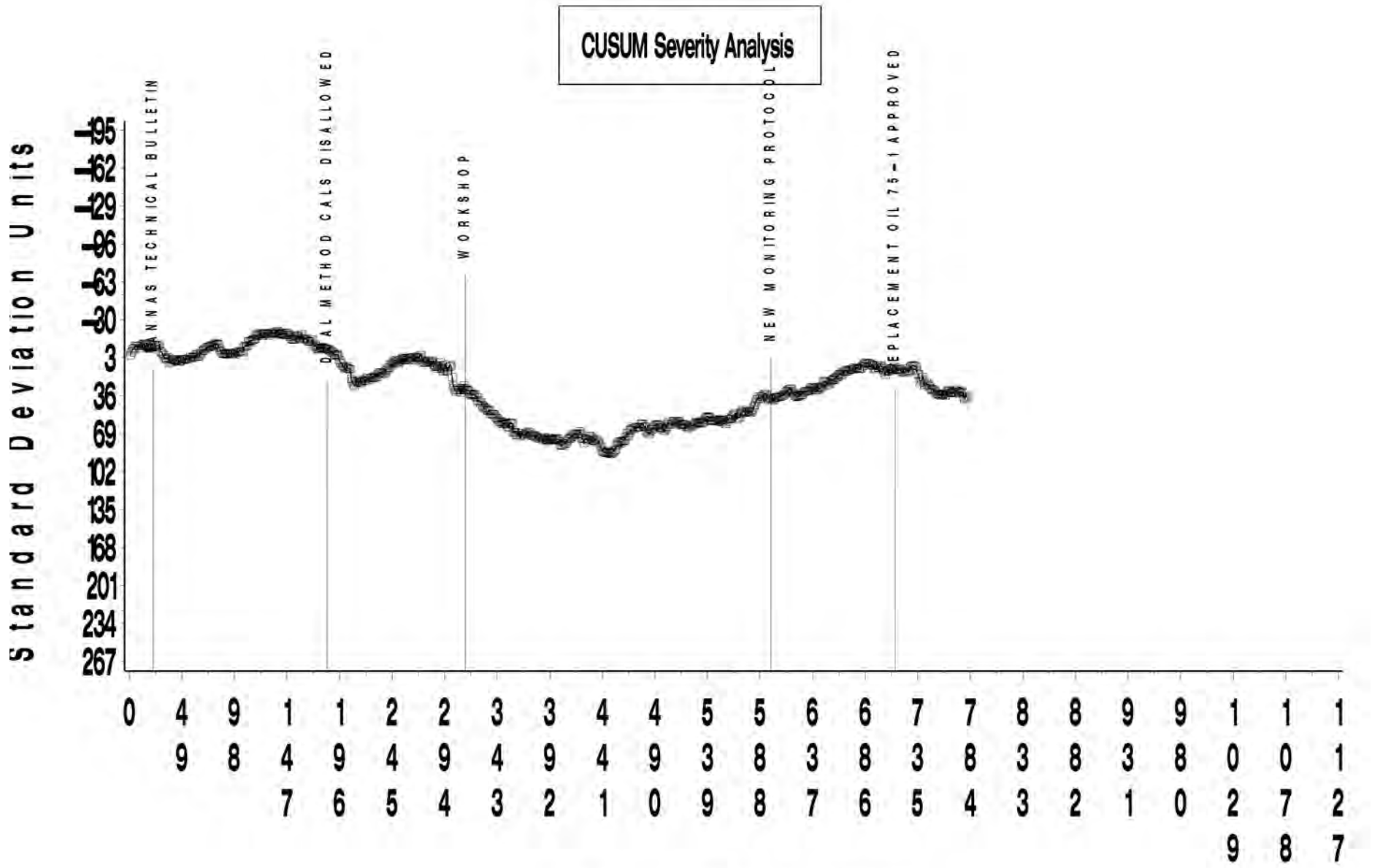
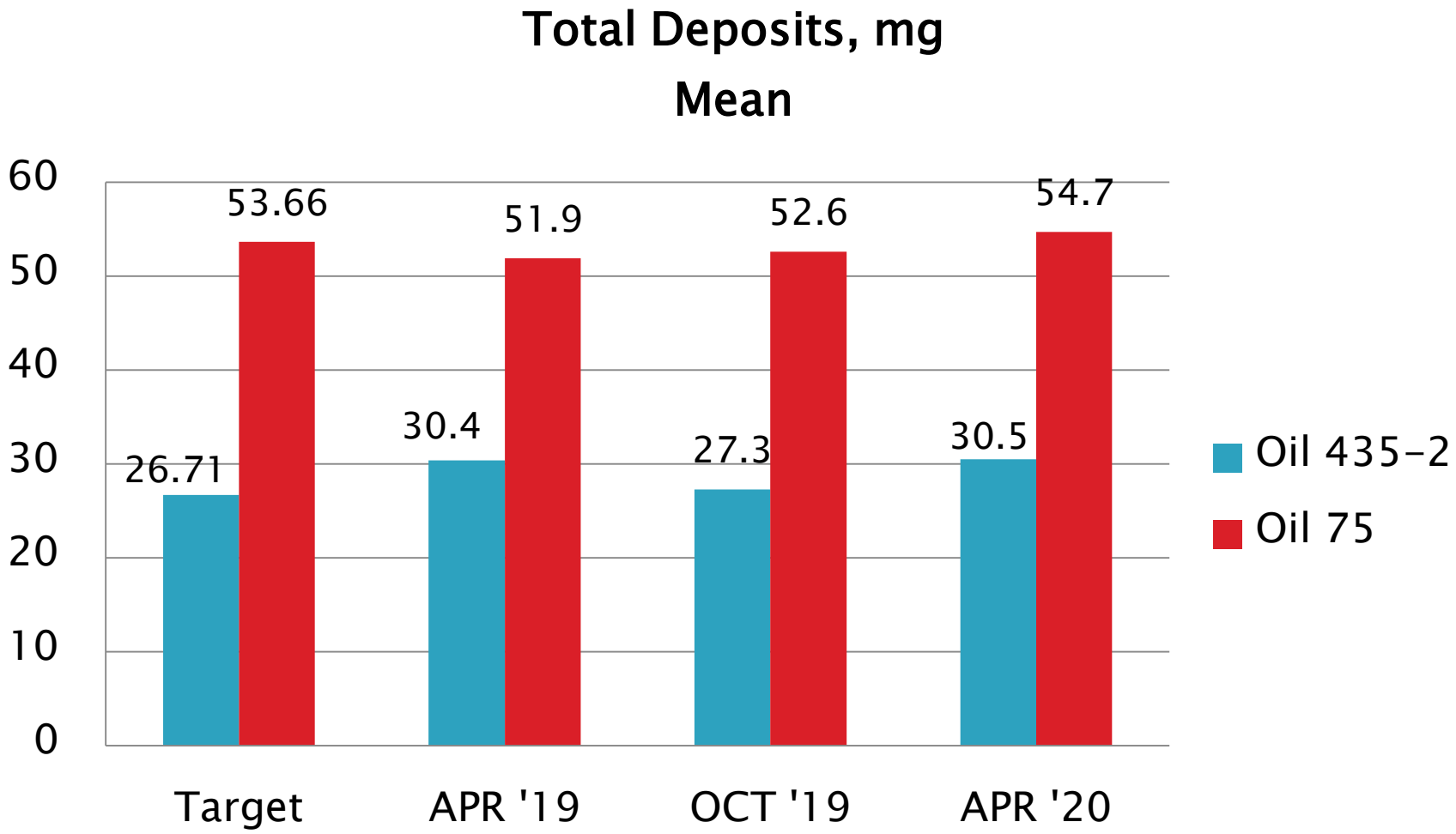
TEOST –33C INDUSTRY OPERATIONALLY VALID DATA

TOTAL DEPOSITS MG

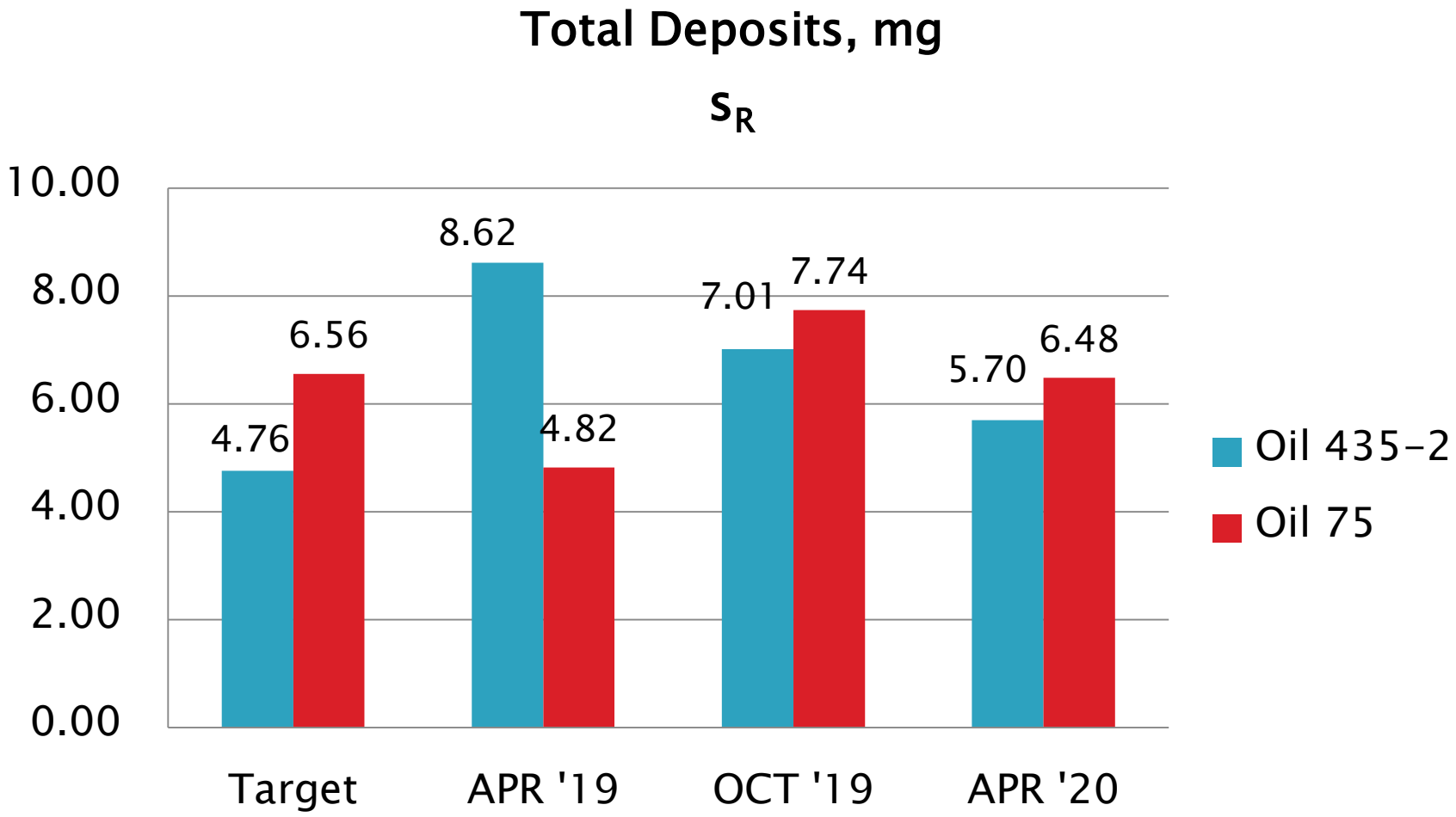


15MAY20:18:38

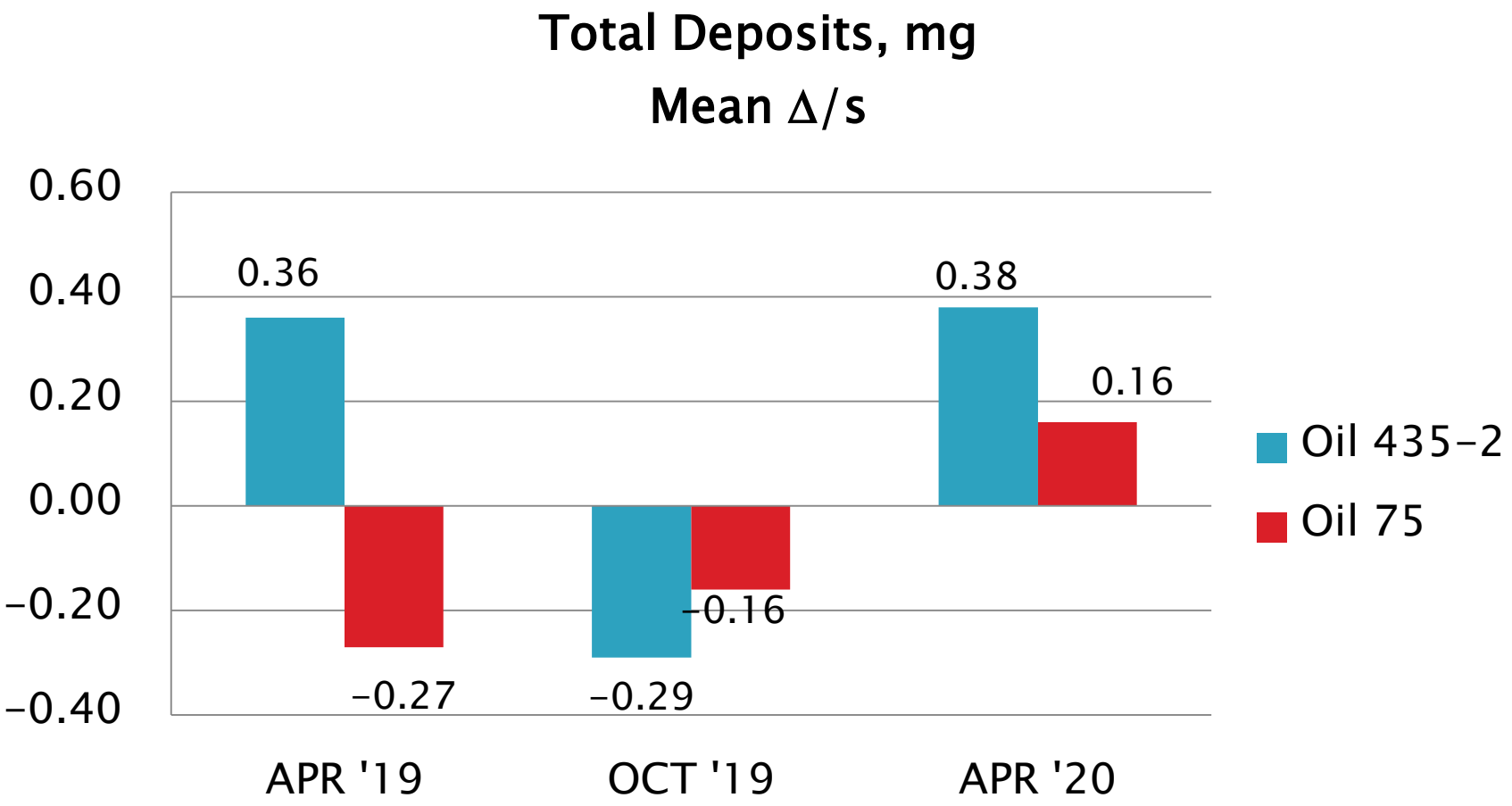
D6335 Performance by Oil



D6335 Performance by Oil



D6335 Performance by Oil



Return to Executive Summary

D7097: Deposits by MHT TEOST

Test Status	Validity Code	No. Tests
Acceptable Calibration Test	AC	96
Failed Calibration Test	OC	7
Operationally Invalidated by Lab	LC, XC	2
Operationally Invalidated After Initially Reported as Valid	RC	2
Total		**107**

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

D7097: Deposits by MHT TEOST

Statistically Unacceptable Tests (OC)	No. Of Tests
Total Deposits Mild	0
Total Deposits Severe	7

- Four operationally invalid calibration test reported this period:
  - 1 test aborted due to heater failure (XC)
  - 1 test broken mantle discovered post-test (LC)
  - 2 tests with off-spec pump speed, initially reported as operationally valid but failed statistically (RC), post-test discovery
- There were two MTEOS technical updates issued this report period:
  - TMC Memo 19-060, November 26, 2019, Updated Reference Oil Targets
  - TMC Memo 20-003, January 14, 2020, Updated Test Method D7097-19
- Calibration requirement updates are issued as LTMS document updates.

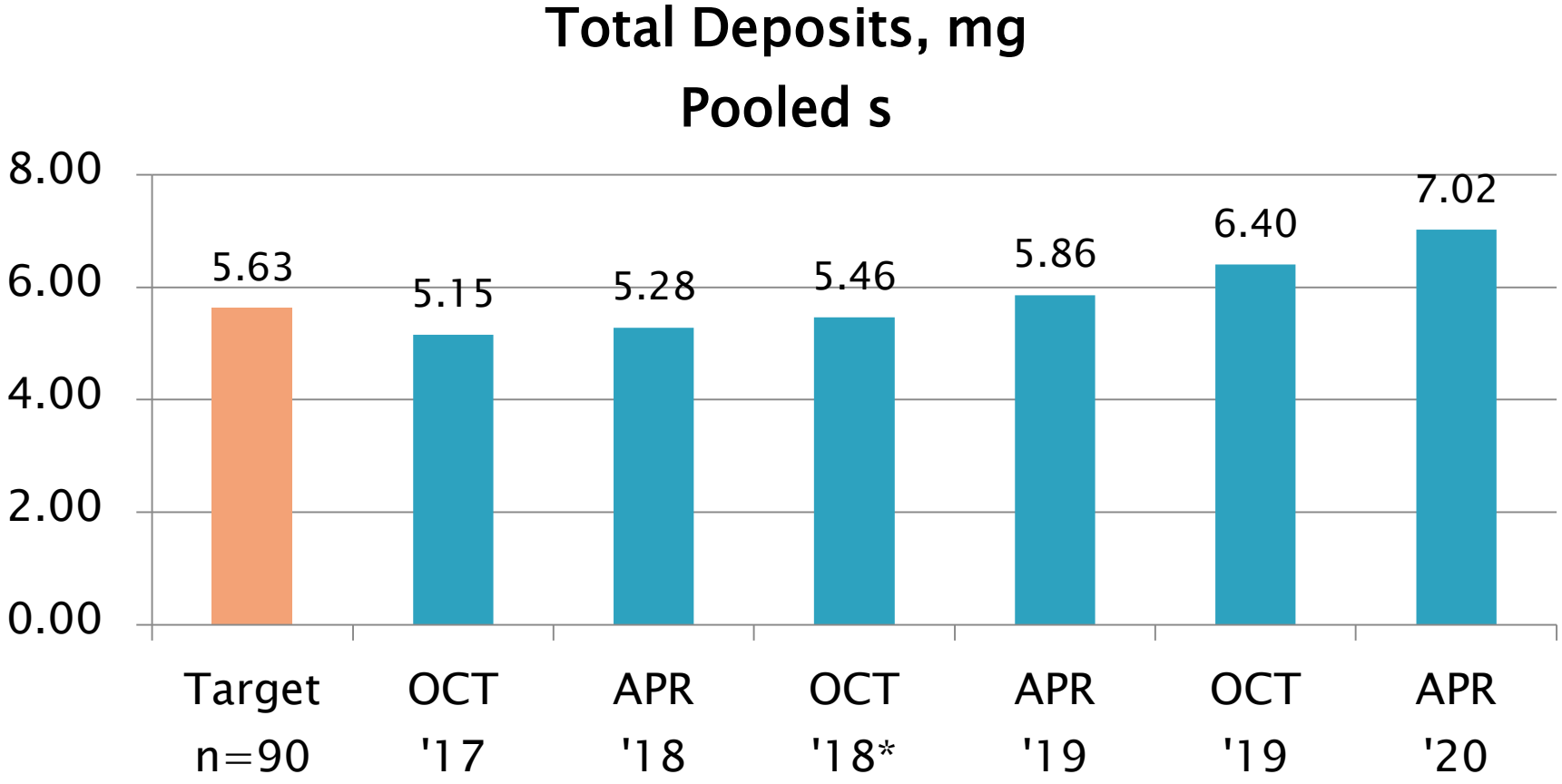
D7097: Deposits by MHT TEOST

Period Precision and Severity Estimates

Total Deposits, mg	n	df	Pooled s	Mean Δ/s
Current Targets 7/31/2006	90	87	5.63	-----
4/1/17 through 9/30/17	83	81	5.15	0.14
10/1/17 through 3/31/18	88	86	5.28	0.33
4/1/18 through 9/30/18*	95	93	6.69	0.29
4/1/18 through 9/30/18*	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

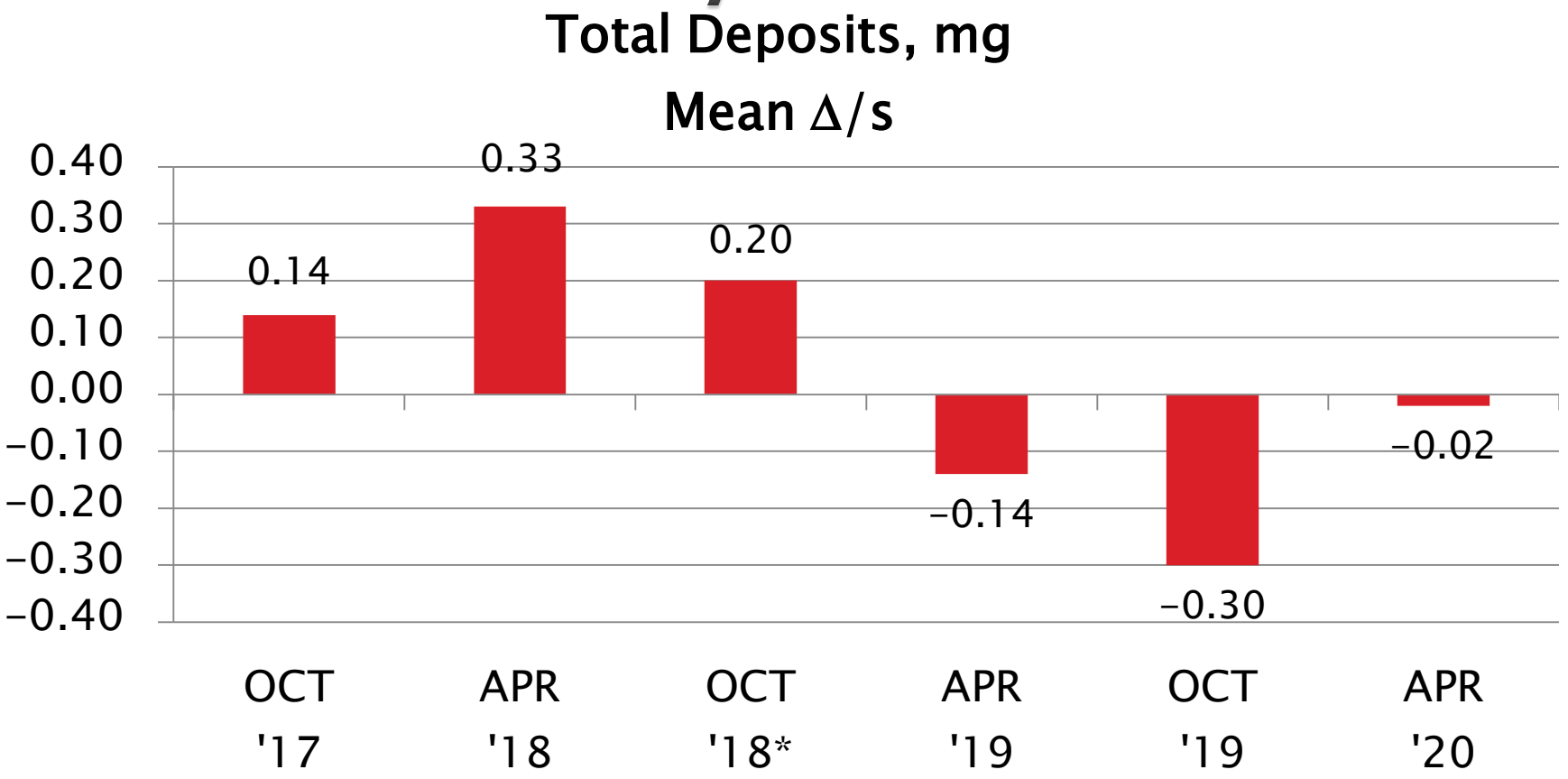
*One severe OC test from instrument G5 included and excluded (8.9 s)

D7097 Precision Estimates



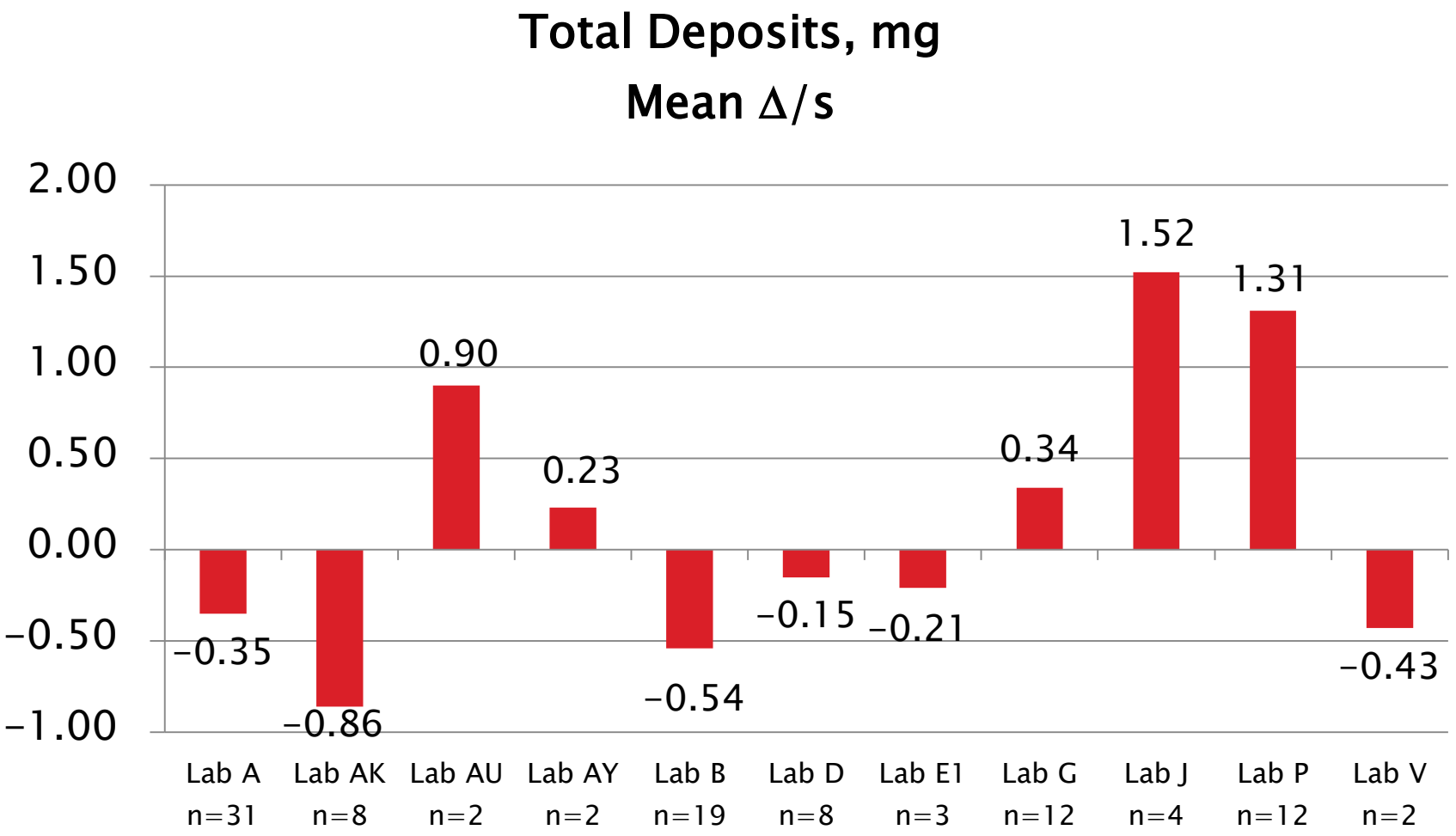
*One severe OC test from instrument G5 excluded (8.9 s)

D7097 Severity Estimates



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

D7097 Lab Severity Estimates



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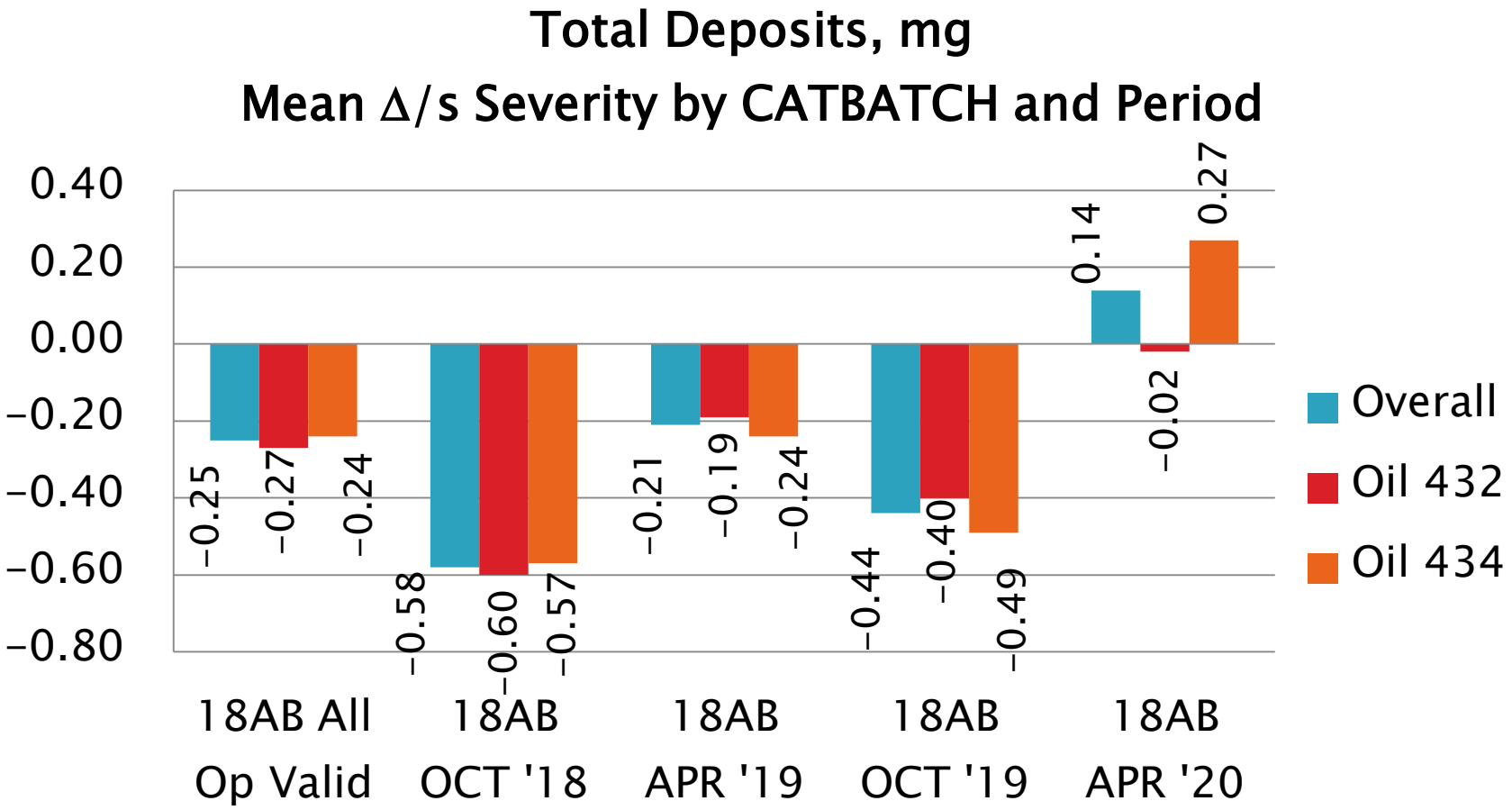
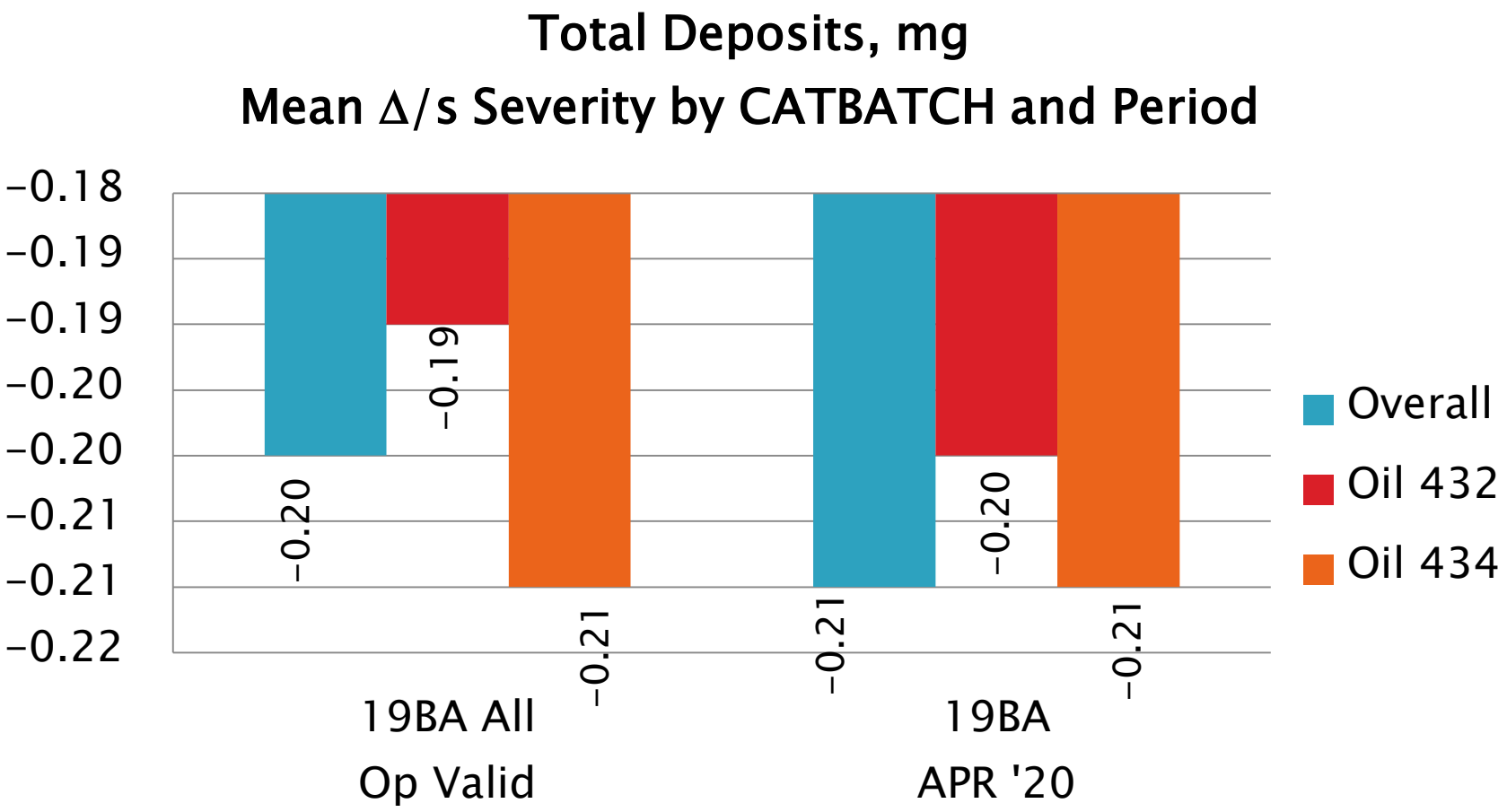
D7097: Deposits by MHT TEOST



D7097: Deposits by MHT TEOST



D7097: Deposits by MHT TEOST

- Precision (Pooled s) is less precise than the prior report period and less precise than target precision
  - Increasingly poorer precision trend noted for each period since at least October 2017
- Performance (Mean Δ/s) is on-target
  - Failing tests all trending severe, no mild fails,
    - Three on oil 432 and four on oil 434
    - Across four labs and four instruments
    - Four tests exceed 3 s severe, most severe was 4.6 s
- All operationally valid tests this period report using Rod Batch M
- All operationally valid calibration tests this period report using Catalyst Batch 15AA (n=2), 18AB (n=51) or 19BA (n=48)
- Overall severity on catalyst batch 19BA (n=51) appears to be about -0.20 s mild, and comparably mild on both reference oils.
  - Catalyst Batch 18AB is, overall, performing similarly mild (n=242)

MHT—4 TEOST INDUSTRY OPERATIONALLY VALID DATA

TOTAL DEPOSITS MG

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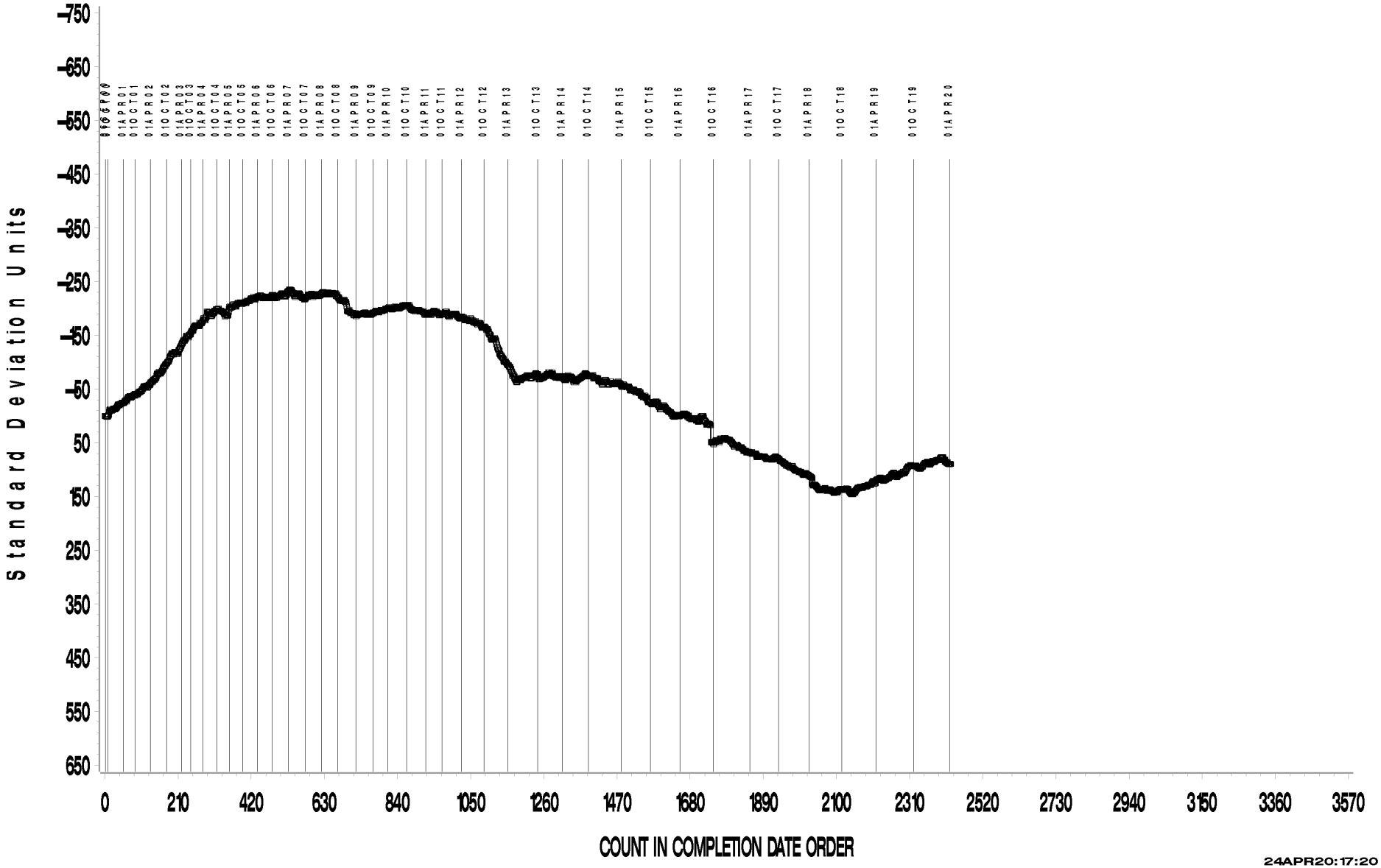
CUSUM Severity Analysis



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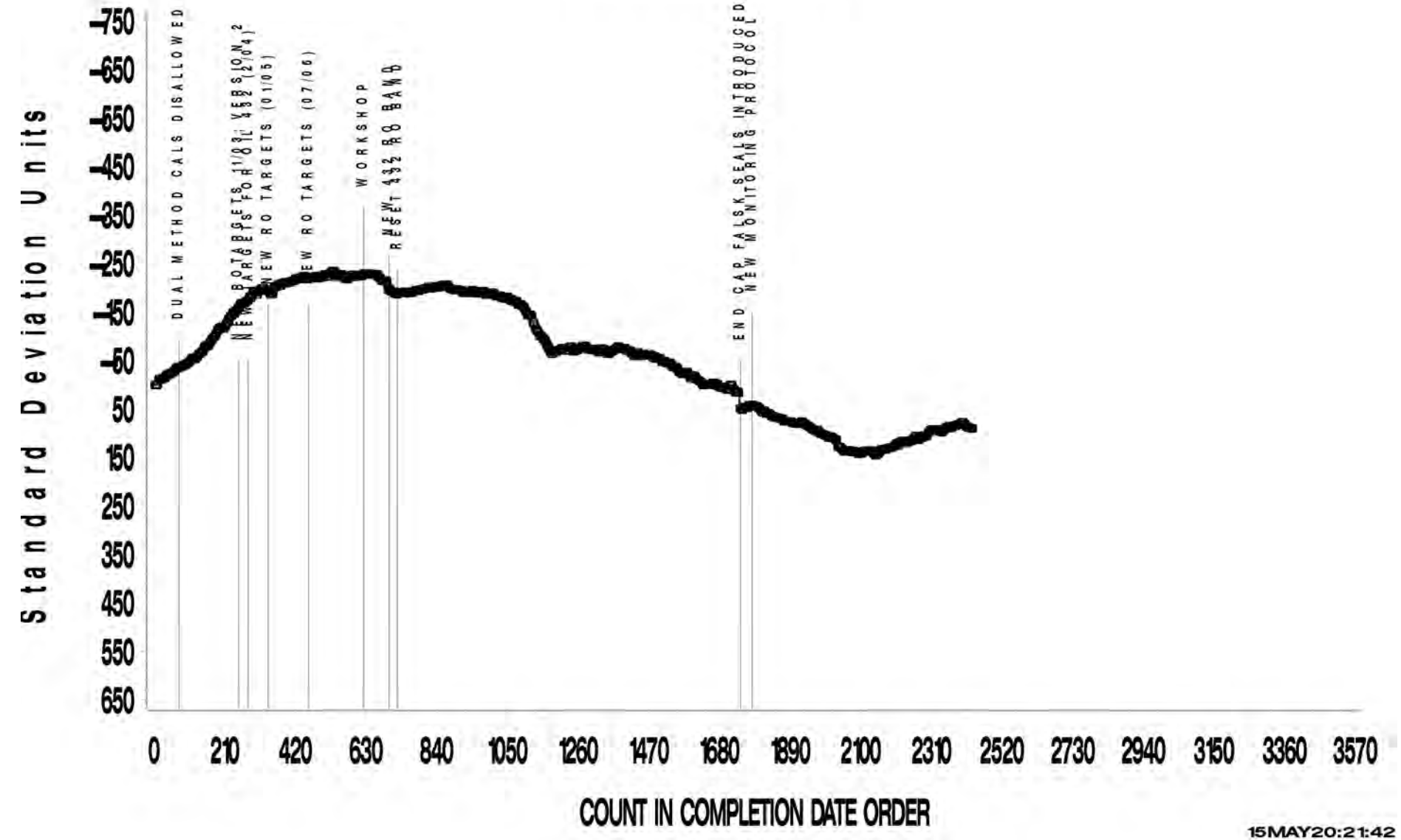
MHT –4 TEOST INDUSTRY OPERATIONALLY VALID DATA

TOTAL DEPOSITS MG

CUSUM Severity Analysis

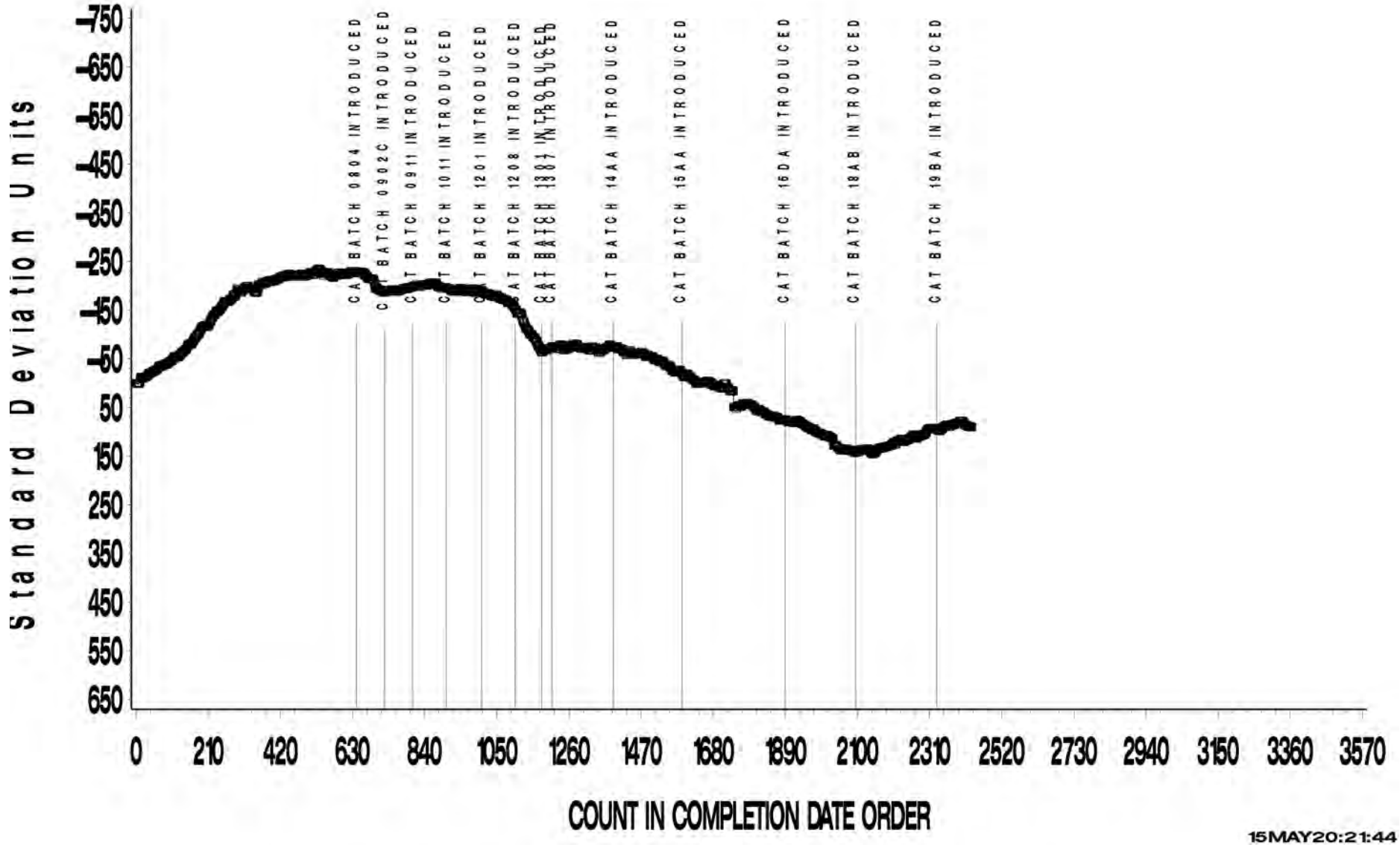


15MAY20:21:42

MHT –4 TEOST INDUSTRY OPERATIONALLY VALID DATA

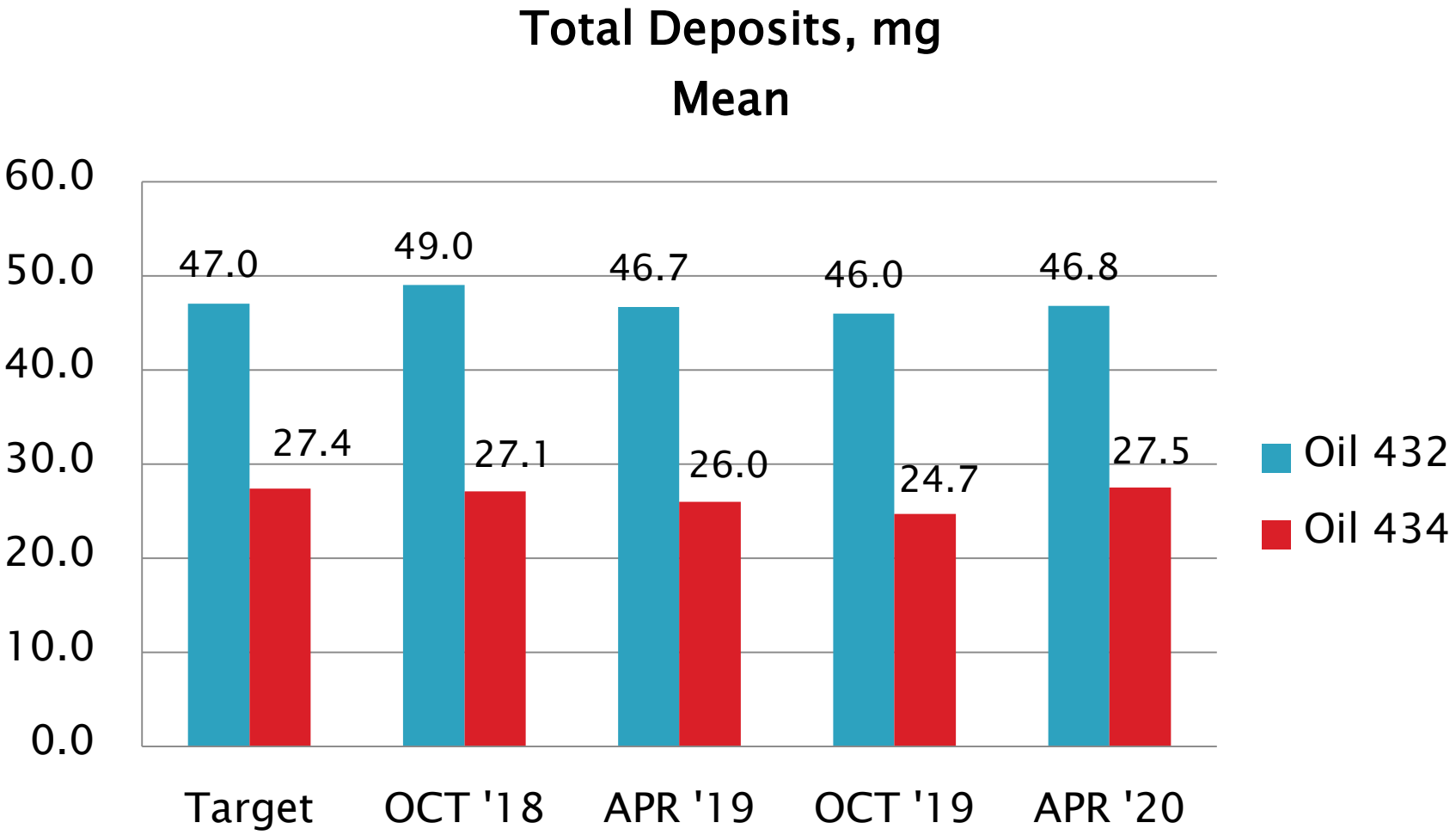
TOTAL DEPOSITS MG

CUSUM Severity Analysis

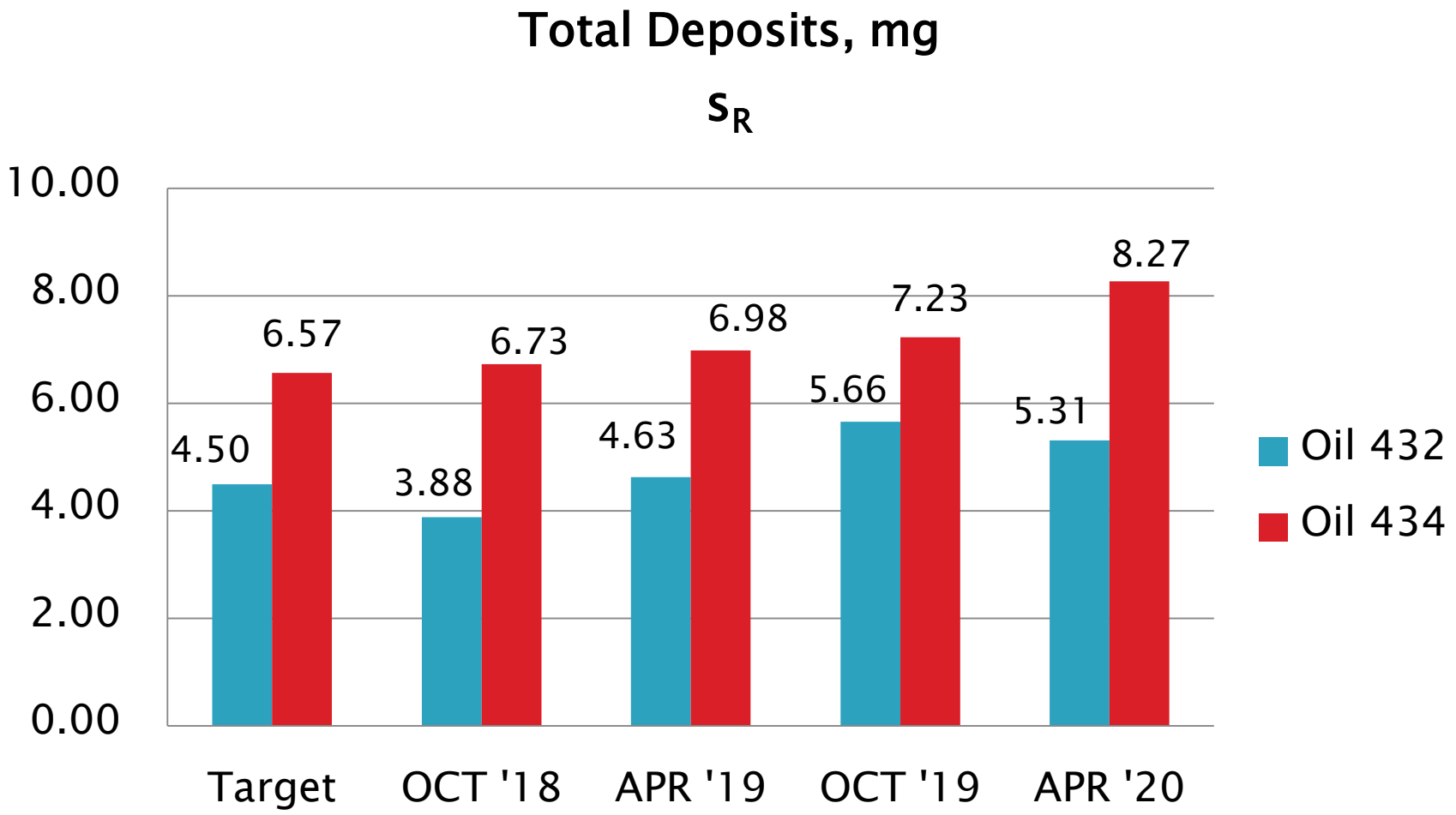


15MAY20:21:44

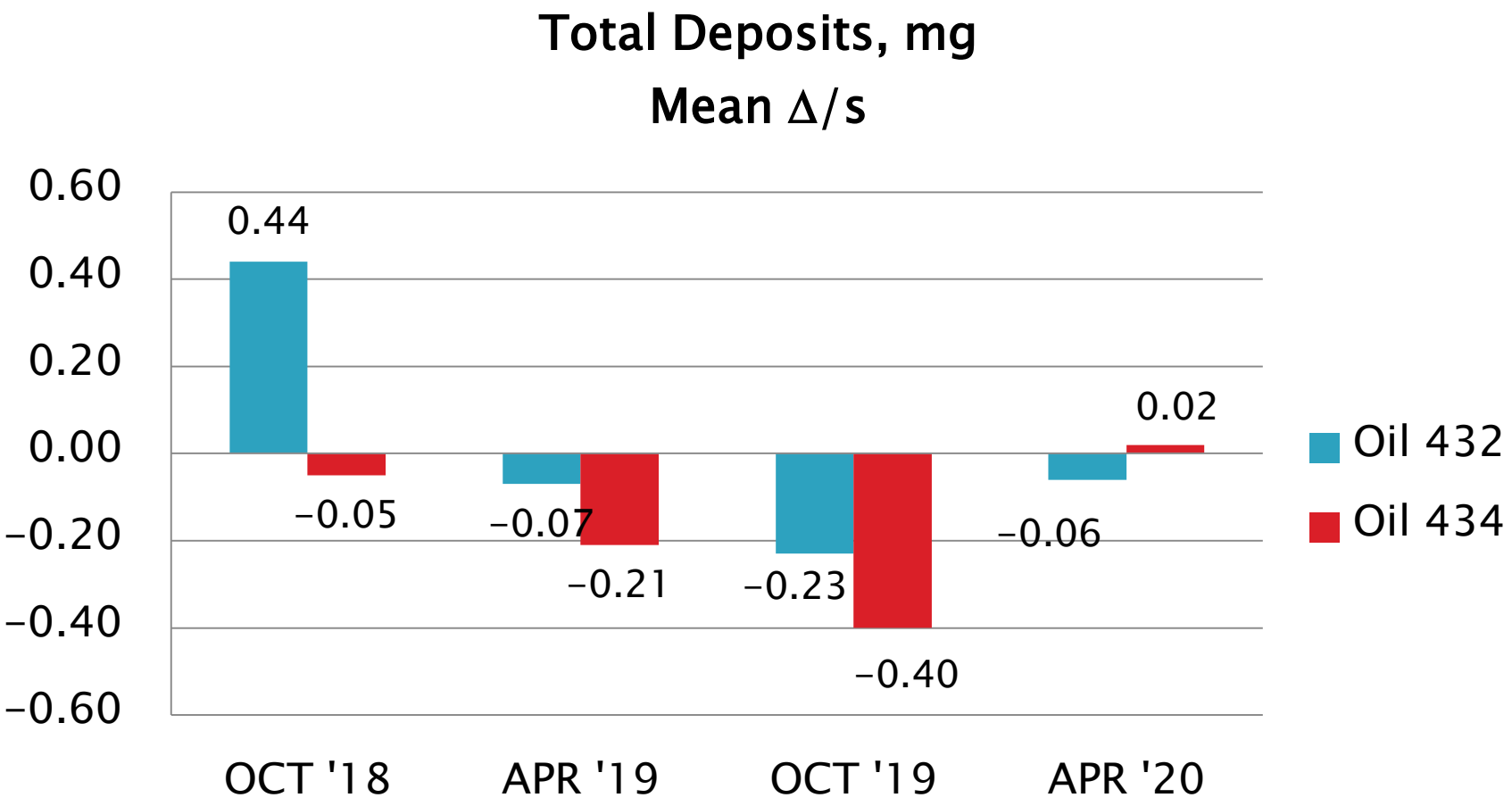
D7097 Performance by Oil



D7097: Deposits by MHT TEOST



D7097: Deposits by MHT TEOST



Return to Executive Summary

D6082: High Temperature Foam

Test Status	Validity Code	No. Tests
Acceptable Calibration Test	AC	15
Acceptable Discrimination Test	AS	6
Failed Statistically	OC	0
Operationally Invalidated by Lab	LC, XC	0
Total		**21**

Number of Labs Reporting Data: 7
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.
- No invalid runs this period.
- 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
Current Targets	28	27	19.28	-----
4/1/16 through 9/30/16	12	11	18	-0.38
10/1/16 through 3/31/17	14	13	19	-0.62
4/1/17 through 9/30/17	12	11	10	0.17
10/1/17 through 3/31/18*	14	13	17	-0.02
10/1/17 through 3/31/18*	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

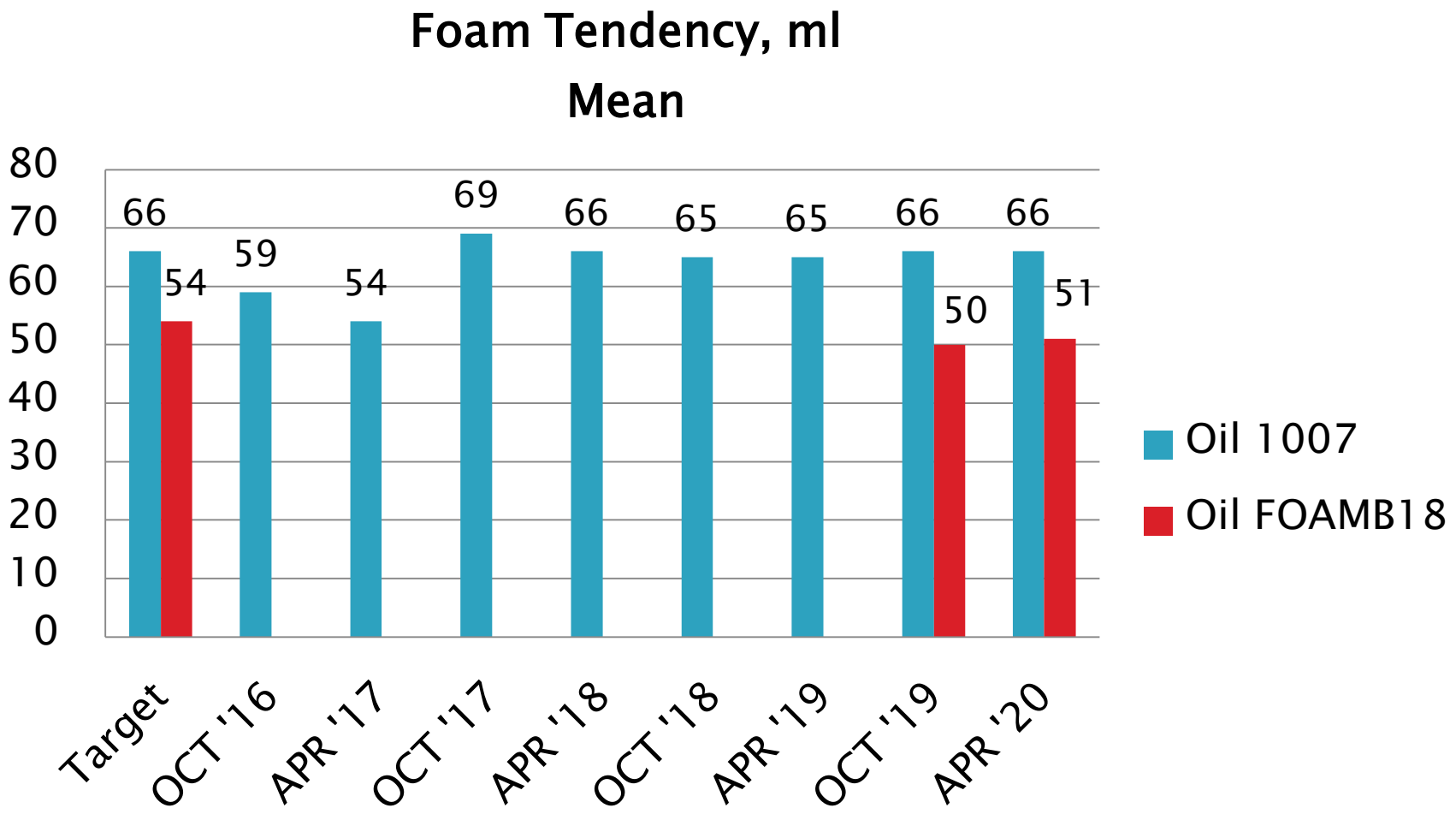
*Single OC result Yi=2.3 s severe included and excluded

D6082: High Temperature Foam

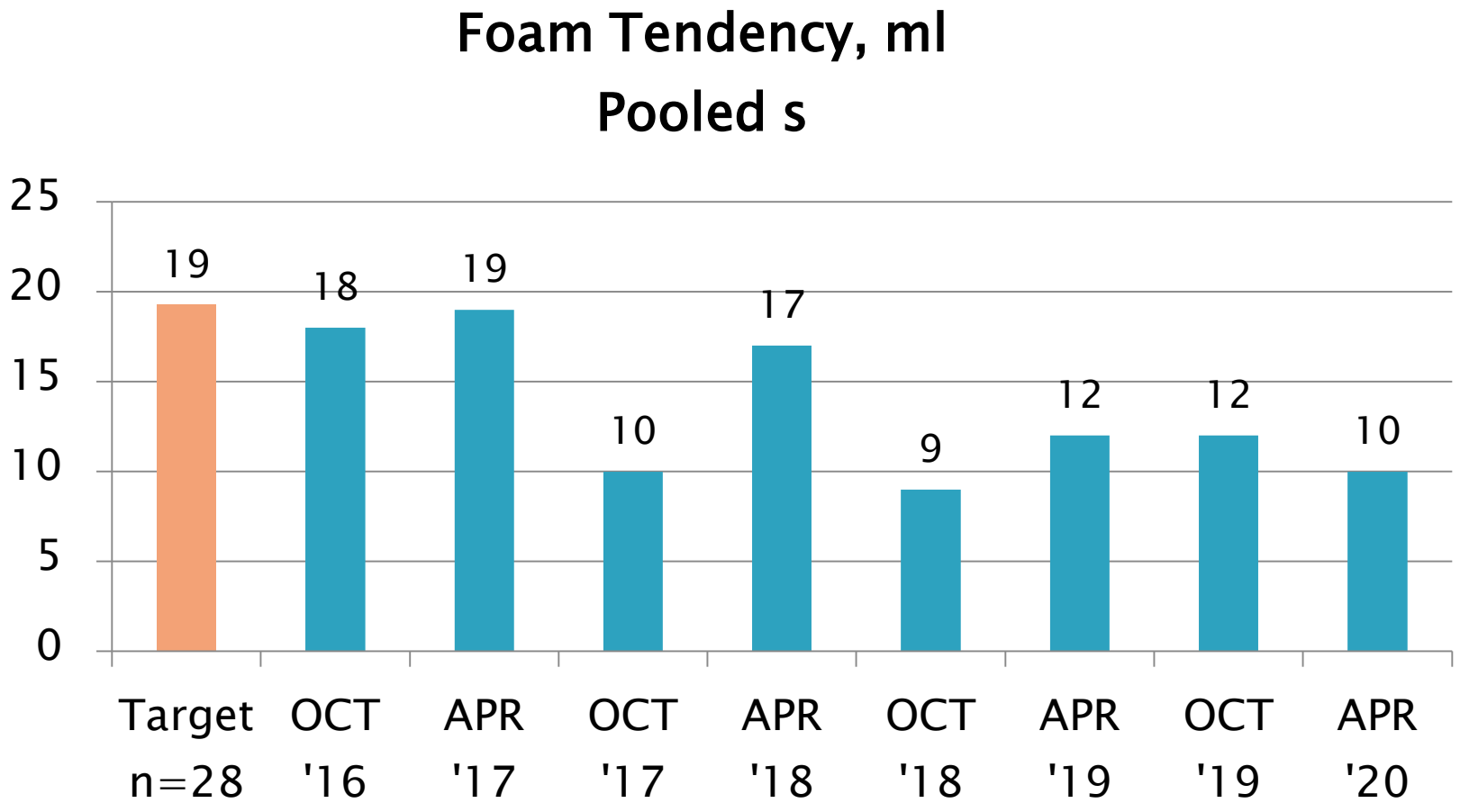
Period Precision and Severity Estimates

Foam Stability @ 1 min, ml	n	Mean	s
Current Targets	28	0.00	0.00
4/1/16 through 9/30/16	12	No non-zero occurrences	
10/1/16 through 3/31/17	14	No non-zero occurrences	
4/1/17 through 9/30/17	12	No non-zero occurrences	
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	

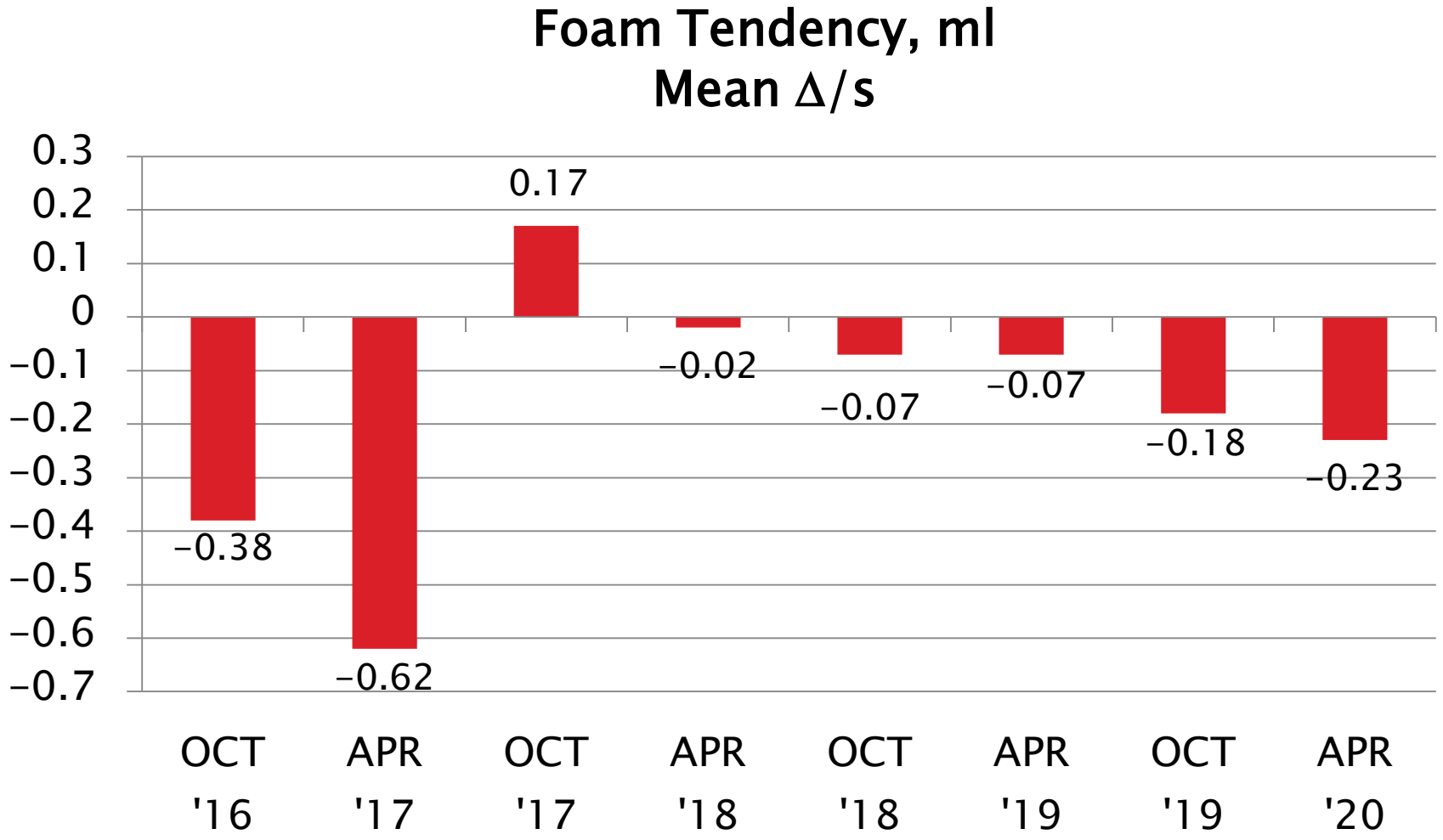
D6082 Performance by Oil



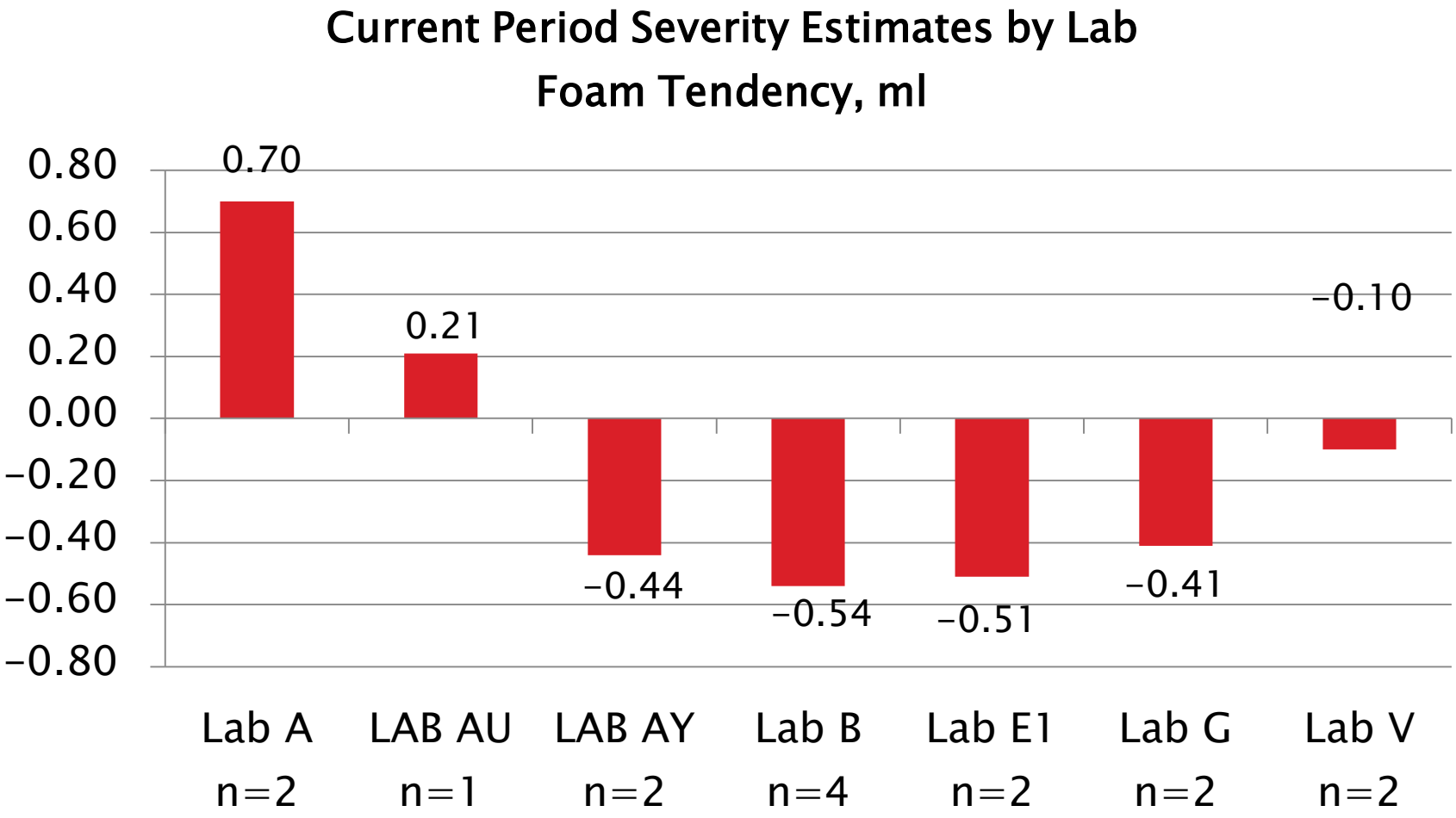
D6082: High Temperature Foam



D6082: High Temperature Foam



D6082: High Temperature Foam



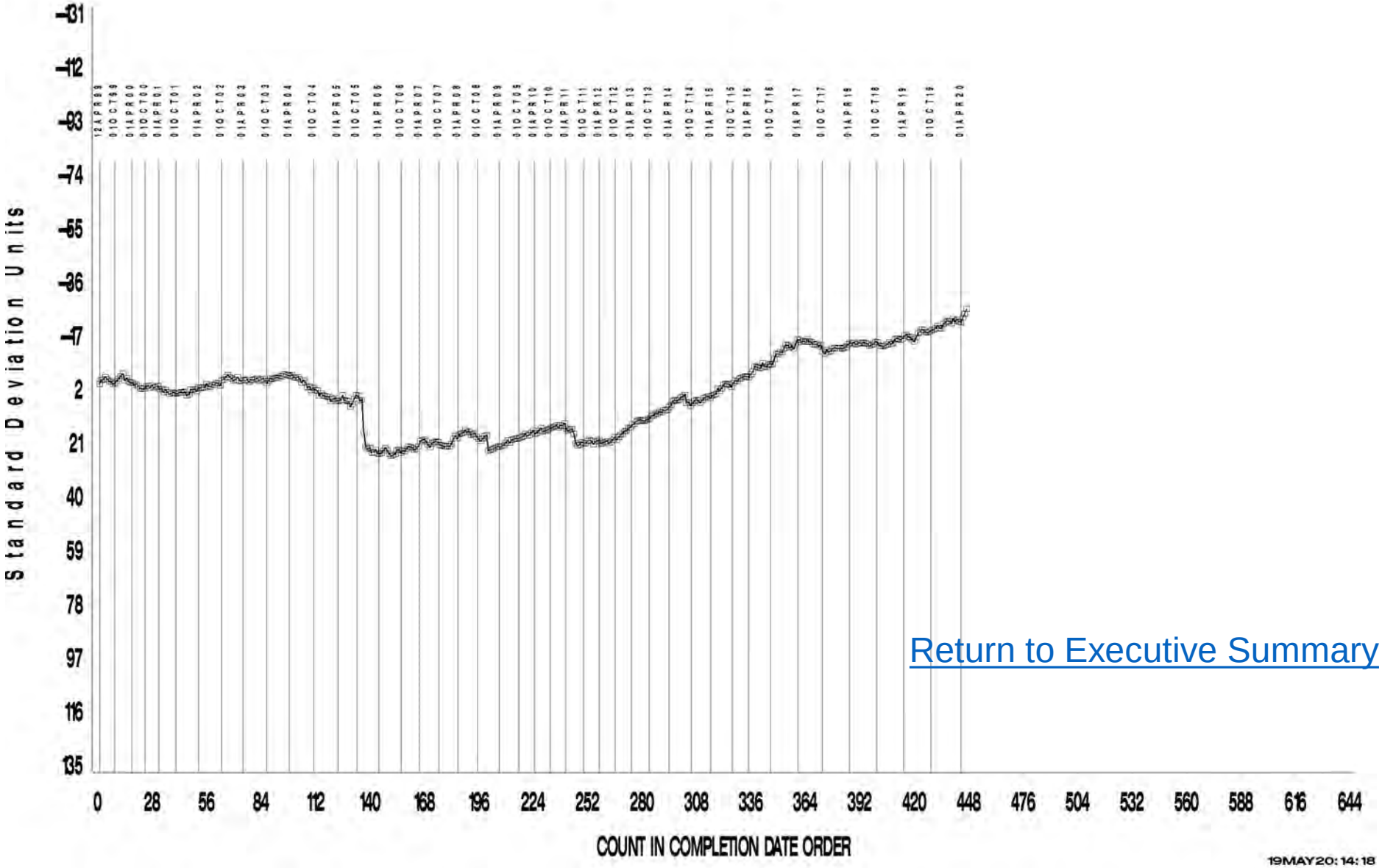
D6082: High Temperature Foam

- Foam Tendency Precision (Pooled s) is more precise than the prior report period
  - More precise than target precision
- Performance (Mean Δ/s) is -0.23 s mild
- No non-zero occurrences of Foam Stability
- All six severe oil discrimination runs (on TMC oil 66) demonstrated acceptable discrimination.
- Replacement oil FOAMB18 was introduced last period.
  - Period estimates are a combination of oils 1007 and FOAMB18.

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

A Program of ASTM International

CUSUM Severity Analysis



Return to Executive Summary

19MAY20:14:18

D874: Sulfated Ash

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

Number of Labs Reporting Data: 4
Fail Rate of Operationally Valid Tests: 0%

D874: Sulfated Ash

Statistically Unacceptable Tests (OC)	No. Of Tests
Sulfated Ash Mild	0
Sulfated Ash Severe	0

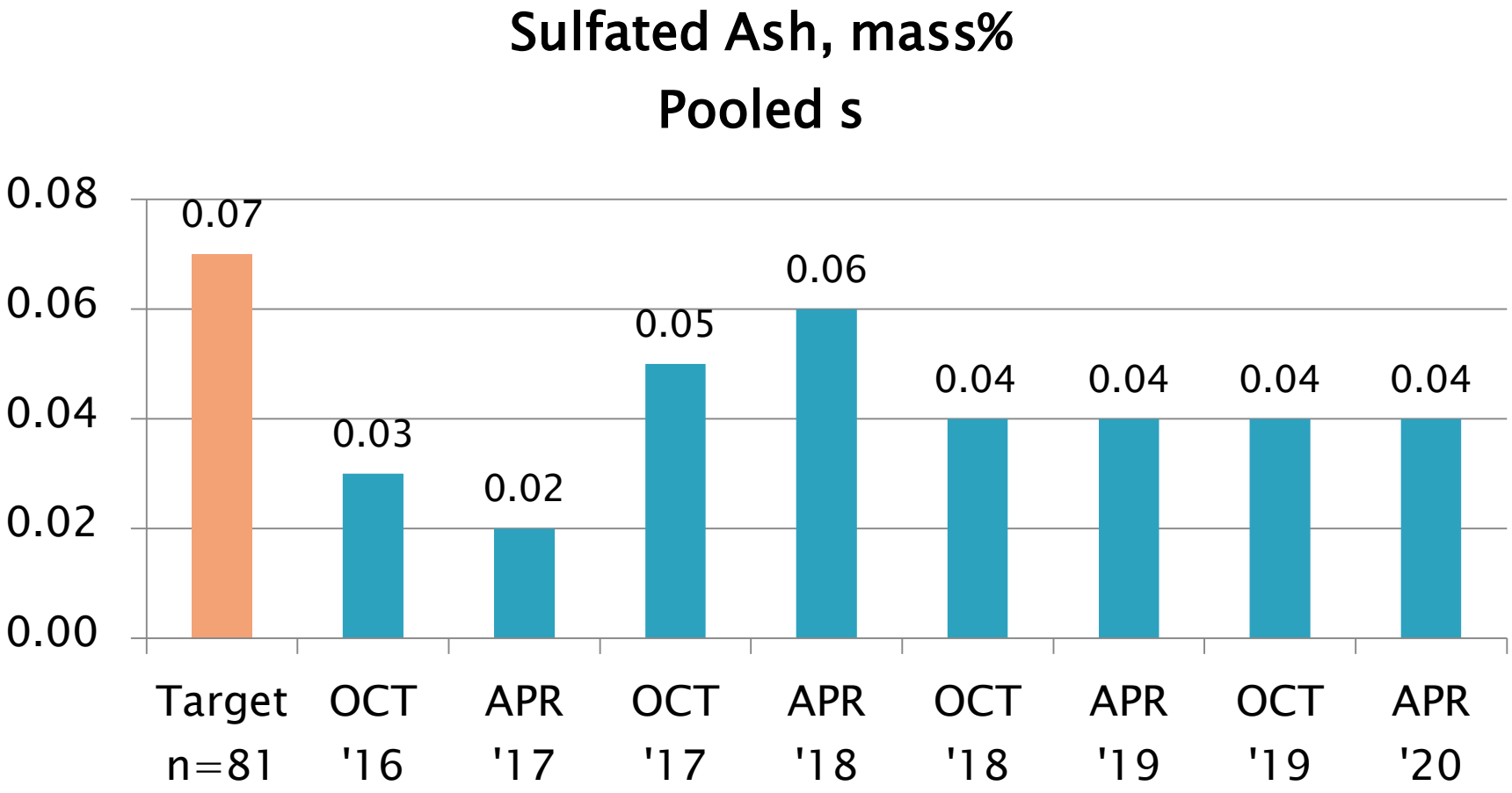
- No statistically or operationally invalid tests reported this period
- No TMC technical updates issued this period

D874: Sulfated Ash

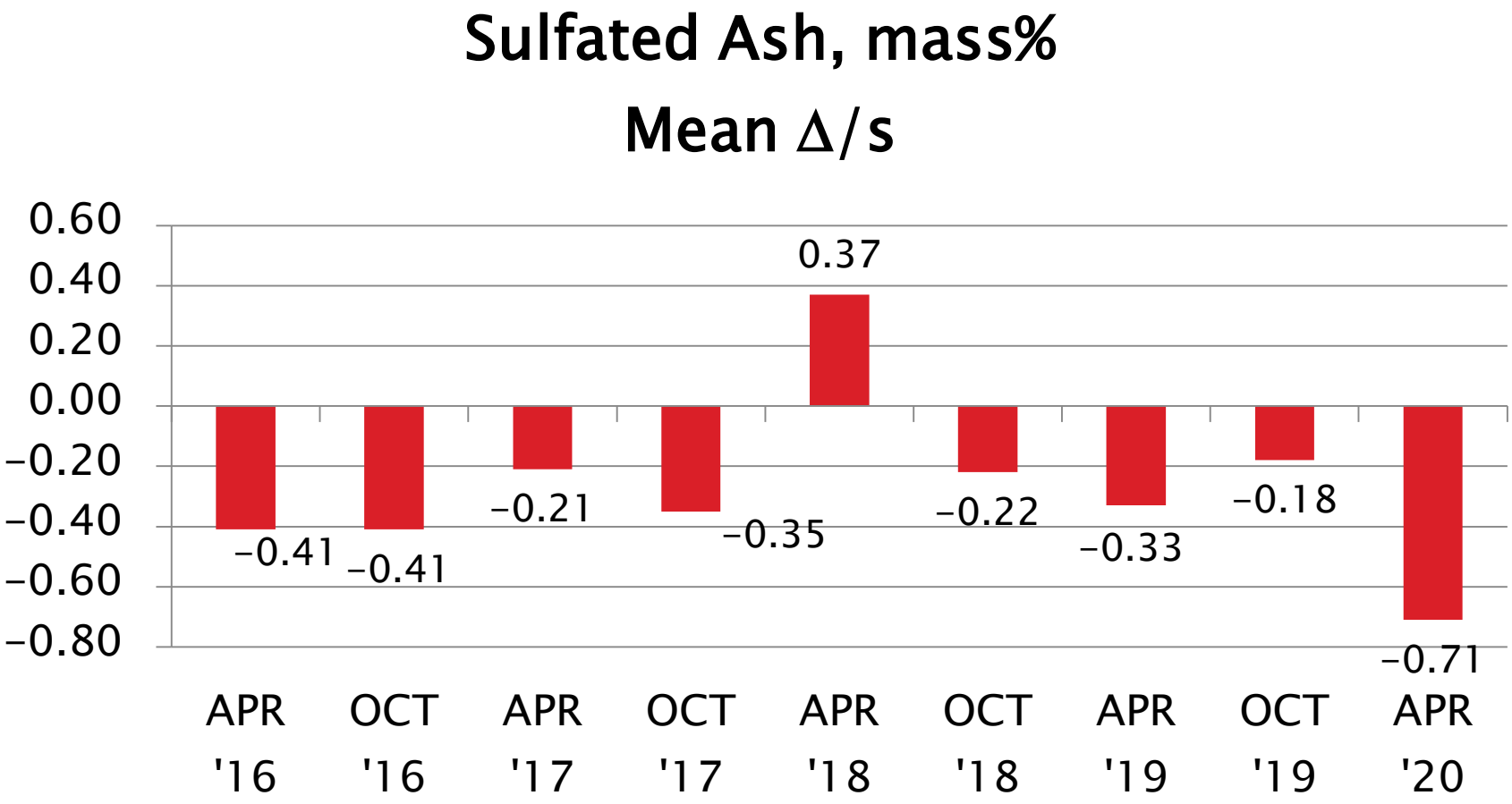
Period Precision and Severity Estimates

Total Deposits, mg	n	df	Pooled s	Mean Δ/s
Current Targets	81	78	0.07	-----
4/1/16 through 9/30/16	6	3	0.03	-0.41
10/1/16 through 3/31/17	7	4	0.02	-0.21
4/1/17 through 9/30/17	8	5	0.05	-0.35
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

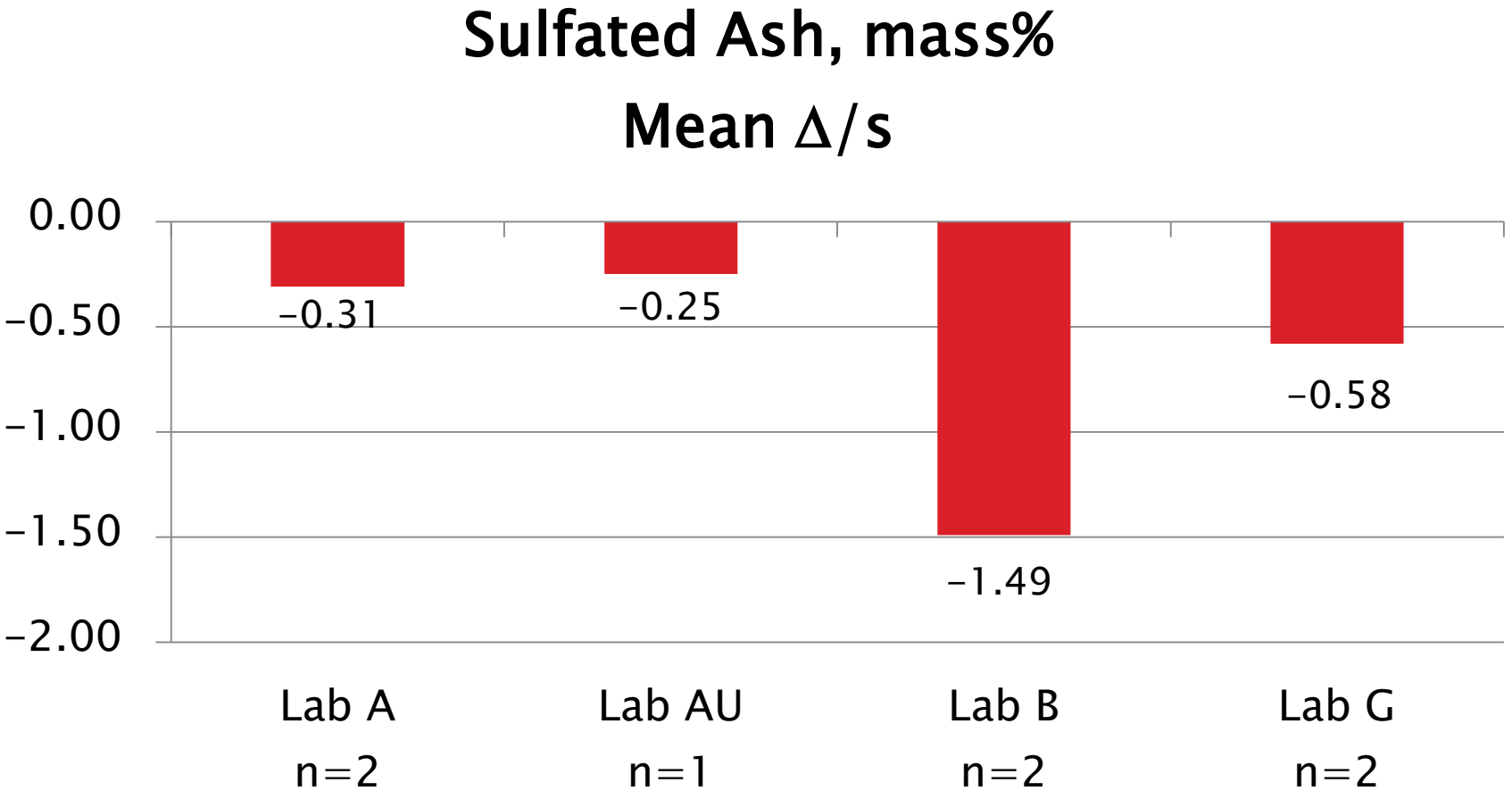
D874: Sulfated Ash



D874: Sulfated Ash



D874: Sulfated Ash



D874: Sulfated Ash

- Precision (Pooled s) is comparable to prior periods
  - More precise than target precision
- Performance (Mean Δ/s) is -0.71 s mild
  - Notably more mild than prior periods
    - Biased by two mild results from lab B
  - CUSUM severity plot shows a distinct mild slope for the report period

D874 INDUSTRY OPERATIONALLY VALID DATA

TEST SAMPLE PERCENT SULFATED ASH

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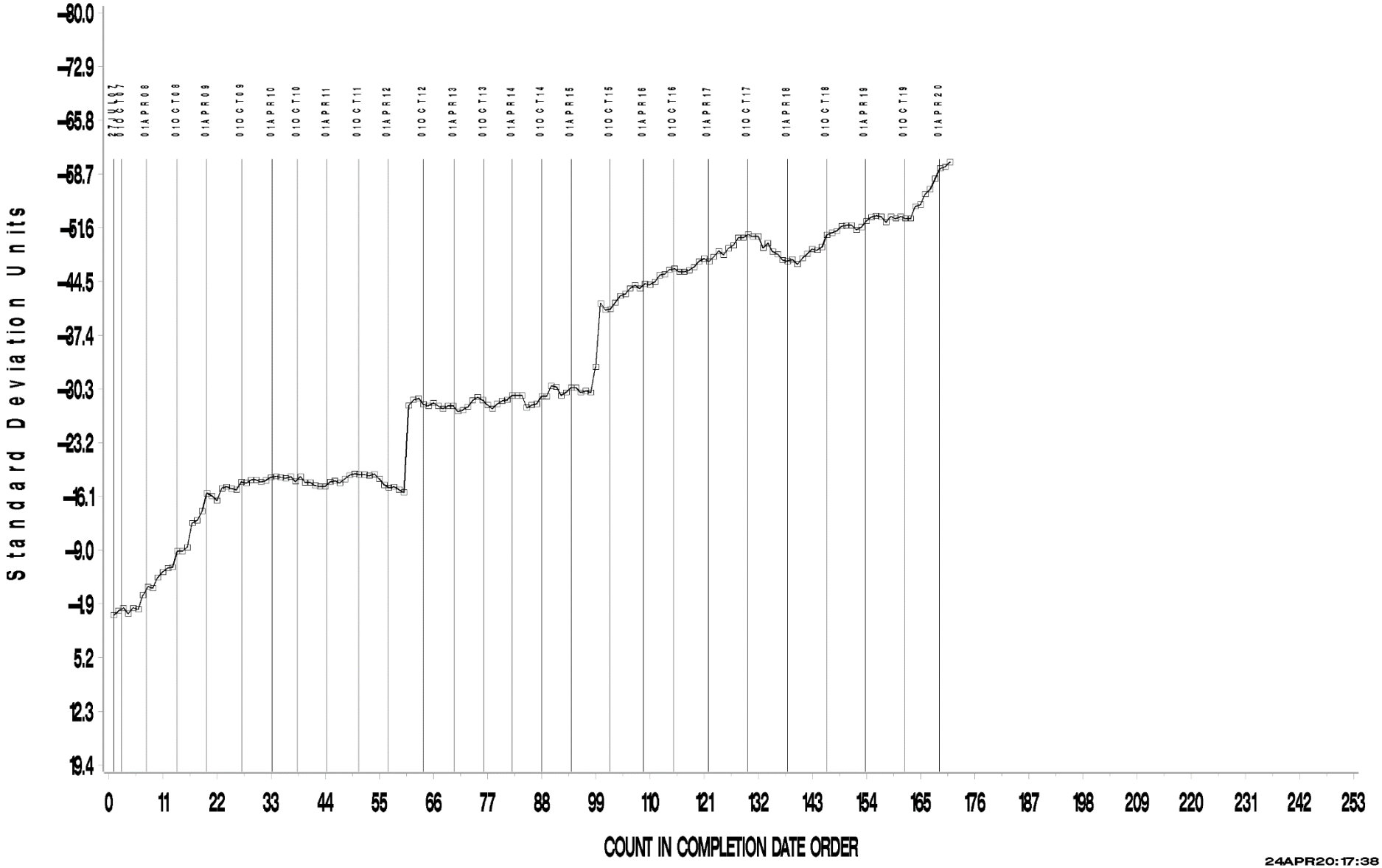
CUSUM Severity Analysis



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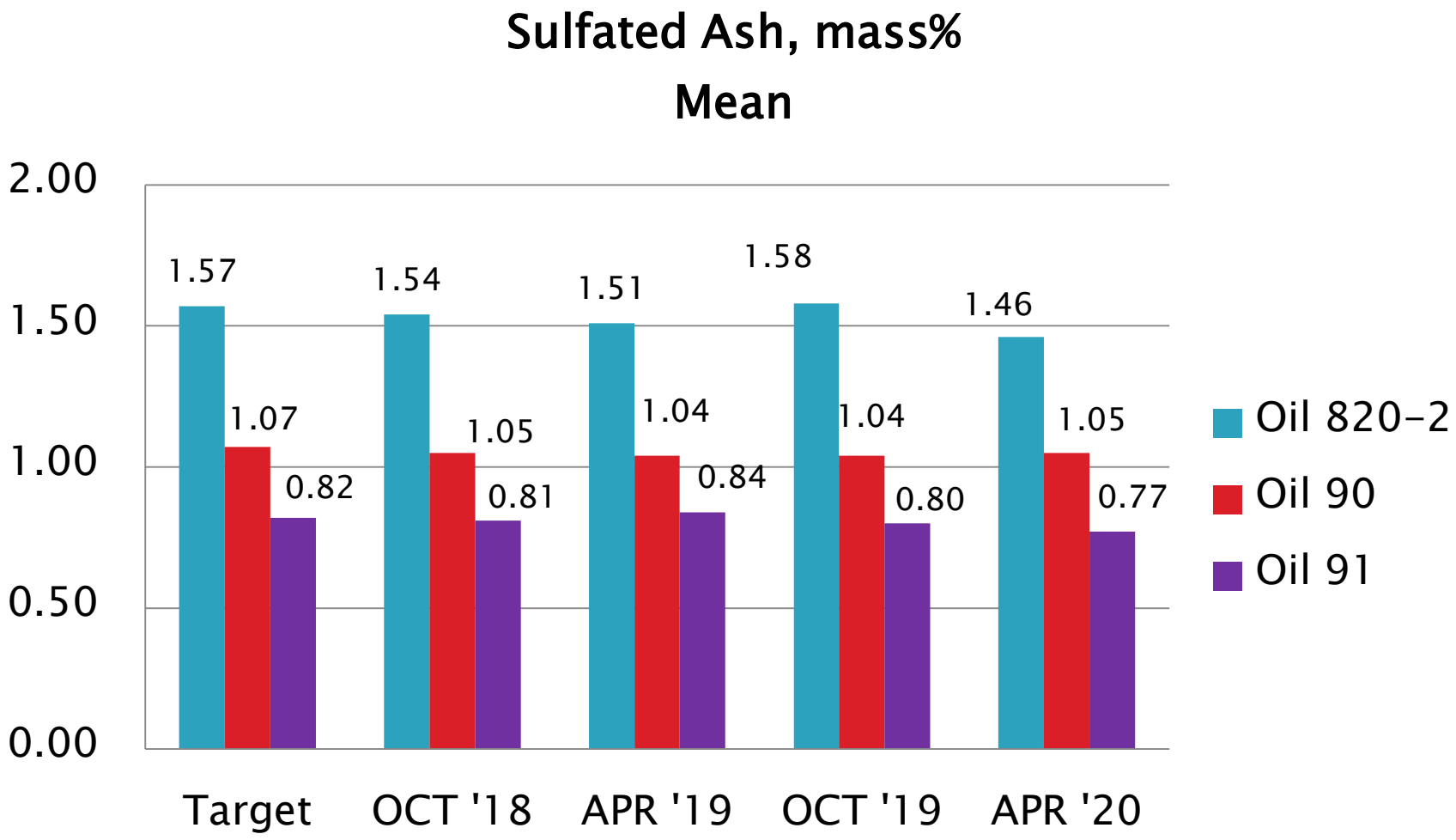
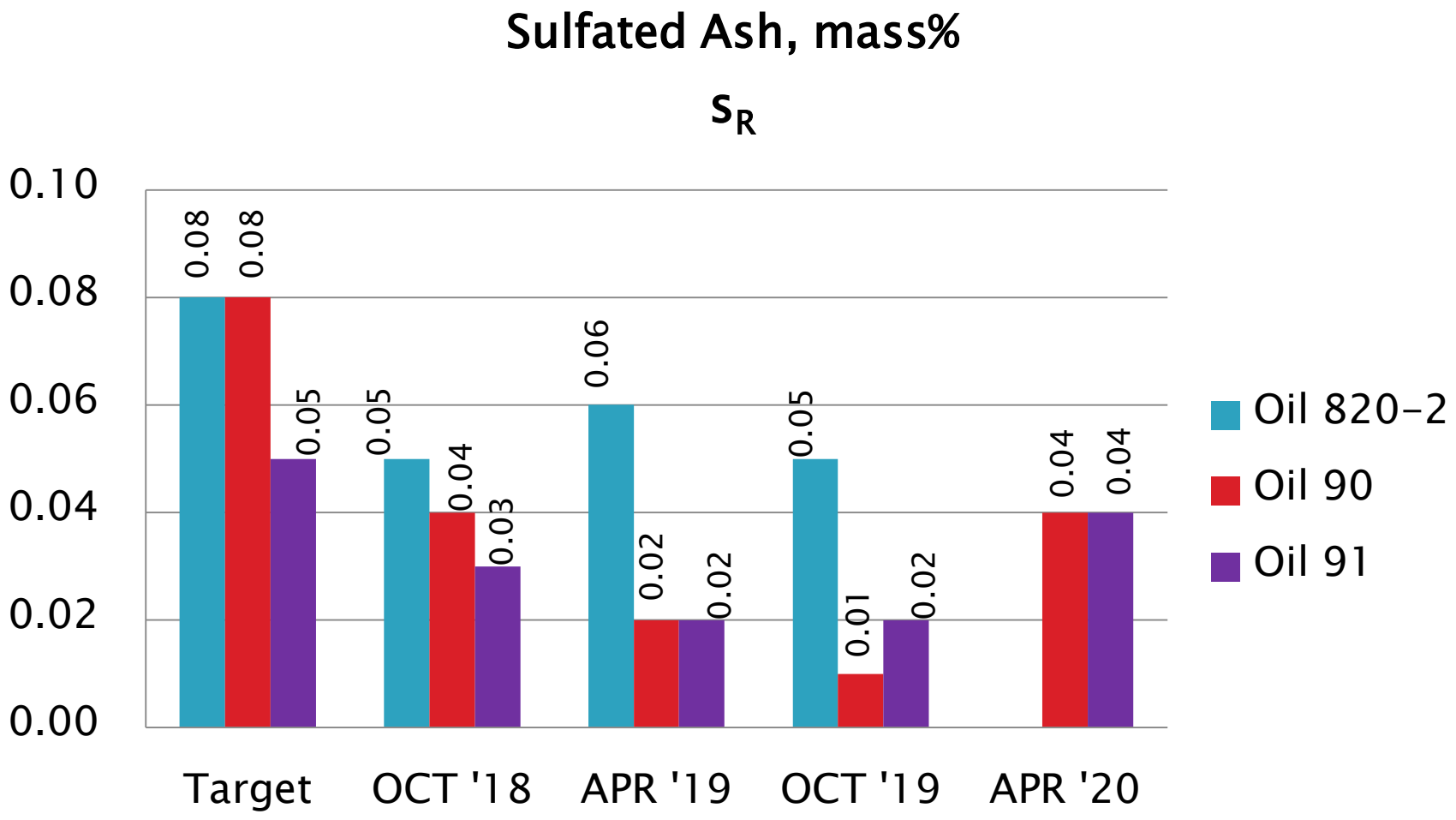
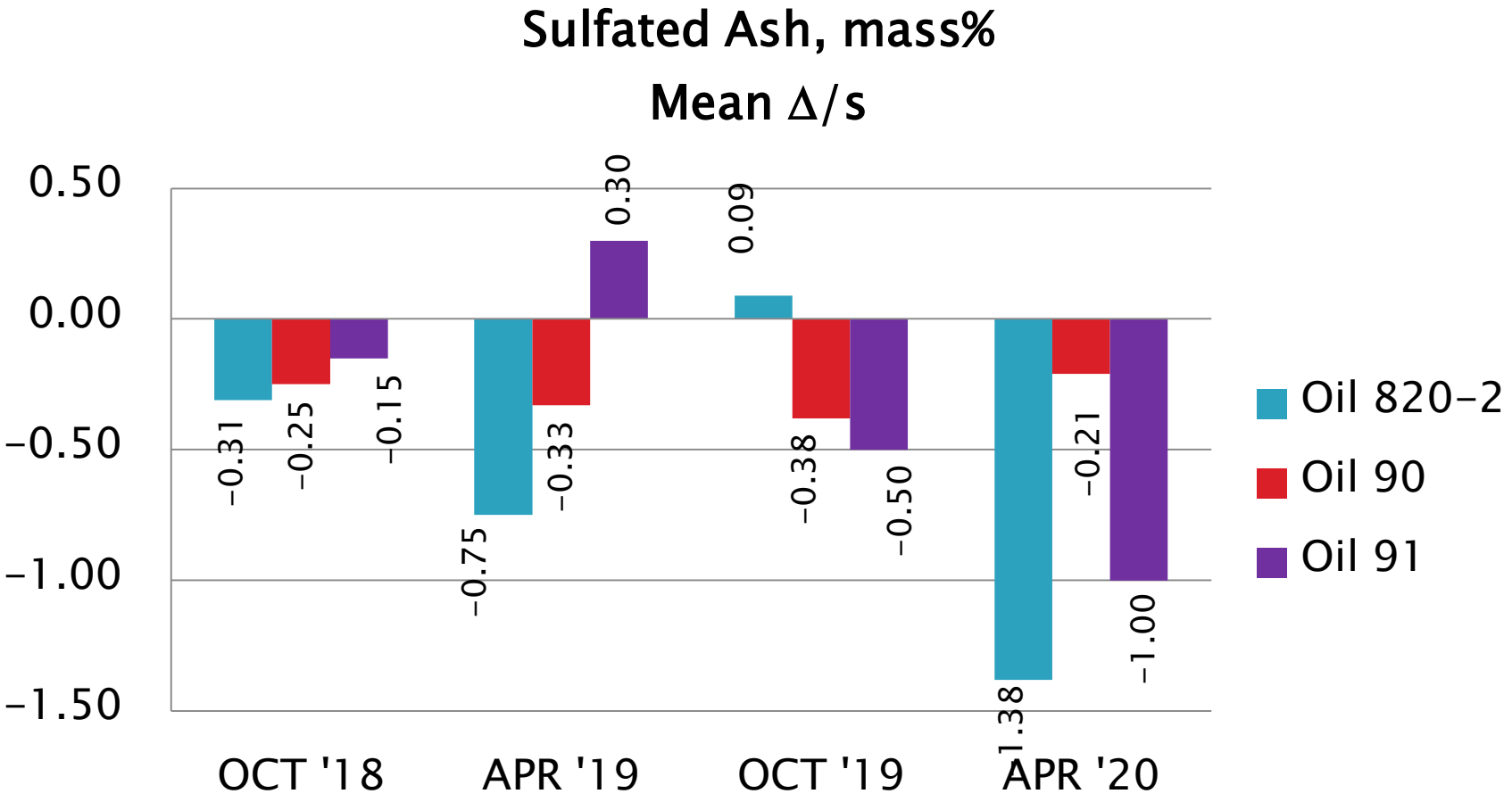
D874: Sulfated Ash



D874: Sulfated Ash



D874: Sulfated Ash



Return to Executive Summary

D7528: Oxidation by ROBO

Test Status	Validity Code	No. Tests
Acceptable Calibration Test	AC	131
Failed Calibration Test	OC	27
Operationally Invalidated by Lab	LC, XC	16
Operationally Invalidated After Initially Reported as Valid	RC	1
Non-Blind Instrument Shakedown	NN	1
Total		**176**

Number of Labs Reporting Data: 6
Fail Rate of Operationally Valid Tests: 17%

D7528: Oxidation by ROBO

Operationally Invalid Calibration Tests

- 3 tests NO_2 flow off-spec (XC)
- 3 tests vacuum leak (LC)
- 5 tests heater problems (LC, XC)
- 2 tests power failure (XC)
- 3 tests exhibited unexpected yield stress (RC, LC)
- 1 test excess EOT volatiles (XC)

Other Tests

- 1 Rig shakedown run (NN)

D7528: Oxidation by ROBO

Statistically Unacceptable Tests (OC)	No. Of Tests
Natural Log (MRV Viscosity) Mild	18
Natural Log (MRV Viscosity) Severe	9

- 9 tests mild on 434-2
- 5 tests severe on 434-2
- 7 tests mild on oil 435-1
- 1 test severe on oil 438
- 2 tests mild on 438-2
- 3 tests severe on 438-2

- There was one technical update issued this period:
  - Updated Reference Oil Targets, TMC Memo 19-051, October 31, 2019

- Calibration requirement updates are issued as LTMS document updates

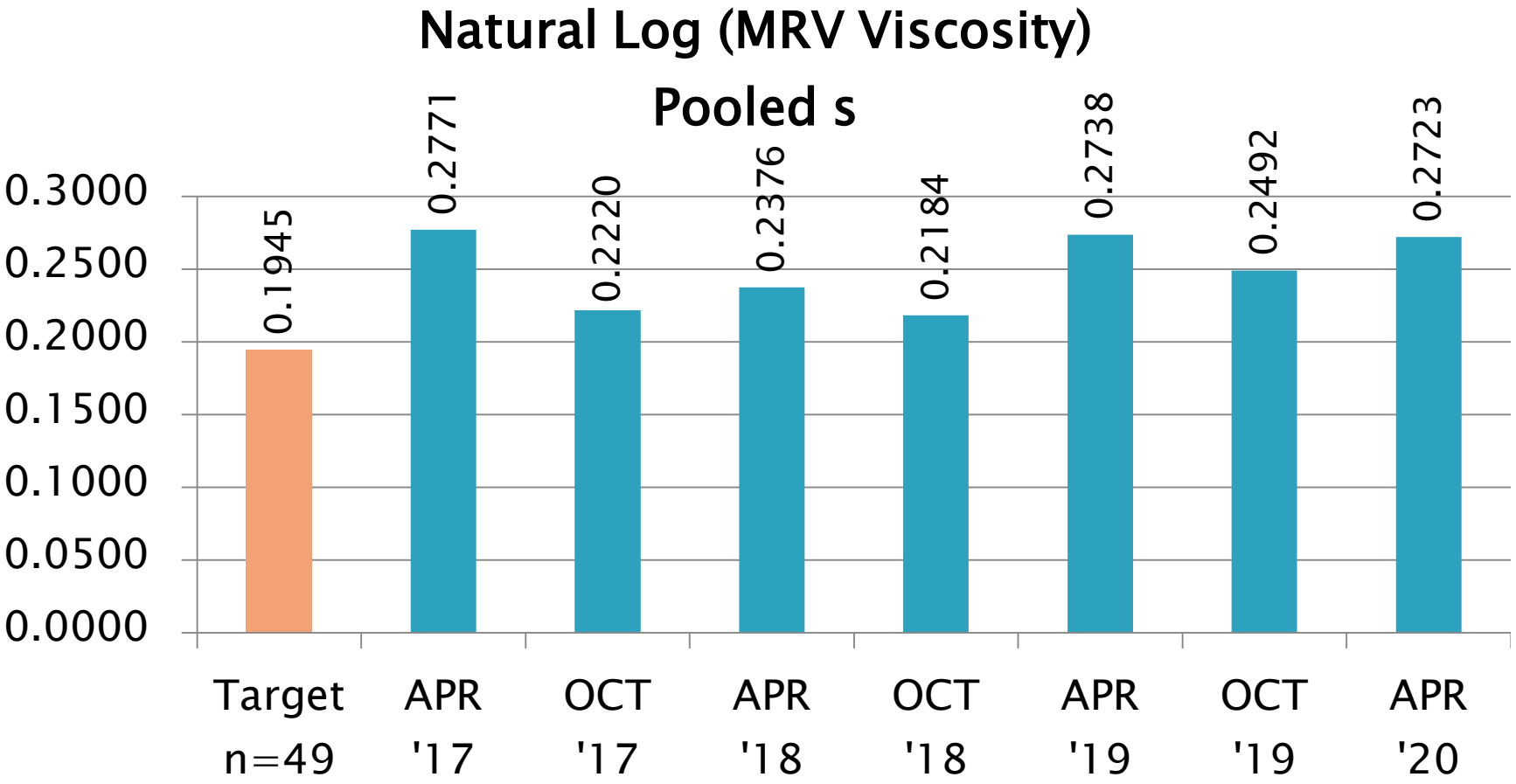
D7528: Oxidation by ROBO

Period Precision and Severity Estimates

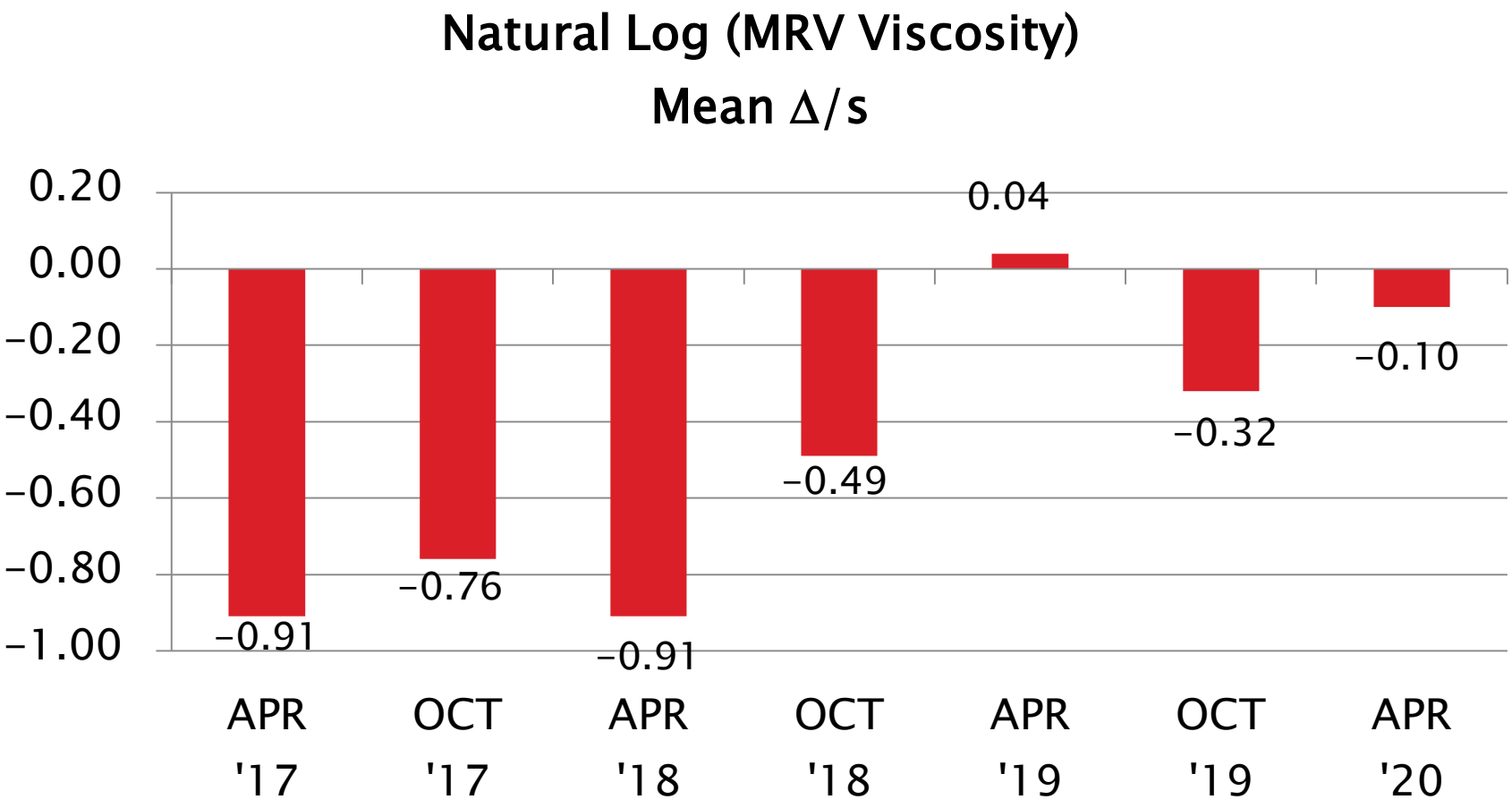
Natural Log (MRV Viscosity)	n	df	Pooled s	Mean Δ/s
Current Targets	49	46	0.1945	-----
10/1/16 through 3/31/17	78	75	0.2771	-0.91
4/1/17 through 9/30/17	99	95	0.2220	-0.76
10/1/17 through 3/31/18*	90	86	0.2376	-0.91
10/1/17 through 3/31/18*	83	79	0.2076	-0.74
4/1/18 through 9/30/18	126	122	0.2184	-0.49
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

**Period statistics with seven suspect results from two rigs included and excluded

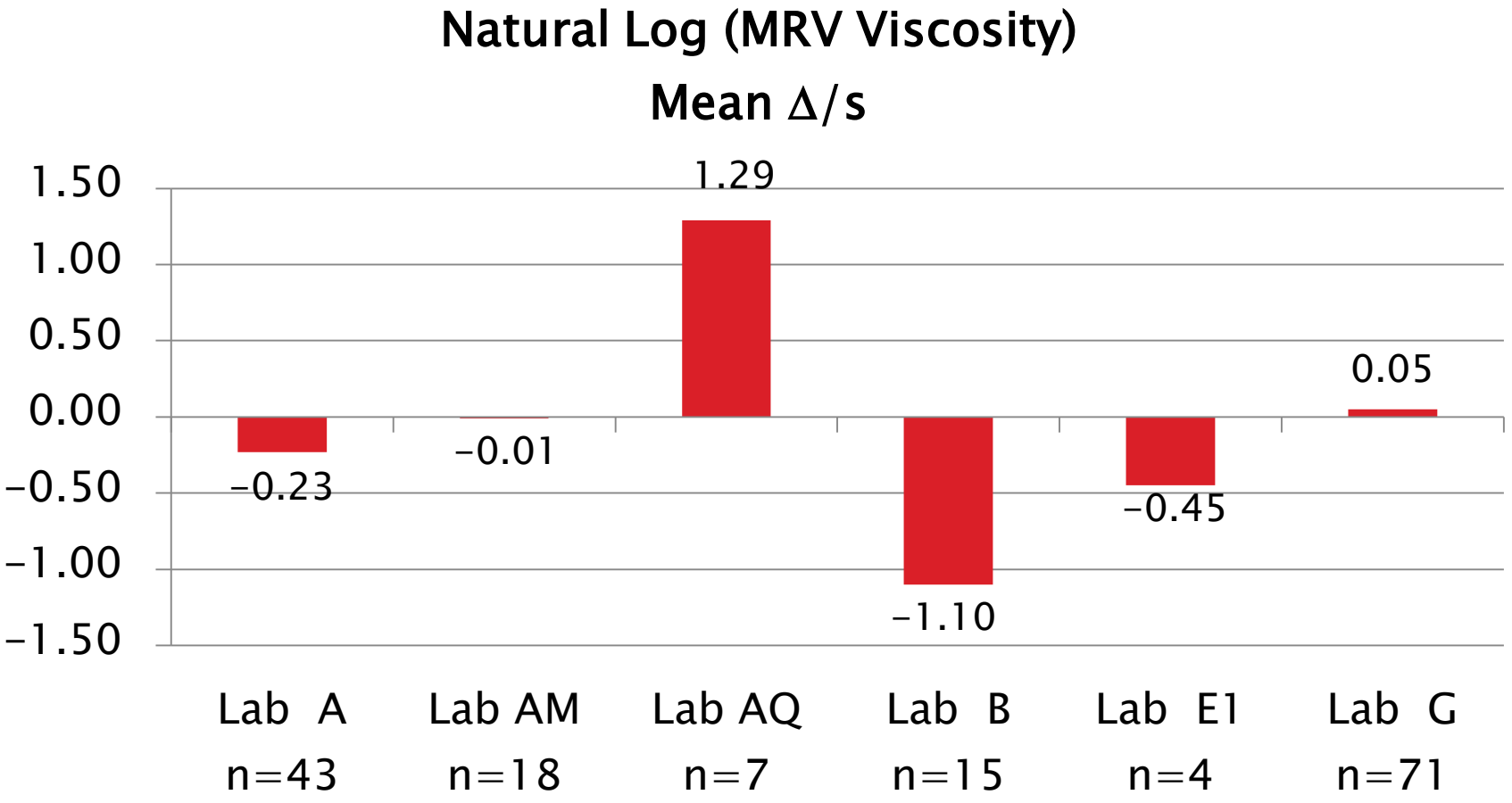
D7528: Oxidation by ROBO



D7528: Oxidation by ROBO



D7528: Oxidation by ROBO



D7528: Oxidation by ROBO

- One test reported this period as operationally valid failed 4.9 s severe (Rig G 5). As failing ROBO results of similar magnitude (mild or severe) now occur most every report period, these will no longer be singled out as extreme events in period statistics, but will be noted in summary.

D7528: Oxidation by ROBO

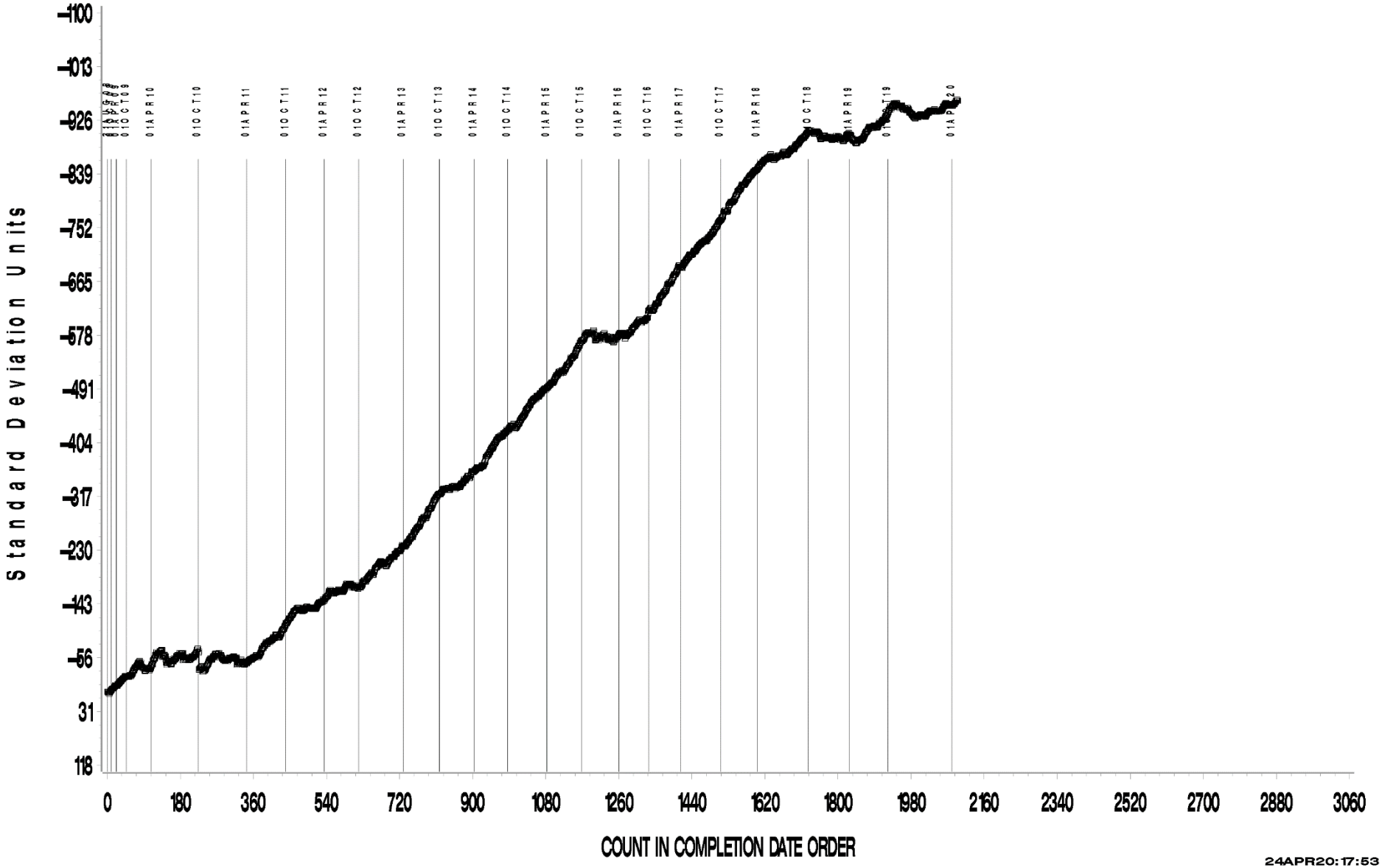
- Precision (Pooled s) is less precise than last period
  - Continues to be less precise than target
- Performance (Mean Δ/s) is -0.10 s mild for this report period
- CUSUM severity plot shows variable performance past three report period, but prior severe trend has improved

ROBO TEST INDUSTRY OPERATIONALLY VALID DATA

AGED OIL MRV APPARENT VISCOSITY

A Program of ASTM International

CUSUM Severity Analysis



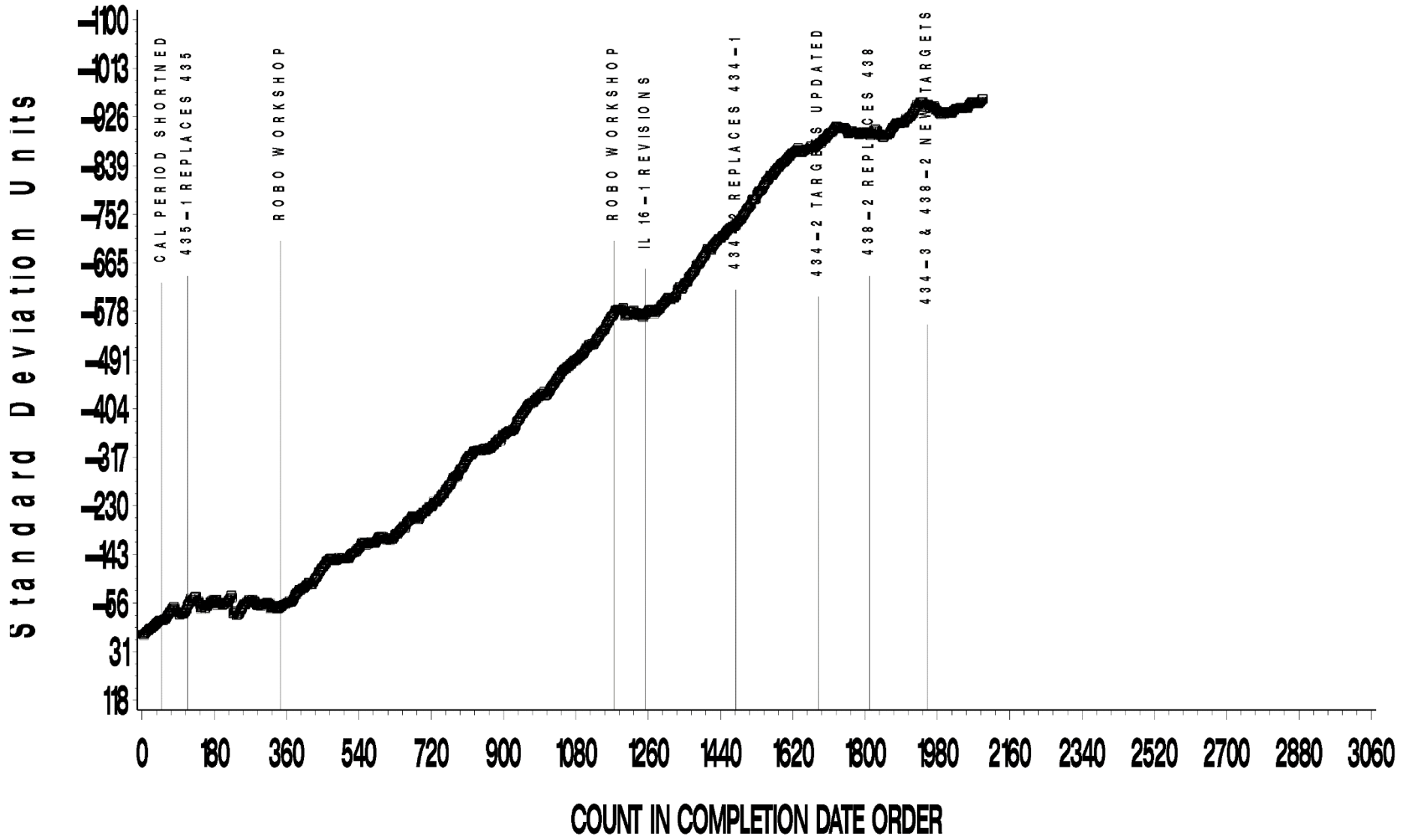
24APR20:17:53

ROBO TEST INDUSTRY OPERATIONALLY VALID DATA

AGED OIL MRV APPARENT VISCOSITY

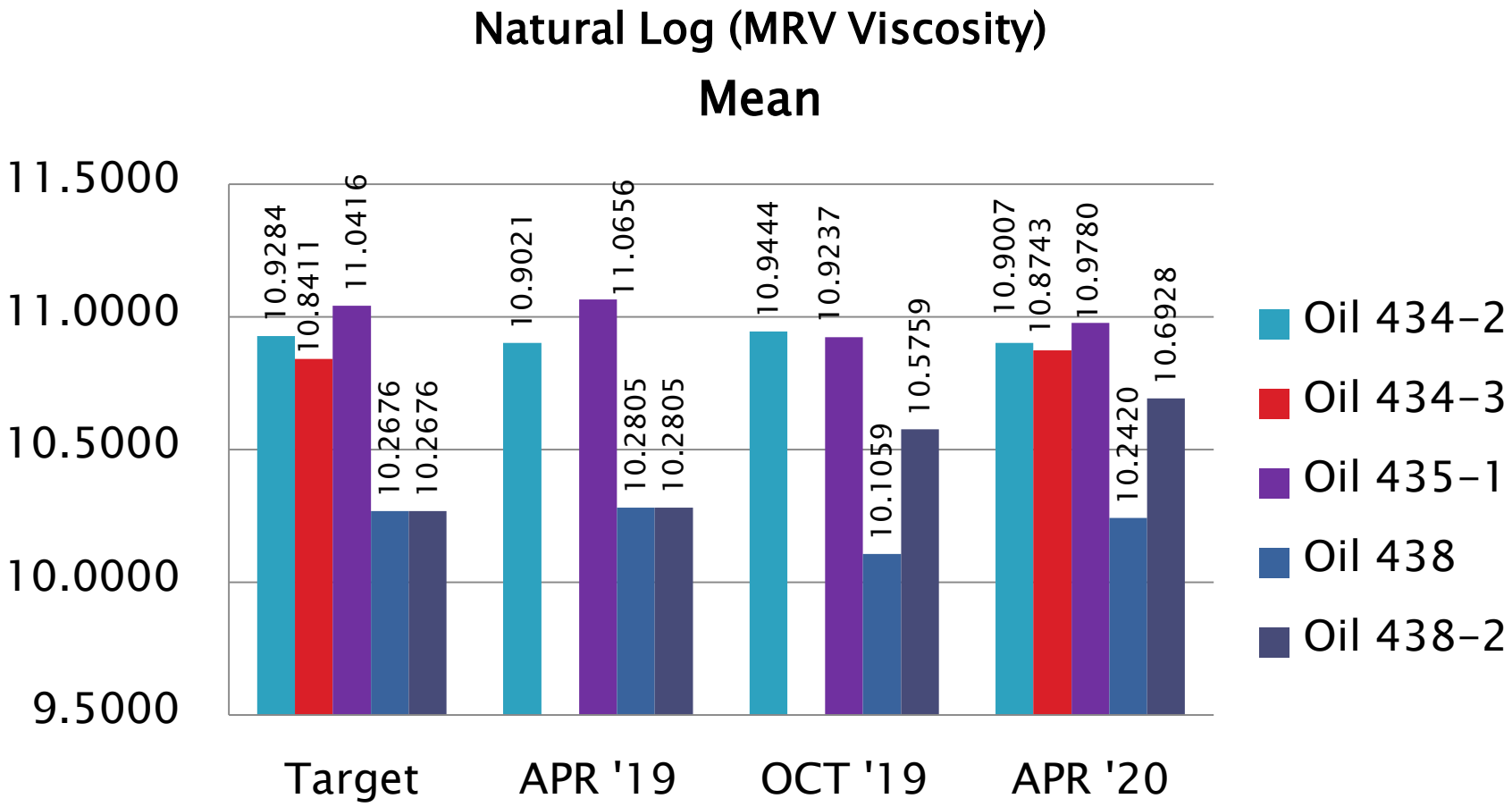
A Program of ASTM International

CUSUM Severity Analysis

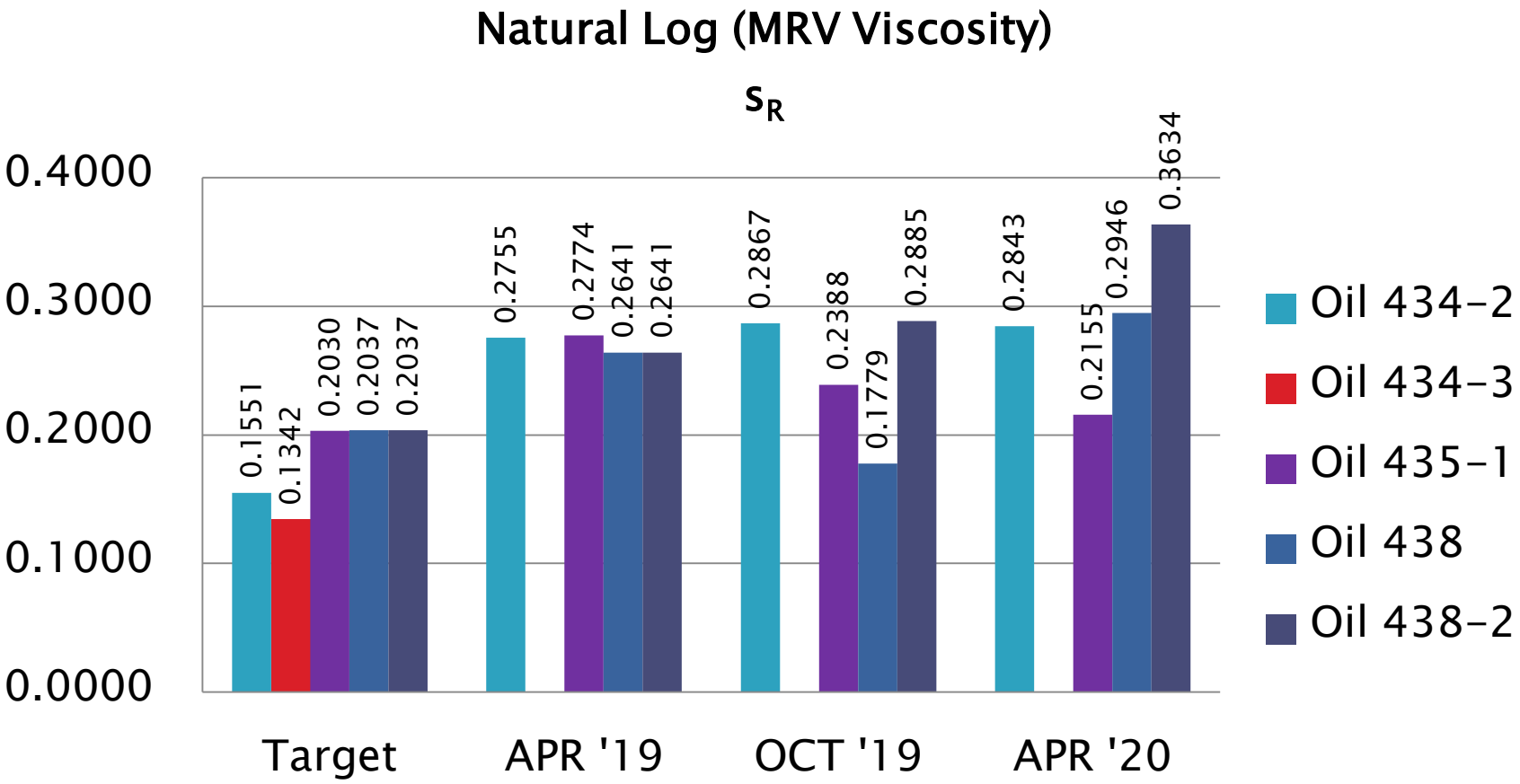


24APR20:17:54

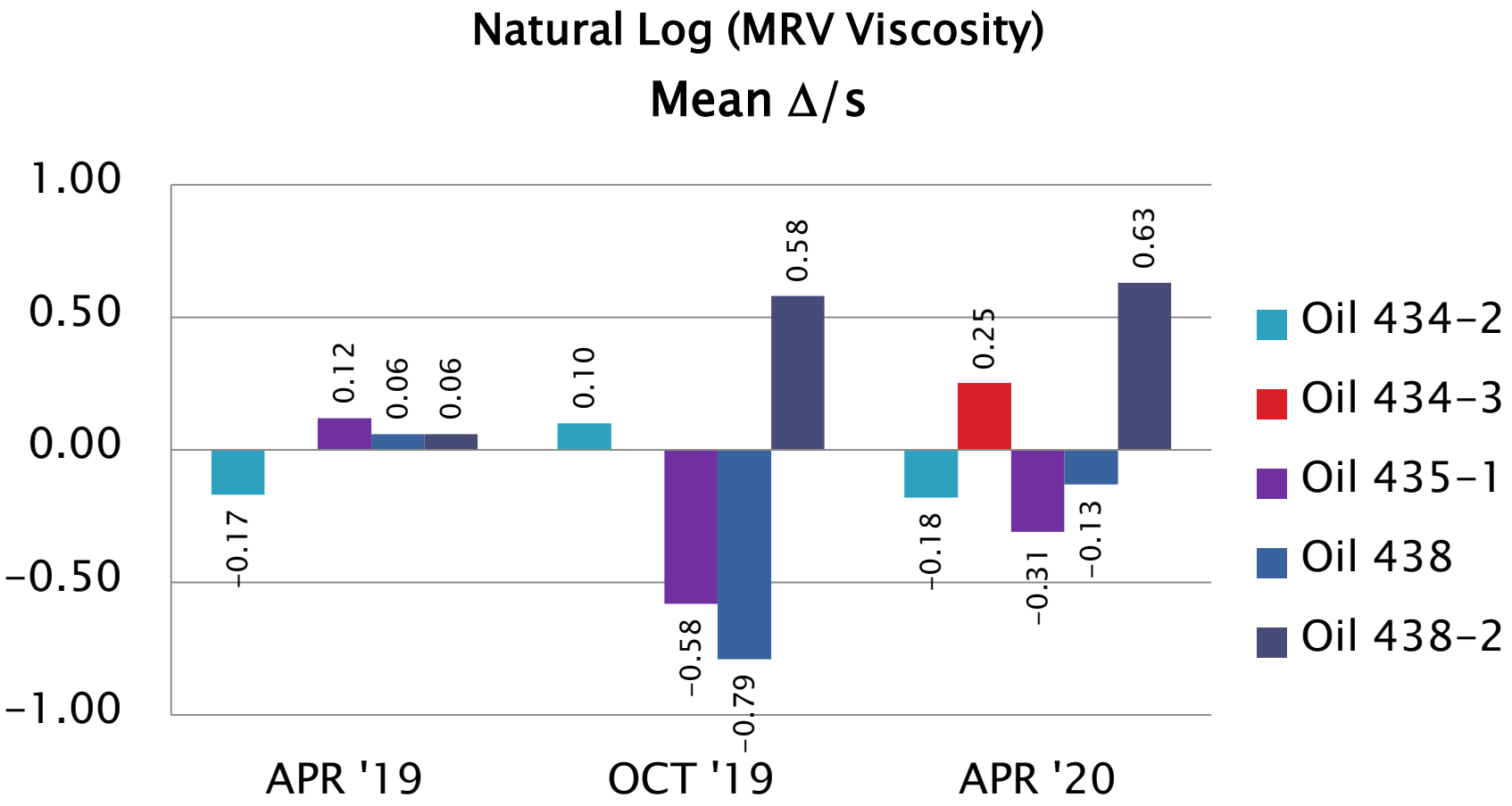
D7528: Oxidation by ROBO



D7528: Oxidation by ROBO



D7528: Oxidation by ROBO



Return to Executive Summary

Reference Oil Inventory

- As of 3/31/2020

Reference Oil Inventory

D5800

Oil	Year Rec'd By TMC[A]	Tests	TMC Inventory, gallons	Gallons Shipped last 12 months
VOLC12	2013	D5800	30.3	3.6
VOLD12	2013	D5800	28.6	3.2
VOLE12	2013	D5800	26.4	4.0
VOLD14[B]	2014	D5800QC	2.3	1.6
VOLD18[B]	2018	D5800QC	969	108

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

[B] VOLD18 is approved to replace oil VOLD14 as D5800 Daily QC Check Oil

Reference Oil Inventory

D6417, GI

Oil	Year Rec'd By TMC[A]	Tests	TMC Inventory, gallons	Gallons Shipped last 12 months
52	1995	D6417	59.5	0.01
55	1995	D6417	66.0	0.01
58[B]	1998	D6417, GI	115.1	0.3
GIA17[C]	2017	GI	9.8	0.1
1009	2002	GI	37.8	0.1

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

[B] 58 is also used as D6417 QC Check Oil

[C] GIA17 is approved to replace oil 62; oil 62 is depleted at the TMC, but is still being assigned from lab inventories.

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	103.4	0.5
434[B]	2003	MTEOS	52 samples	0.6
75-1	2016	TEOST	7.0	1.0
435-2[C]	2010	TEOST	41.0	0.5
434-2[B]	2014	ROBO	40 samples	4.0
434-3[B,C]	2017	ROBO/MTEOS	46.1	2.9
435-1	2008	ROBO	382	17.0
438-2[C]	2017	ROBO	42.0	4.8

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

[B] 434-3 replaces 434-2 in ROBO and replaces 434 in MTEOS; current inventories of 434-2 and 434 are still being used.

[C] 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	90.4	5.4
66	2002	D6082	76.1	1.5
820-2	2001	D874	8.9	0.1
90[B]	2005	D874/D874QC	16.1	3.0
91	2006	D874	3.6	0.1

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

[B] Oil 90 is also used as a D874 QC Check Oil

Additional Information

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.cmu.edu

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