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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)

Fall 2020

B0.07 Bench Testing Executive Summary

- D6417 (Volatility by GC)
- Precision (Pooled s) is less precise than prior period
  - Less precise than target precision
  - Primarily due to one rig (D5); precision is more precise than target with suspect rig results excluded.
- Performance (Mean Δ/s) is -0.34 s mild.
  - 0.01 s (on target) excluding two mild results from rig D5
- CUSUM severity plot shows overall slight severe performance with leveling to nearly on-target the past two report periods, and an uptick to mild performance this period.

B0.07 Bench Testing Executive Summary

- D5800 (Volatility by Noack)
- Precision (Pooled s) is less precise than the updated target precision (in natural log transformed units).
  - Also less precise than prior period
- Performance (Mean Δ/s) is 0.35 s severe.
  - Procedure B rigs are trending 0.62 s severe while Procedure D rigs are trending -0.33 s mild.
- Five tests exceeded 3 s from targets this period (two on rig G8)
  - Compared with three last period (two on Rig G8; rig continues to trip severity alarms into this period and already into next period).
- 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 17% this period
  - Historic period fail rates have ranged between 6% and 26%
- Precision (Pooled s) is more precise than last period
  - More precise than target precision
- Performance (Mean Δ/s) is -0.11 s mild
- First report period with significant sample population on reference oil GIA17 (replacing nearly depleted oil 62).

B0.07 Bench Testing Executive Summary

D6335 (TEOST-33C)

- Even with problematic rig excluded, precision (Pooled s) is significantly less precise than prior periods
  - Much less precise than target precision
- Performance (Mean Δ/s) is on-target (-0.02 s)
- Period fail rate of 39%
  - Six of the thirteen statistically failing runs (OC) are from one rig
  - Compared to 0% fail rate last period, but 20% and 23% before that, and similarly high in prior periods
- All tests this period report using Rod Batch M.
- First report period with significant sample population on reference oil 75-1 (reblend of depleted oil 75).

B0.07 Bench Testing Executive Summary

- D7097 (MHT-4 TEOST)

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

- Performance (Mean Δ/s) is -0.22 s mild
  - No statistically unacceptable runs reported this period.

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

- All operationally valid calibration tests this period report using Catalyst Batch 18AB (n=5) or 19BA (n=67)

- Overall severity on catalyst batch 19BA (n=122) appears to be about -0.25 s mild, and comparably mild on both reference oils.
  - Catalyst Batch 18AB is, overall, performing similarly mild (n=247)

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 -0.85 s mild
  - Replacement reference oil FOAMB18 performing at -0.95 s mild (n=11)
  - Third consecutive period of mild performance on the new reference oil.
    - 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.

B0.07 Bench Testing Executive Summary

- D874 (Sulfated Ash)
- Precision (Pooled s) is more precise than prior periods
  - More precise than target precision
- Performance (Mean Δ/s) is -0.30 s mild

B0.07 Bench Testing Executive Summary

- D7528 (ROBO)
- Precision (Pooled s) is more precise than last period
  - Continues to be less precise than target
- Performance (Mean Δ/s) is -0.76 s mild for this report period
- CUSUM severity plot shows variable performance past three report period

Calibrated Labs and Stands*

Test	Labs	Stands
D6417	5	6
D5800	9	22
D5133 (GI)	7	10
D6335 (TEOST)	7	10
D7097 (MTEOS)	9	35
D6082	5	6
D874	4	--
D7528 (ROBO)	5	19

*As of 9/30/2020

D02.B0.07
TMC Monitored Tests

- April 1, 2020 –
  September 30, 2020

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D6417: Estimation of Engine Oil Volatility by Capillary GC

Test Status	Validity Code	No. Tests
Acceptable Calibration Test	AC	14
Failed Calibration Test	OC	2
Operationally Invalidated by Lab	LC, XC	1
Operationally Invalidated After Initially Reported as Valid	RC	2
Shakedown Run	AN	1
Total		**20**

Number of Labs Reporting Data: 7
(only 6 labs reported calibration runs)
Fail Rate of Operationally Valid Tests: 12%

D6417: Estimation of Engine Oil Volatility by Capillary GC

Statistically Unacceptable Tests (OC)	No. Of Tests
Volatility Loss Mild	2
Volatility Loss Severe	0

- The two mild results, and one result invalidated due to mild QC performance, were on the same rig (D5). GC column was replaced between failing runs, rig has not subsequently passed calibration. The same rig had a passing calibration earlier in the report period.

- There were three operationally invalid tests reported this period
  - Incorrect QC oil (RC)
  - QC performance severe (RC)
  - QC performance mild (LC)

- One rig shakedown test to evaluate rig performance (validity AN); no calibration runs were reported on that rig this period.

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

- D6417 calibration requirement updates are issued as LTMS document updates

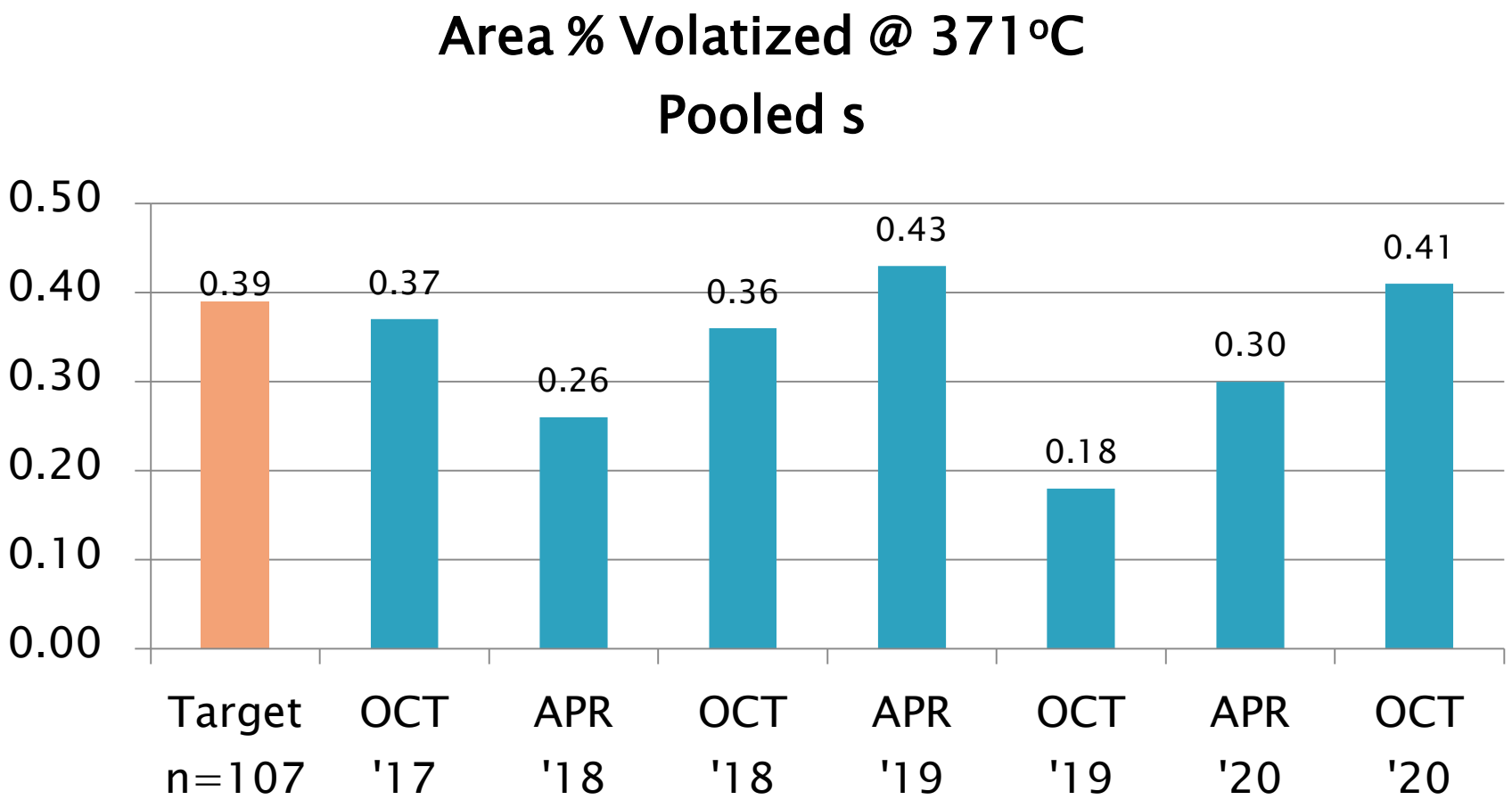
D6417: Estimation of Engine Oil Volatility by Capillary GC

Period Precision and Severity Estimates

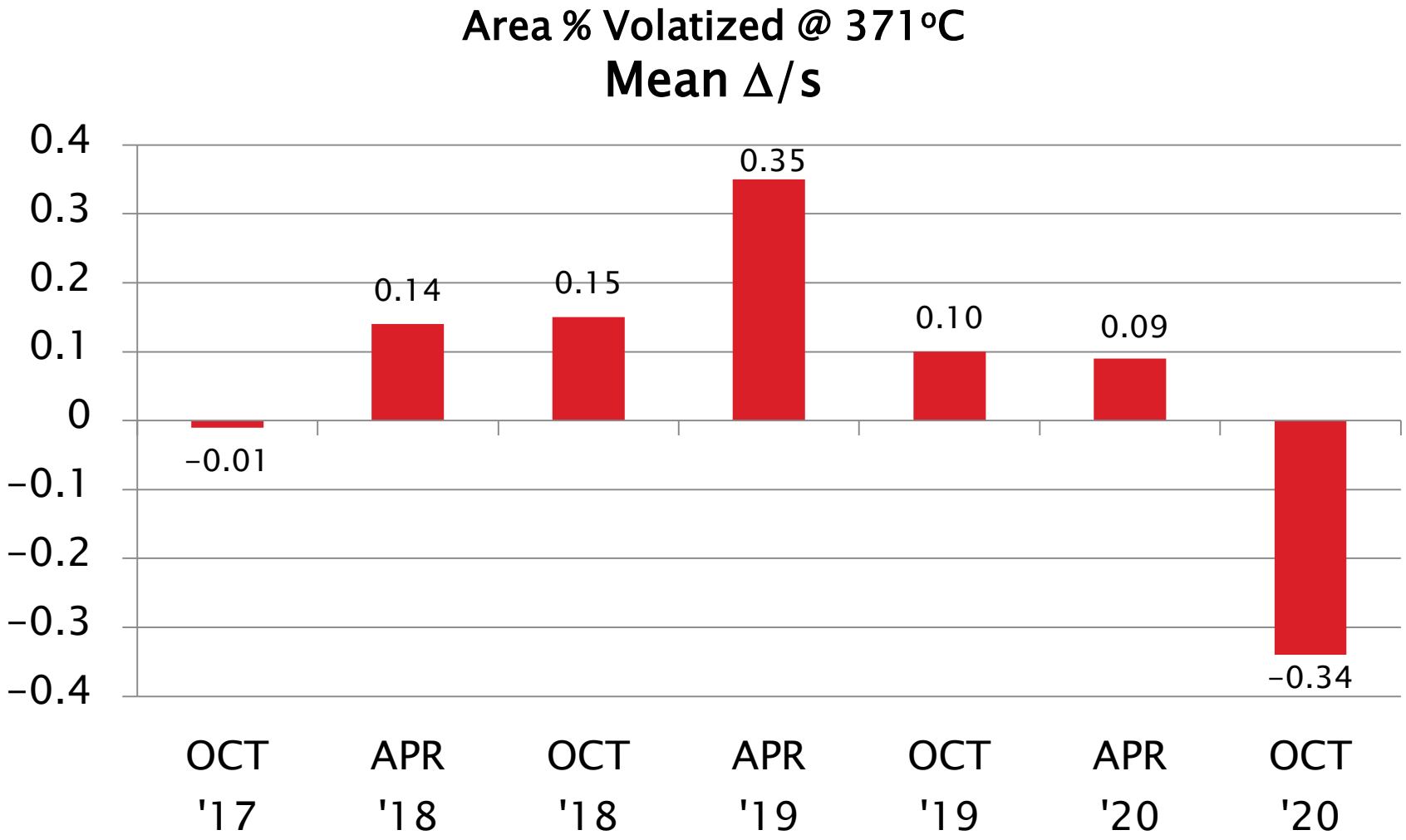
Area % Volatized @ 371°C	n	df	Pooled s	Mean Δ/s
Initial Selected Oils from RR	54	51	0.39	-----
4/1/17 through 9/30/17	15	12	0.37	-0.01
10/1/17 through 3/31/18	15	12	0.26	0.14
4/1/18 through 9/30/18	16	13	0.36	0.15
10/1/18 through 3/31/19	19	16	0.43	0.35
4/1/19 through 9/30/19	19	16	0.18	0.10
10/1/19 through 3/31/20	17	14	0.30	0.09
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

*Period statistics with two mild results from rig D5 included and excluded (operational problem suspected but not yet confirmed)

D6417 Precision Estimates



D6417 Severity Estimates



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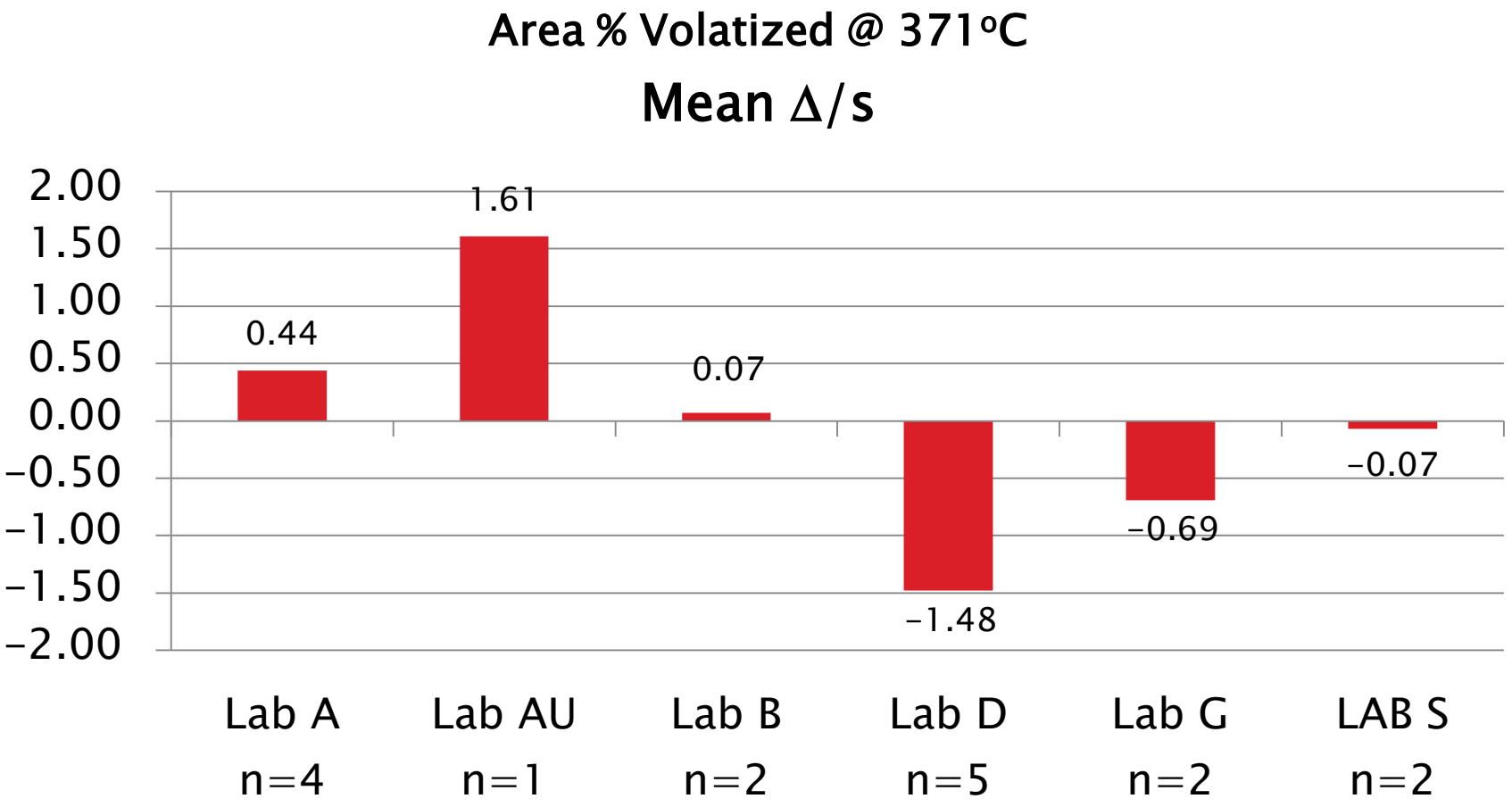
D6417 Lab Severity Estimates



D6417: Estimation of Engine Oil Volatility by Capillary GC

- Precision (Pooled s) is less precise than prior period
  - Less precise than target precision
  - Primarily due to one rig (D5); precision is more precise than target with suspect rig results excluded.

- Performance (Mean Δ/s) is -0.34 s mild.
  - 0.01 s (on target) excluding two mild results from rig D5

- CUSUM severity plot shows overall slight severe performance with leveling to nearly on-target the past two report periods, and an uptick to mild performance this period.

D6417 VOLATILITY BY GC INDUSTRY OPERATIONALLY VALID DATA

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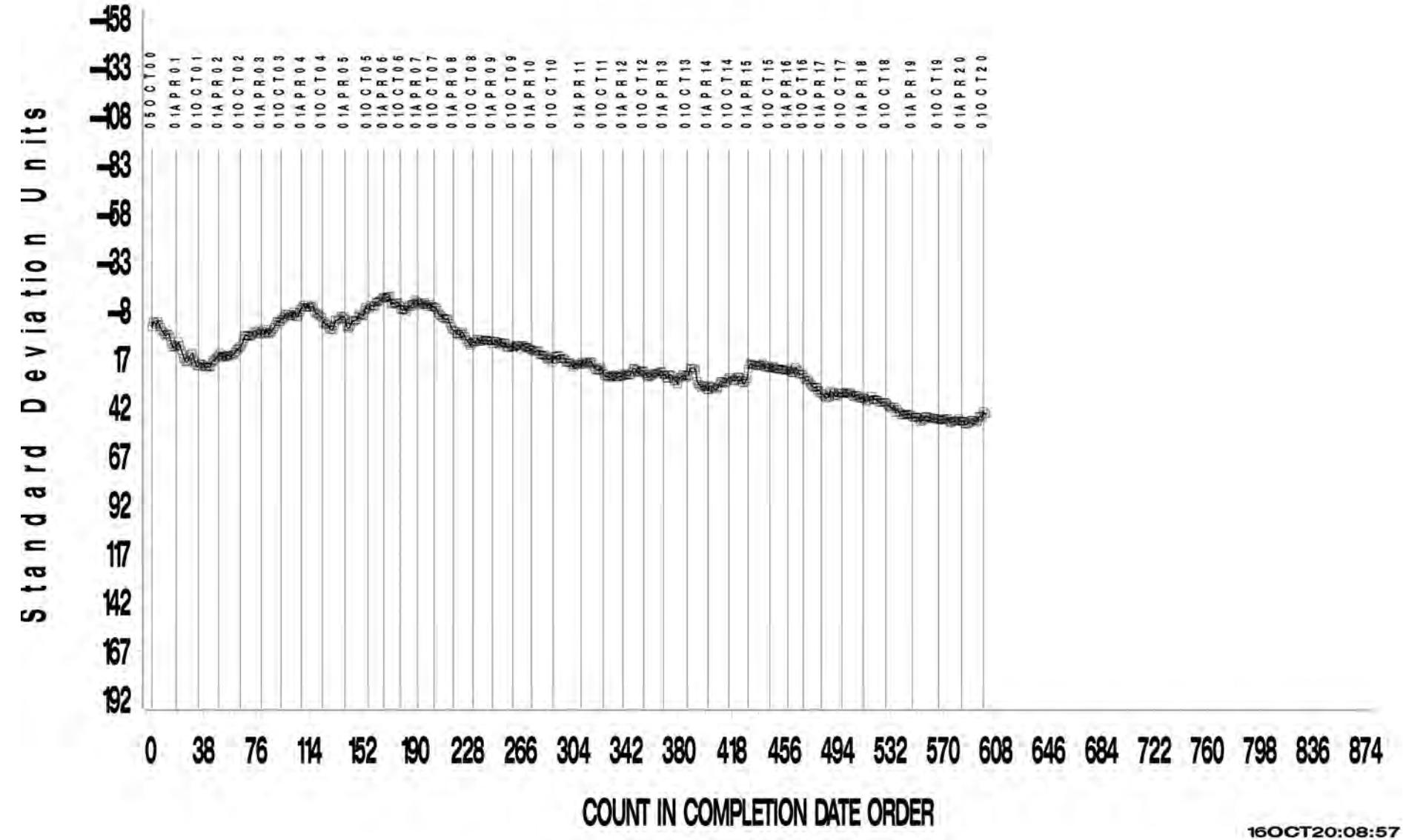
SAMPLE AREA % VOLATIZED

CUSUM Severity Analysis



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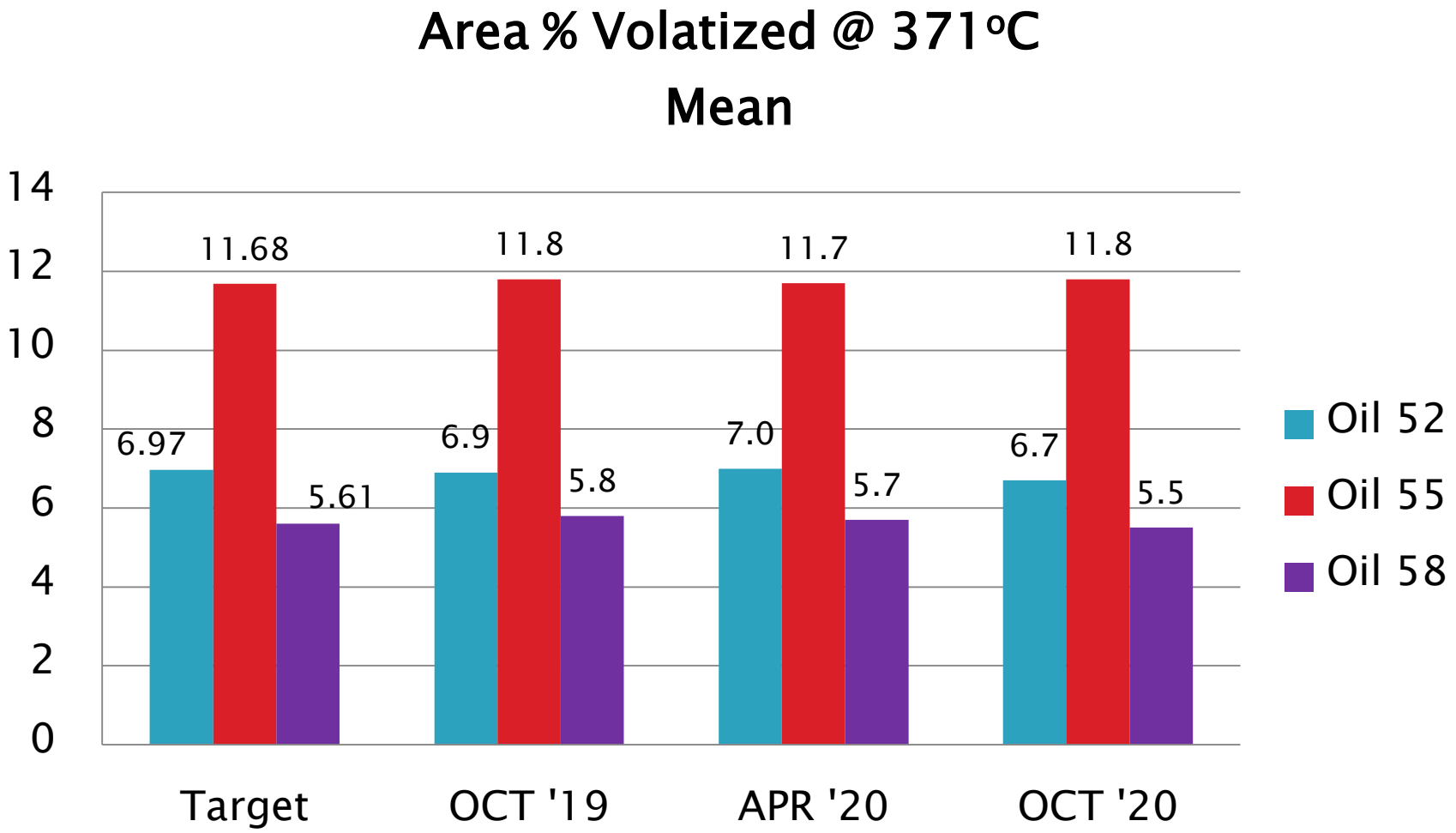
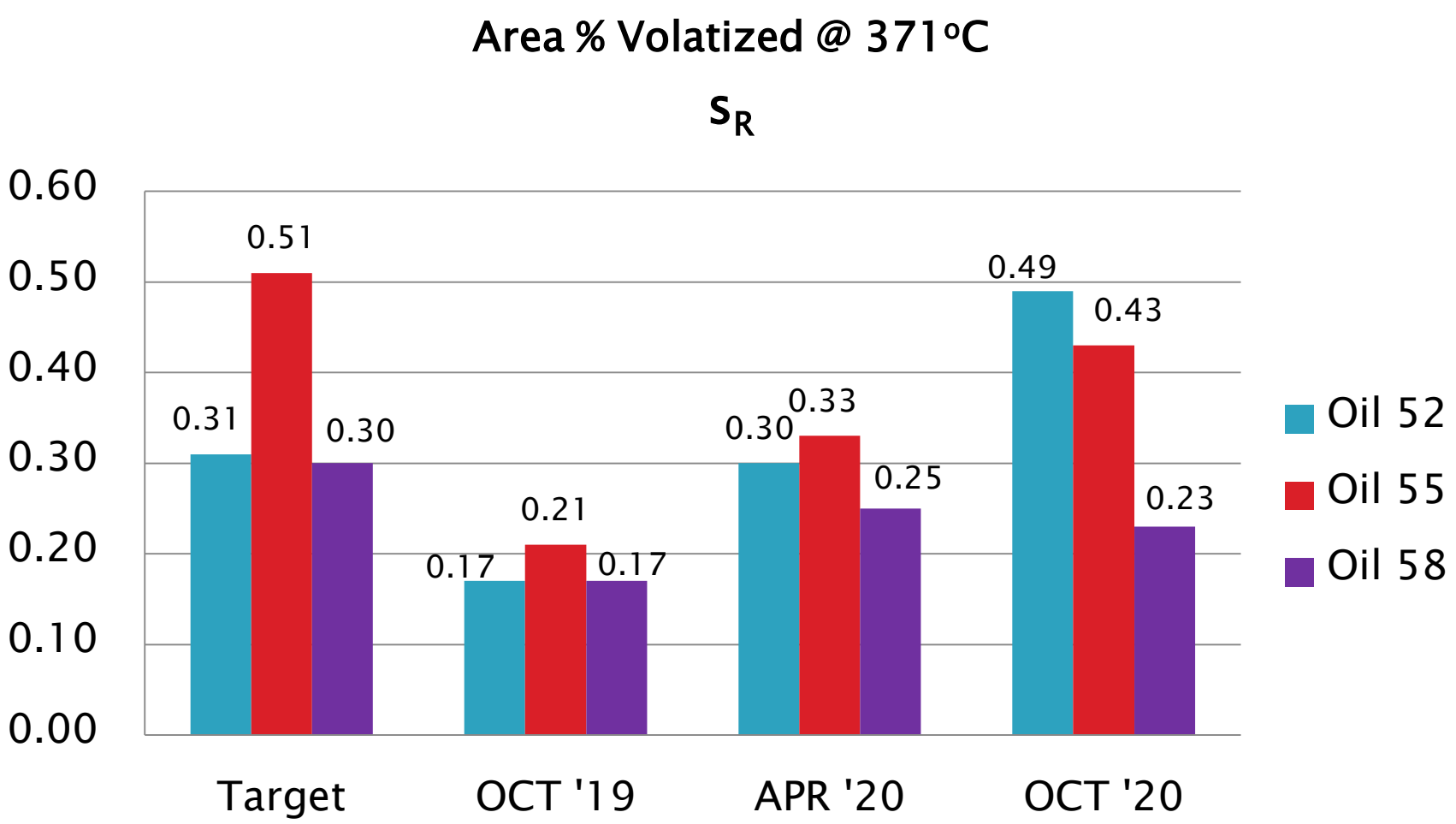
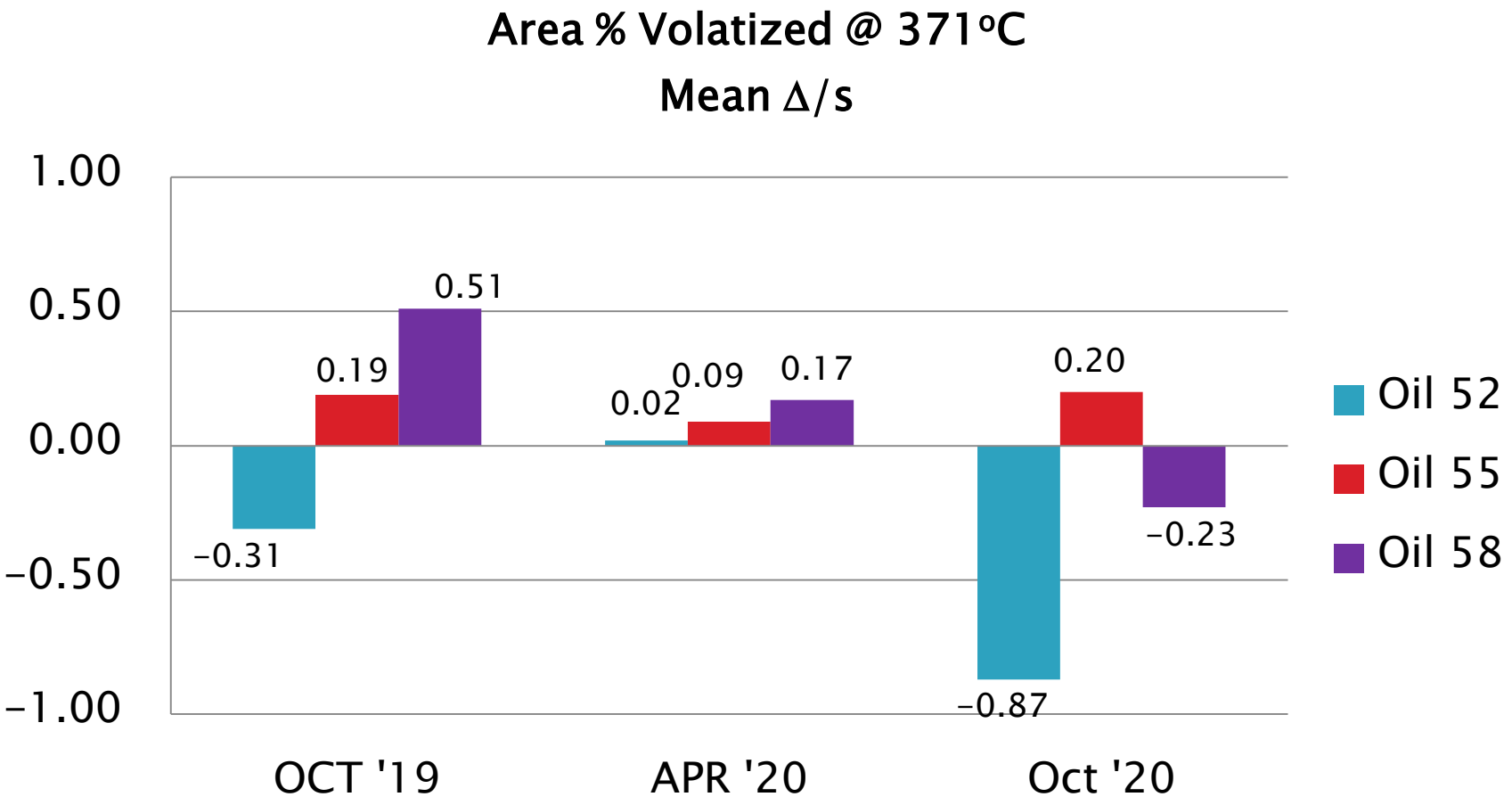
D6417 Performance by Oil



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	125
Failed Calibration Test	OC	11
Operationally Invalidated by Lab	LC, XC	1
Operationally Invalidated After Initially Reported as Valid	RC	1
Held out of statistics (new rig, failed to calibrate)	MC	2
Total		**140**

Number of Labs Reporting Data: 10
Fail Rate of Operationally Valid Tests: 8%

D5800: Evaporation Loss of Lubricating Oil by Noack Method

Statistically Unacceptable Tests (OC)	No. Of Tests
Ei Level 3 Precision Alarm Mild	5
Ei Level 3 Precision Alarm Severe	2
Zi Level 2 Severity Alarm Severe	4
Zi Level 2 Severity Alarm Mild	1

- The 11 OC tests were on seven different rigs at four labs.
  - One test triggered both Ei L3 and Zi L2 alarms (both mild)
  - Rig G8 had two consecutive Zi L2 (severe) alarms before alarm cleared on the third attempt, repeated on next calibration attempt (four OC fails total for the period, with a fifth failing run reported into next period).
  - Rig D7 had two failing OC results for the period (non-consecutive). One result reported at -8.6 s mild.
  - Rig G5 reported an OC result -5.8 s mild

D5800: Evaporation Loss of Lubricating Oil by Noack Method

- Two operationally invalid calibration runs were reported this period:
  - Pump failure (LC)
  - Differential pressure off-spec (RC)

- Two tests reported as operationally valid on a new rig (J6) were withheld from statistics (MC) because the new rig failed to demonstrate a passing calibration. This was the third consecutive failing two-test calibration attempt on the new rig.

- Technical memo 20-030 was issued on 20200610 advising of test method update to D5800-20

- 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	-----
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
4/1/20 through 9/30/20[1]	136	133	0.0659	0.35

[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

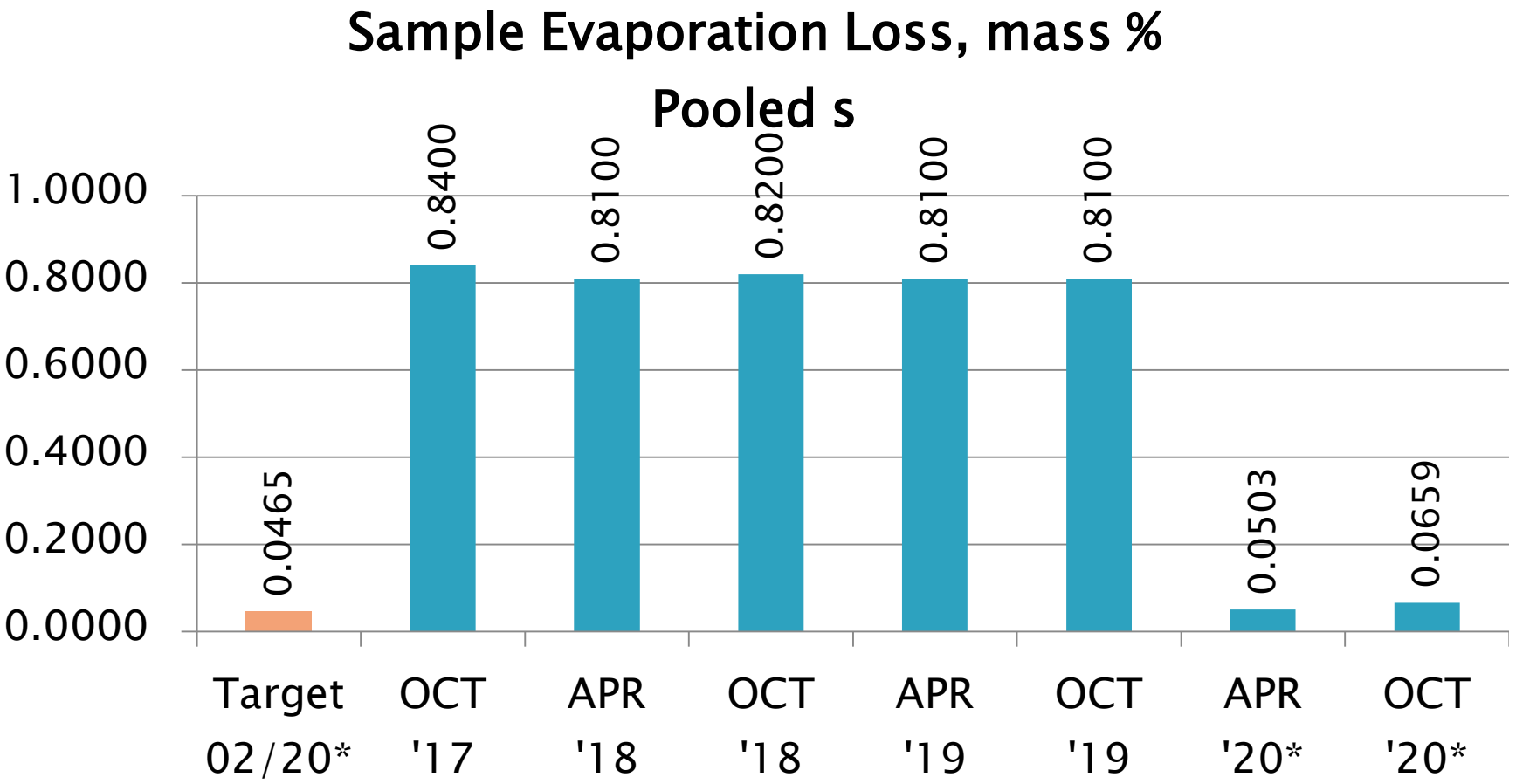
Sample Evaporation Loss, Mass %

Procedure	n	df	Pooled s	Mean Δ/s
Procedure B	97	94	0.06	0.62
Procedure C	No Procedure C tests reported this period.			
Procedure D	39	36	0.07	-0.33

Model	n	df	Pooled s	Mean Δ/s
NCK2	5	2	0.01	0.48
NCK25G	92	89	0.06	0.63
NS2	39	36	0.07	-0.33

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

D5800 Precision Estimates



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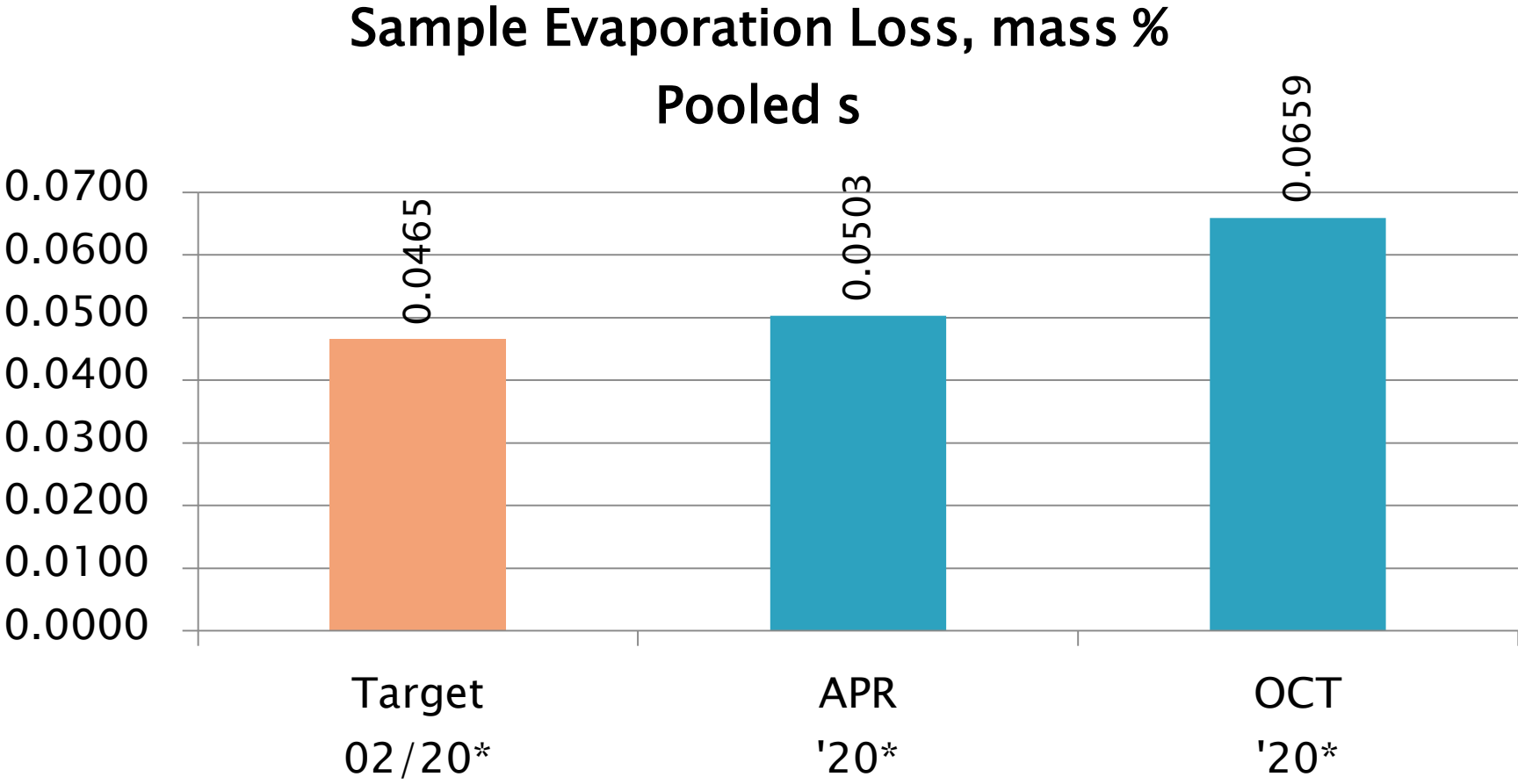
D5800 Precision Estimates



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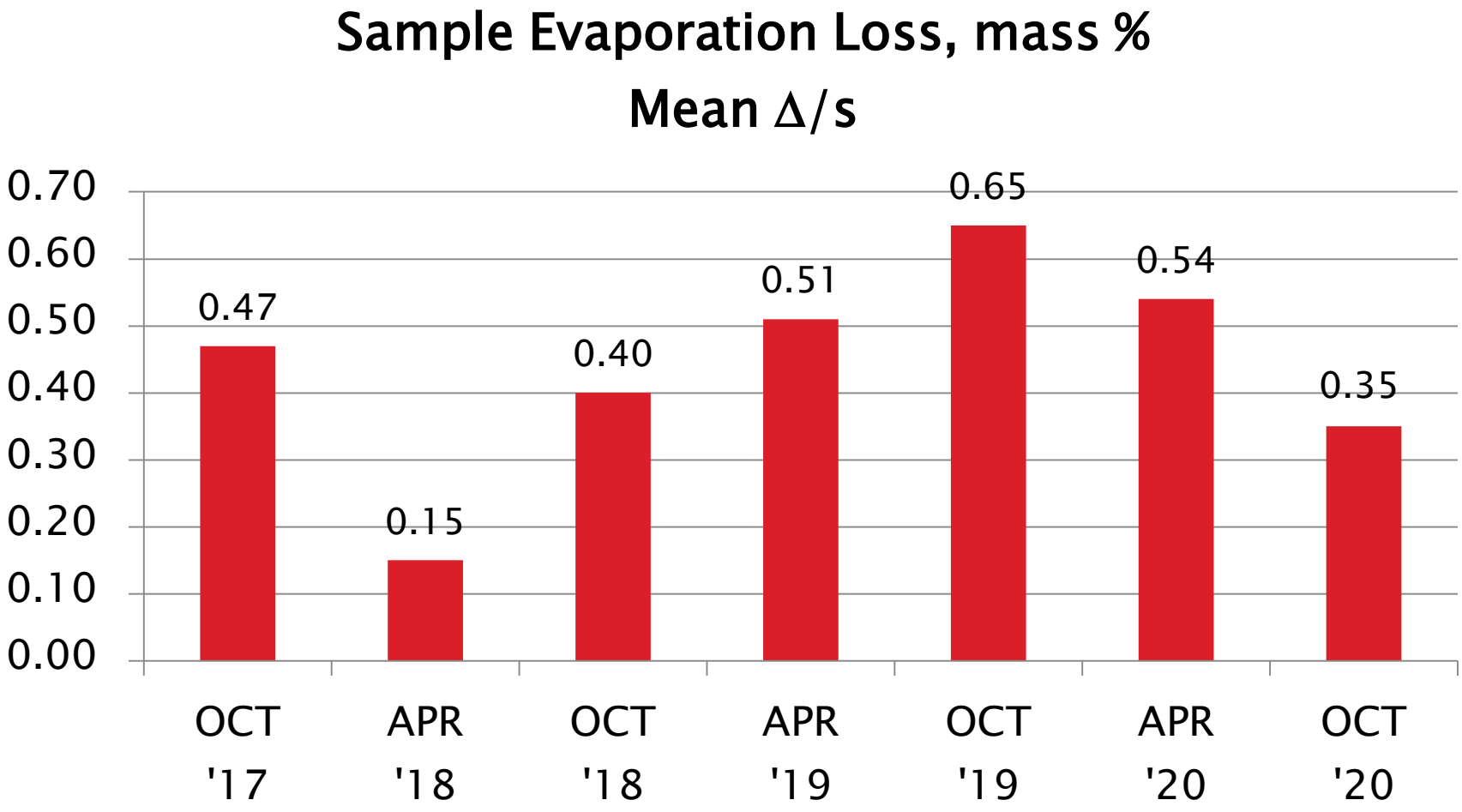
D5800 Severity Estimates



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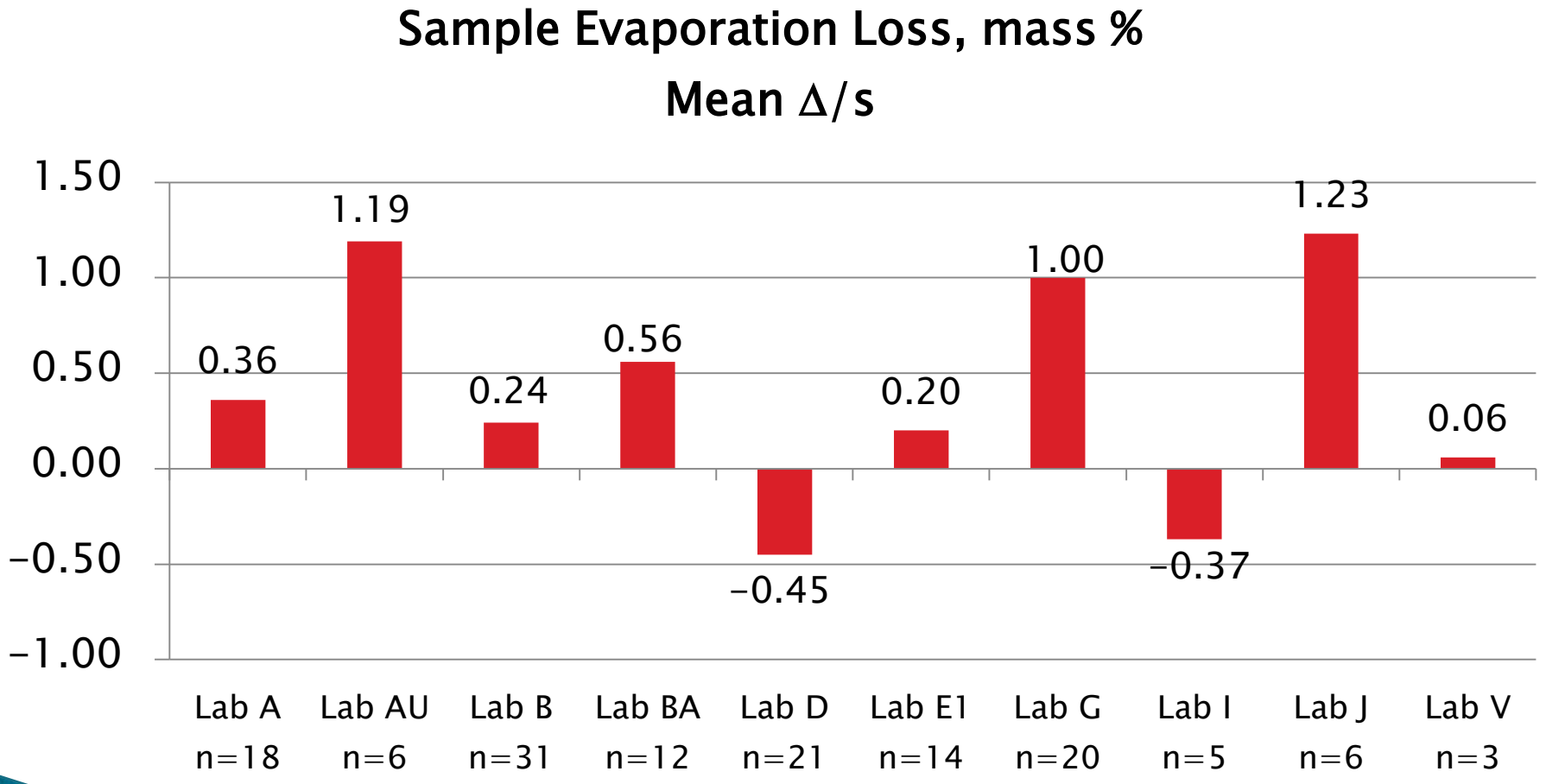
D5800 Lab Severity Estimates



D5800: Evaporation Loss of Lubricating Oil by Noack Method

- Precision (Pooled s) is less precise than the updated target precision (in natural log transformed units).
  - Also less precise than prior period
- Performance (Mean Δ/s) is 0.35 s severe.
  - Procedure B rigs are trending 0.62 s severe while Procedure D rigs are trending −0.33 s mild.
- Five tests exceeded 3 s from targets this period (two on rig G8)
  - Compared with three last period (two on Rig G8; rig continues to trip severity alarms into this period and already into next period).
- 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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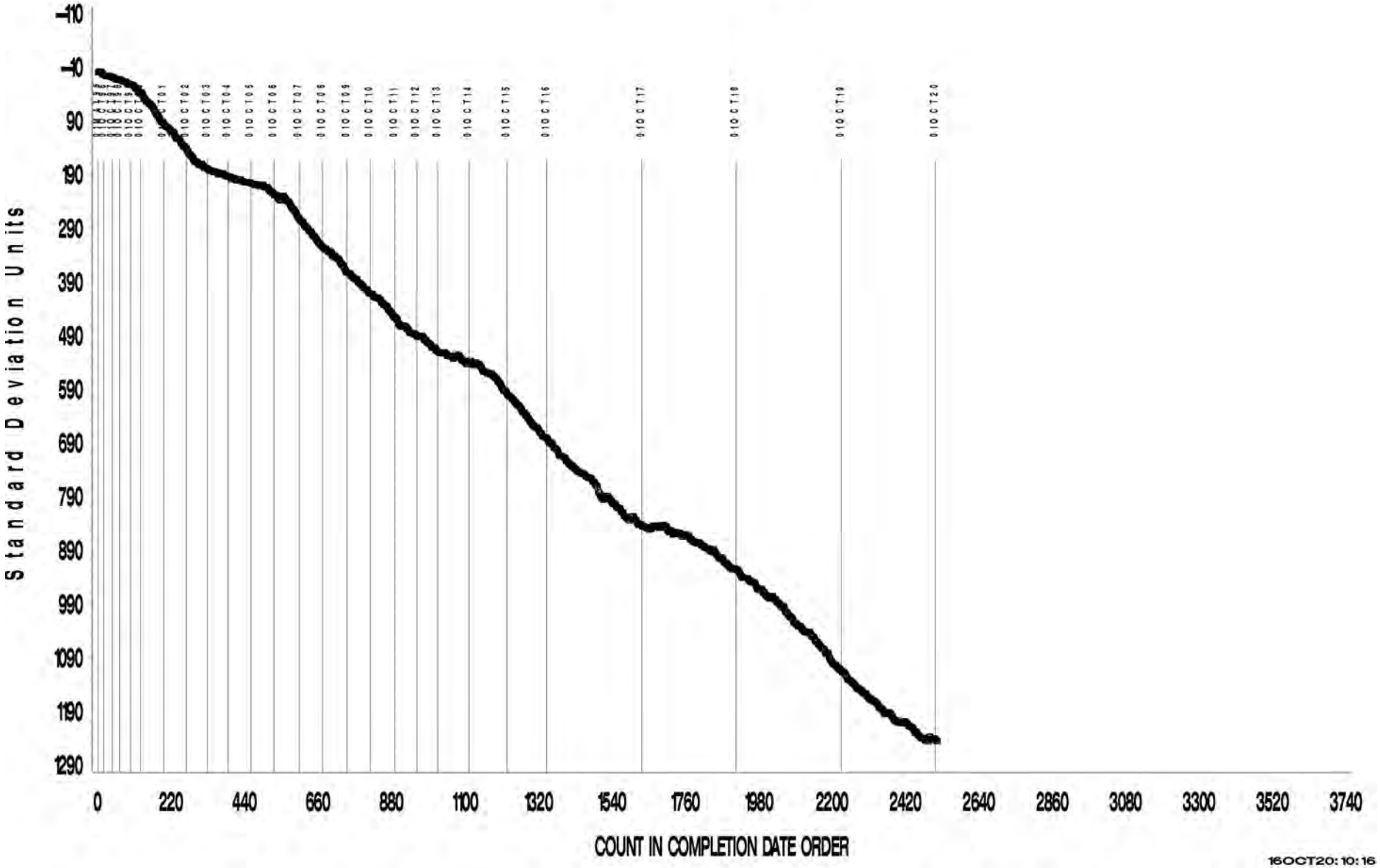
CUSUM Severity Analysis



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D5800 VOLATILITY BY NOACK INDUSTRY OPERATIONALLY VALID DATA

EVAPORATION LOSS, MASS%

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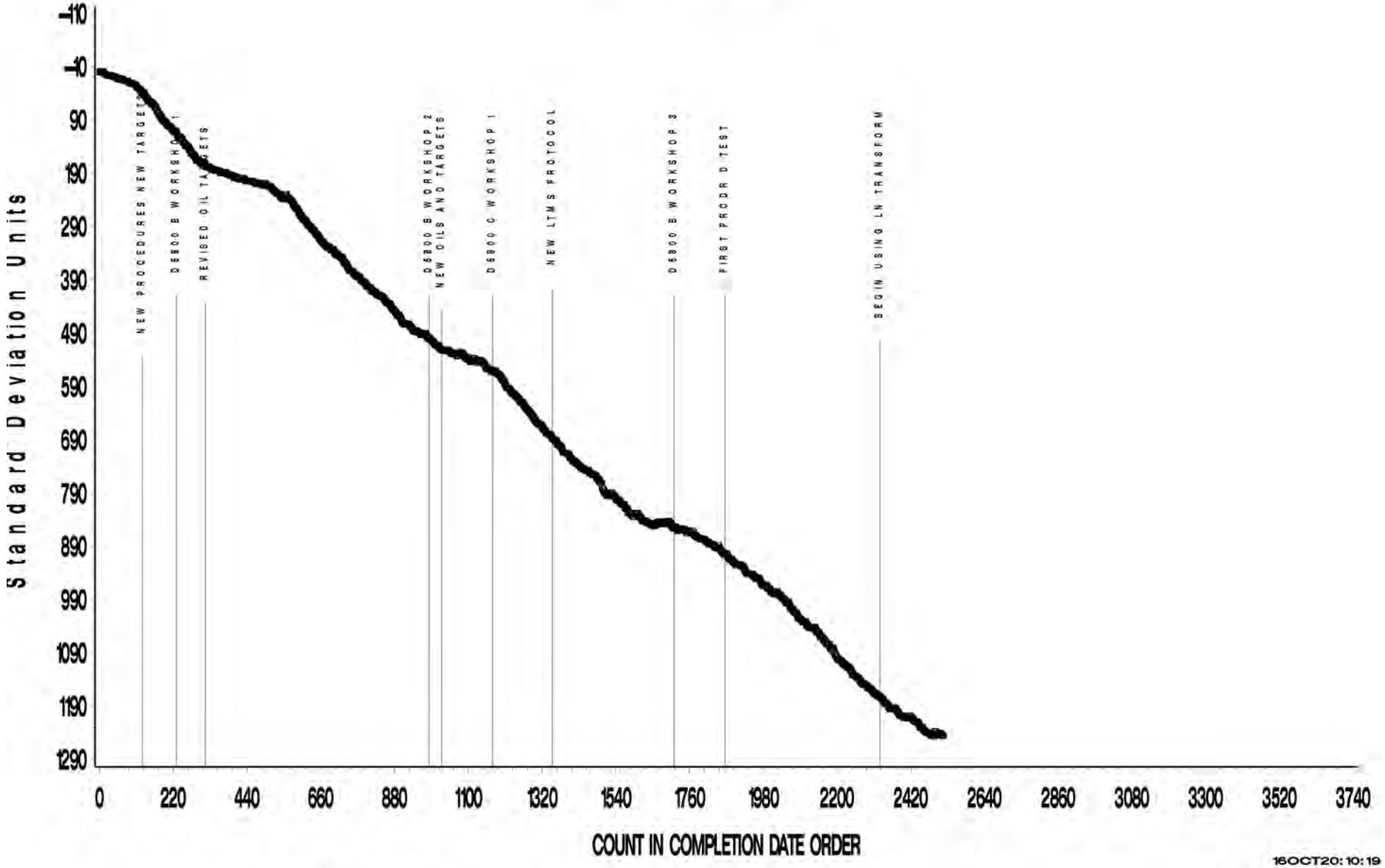
CUSUM Severity Analysis



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EVAPORATION LOSS, MASS%

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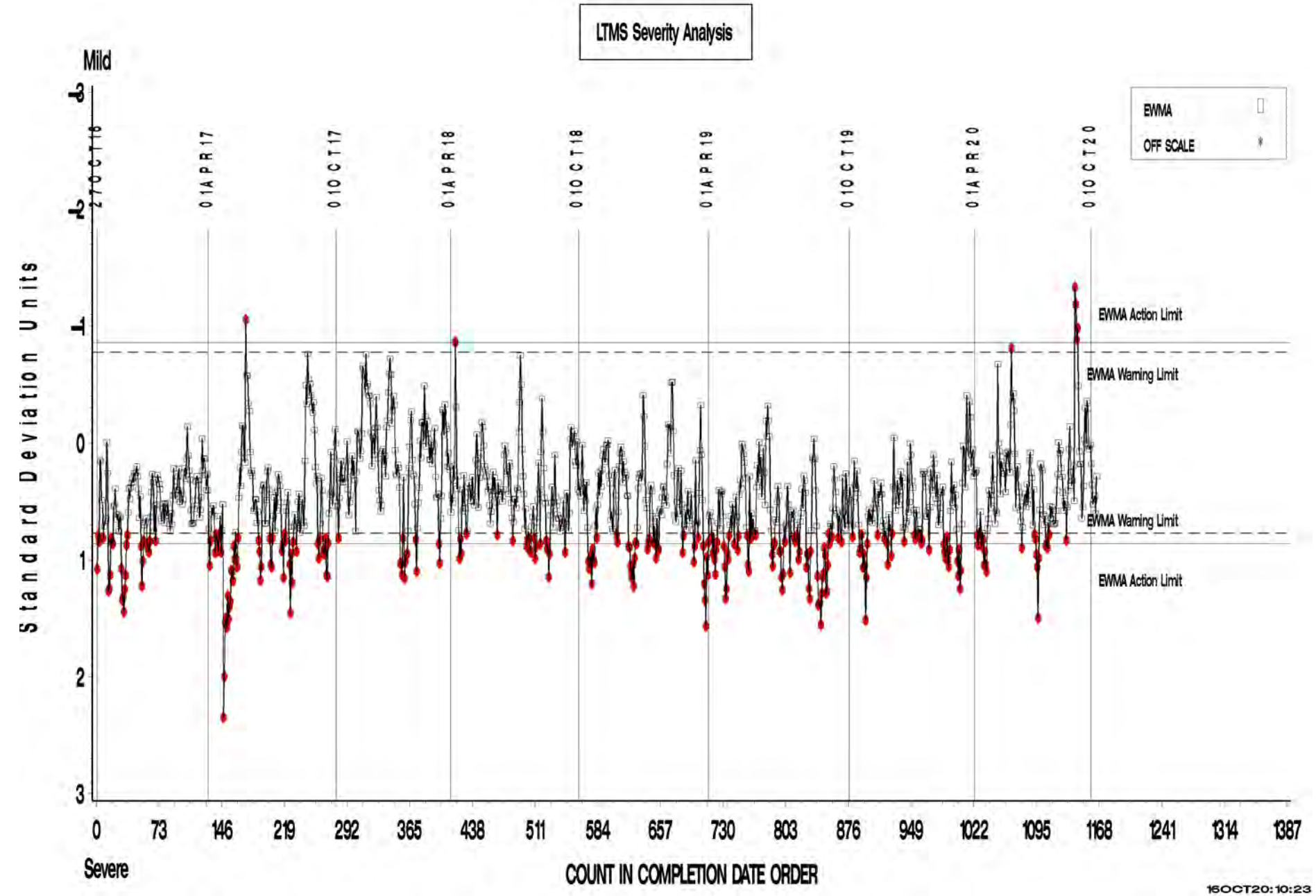

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EVAPORATION LOSS, MASS%

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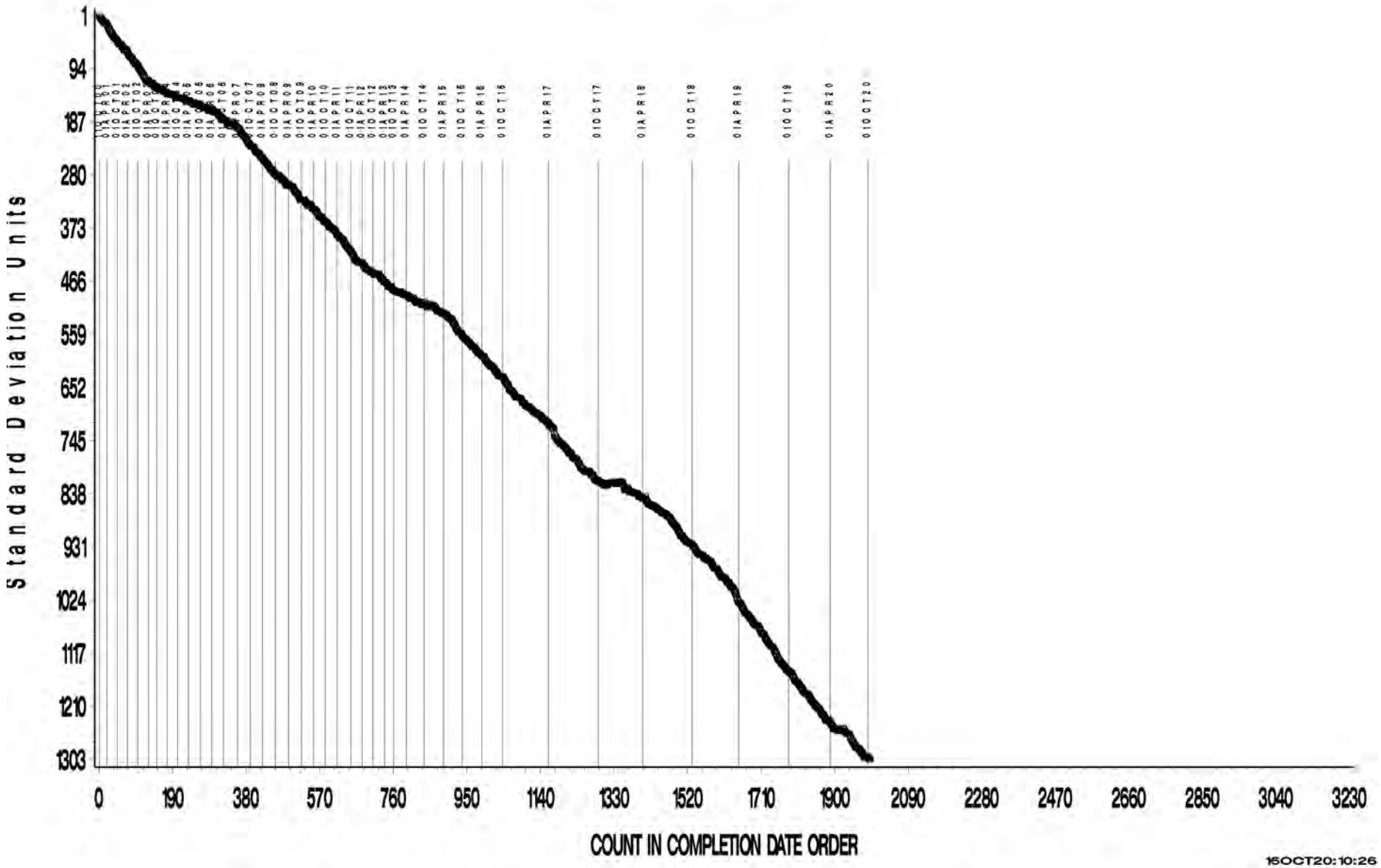
CUSUM Severity Analysis



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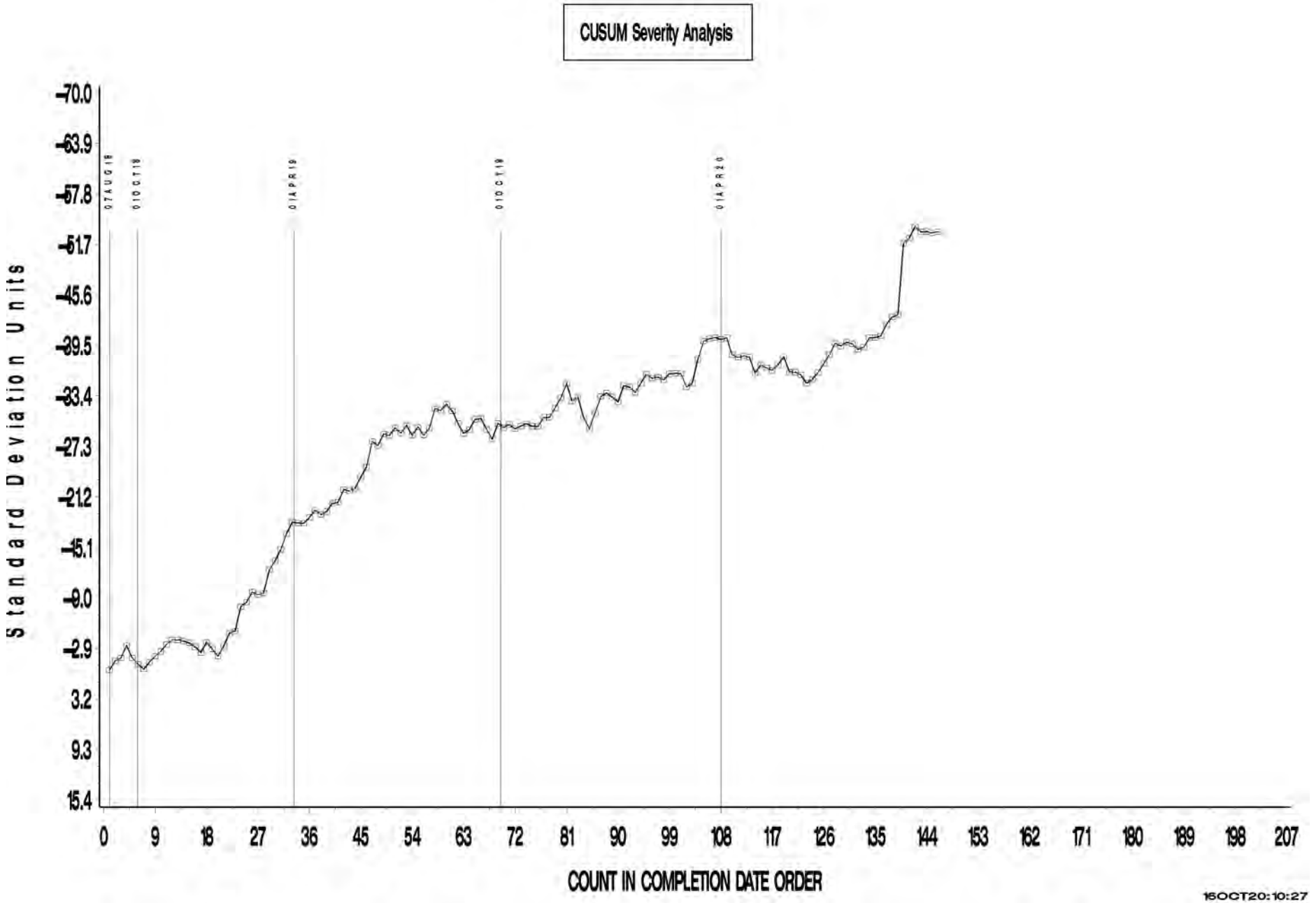
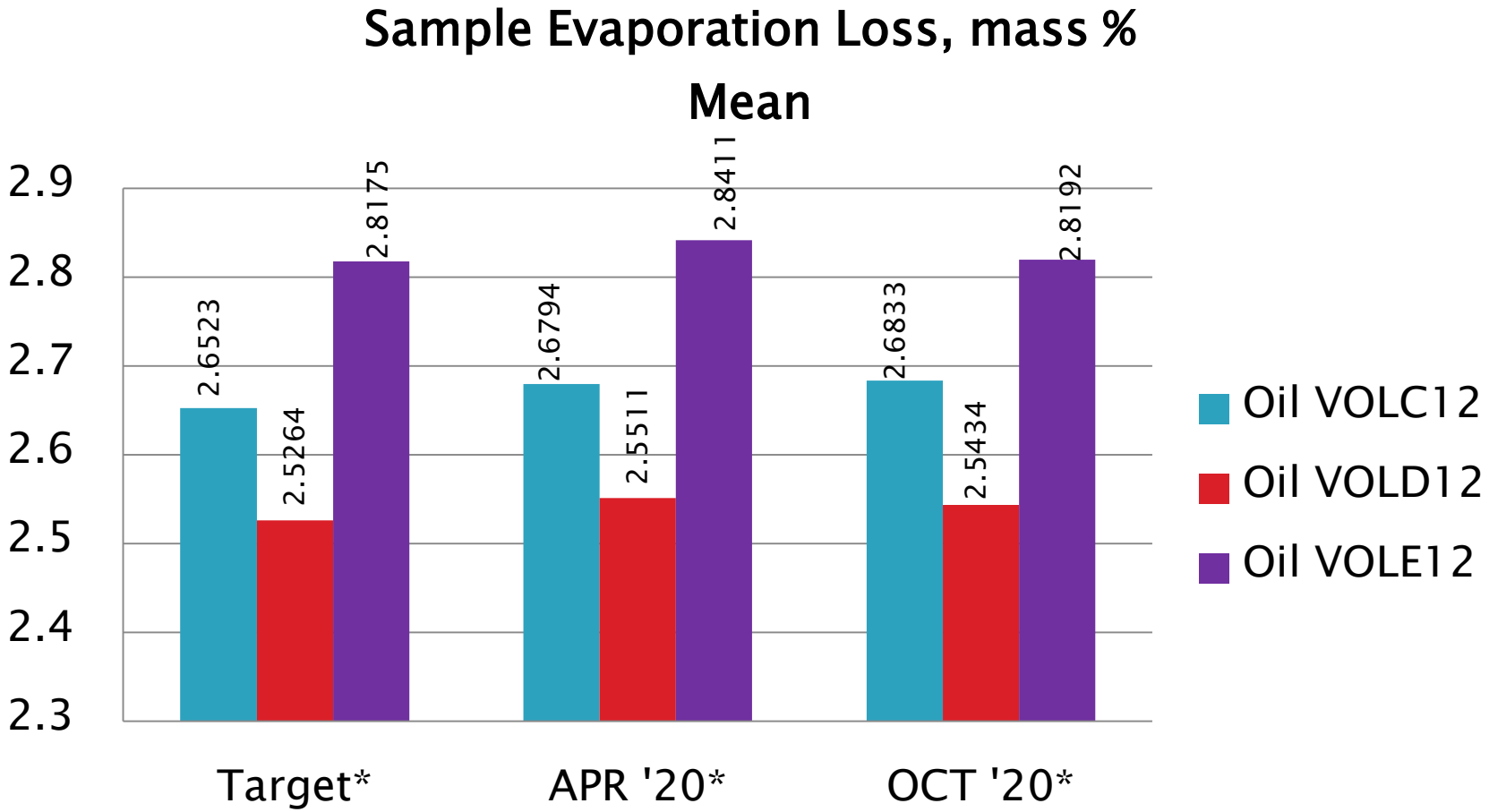
EVAPORATION LOSS, MASS%

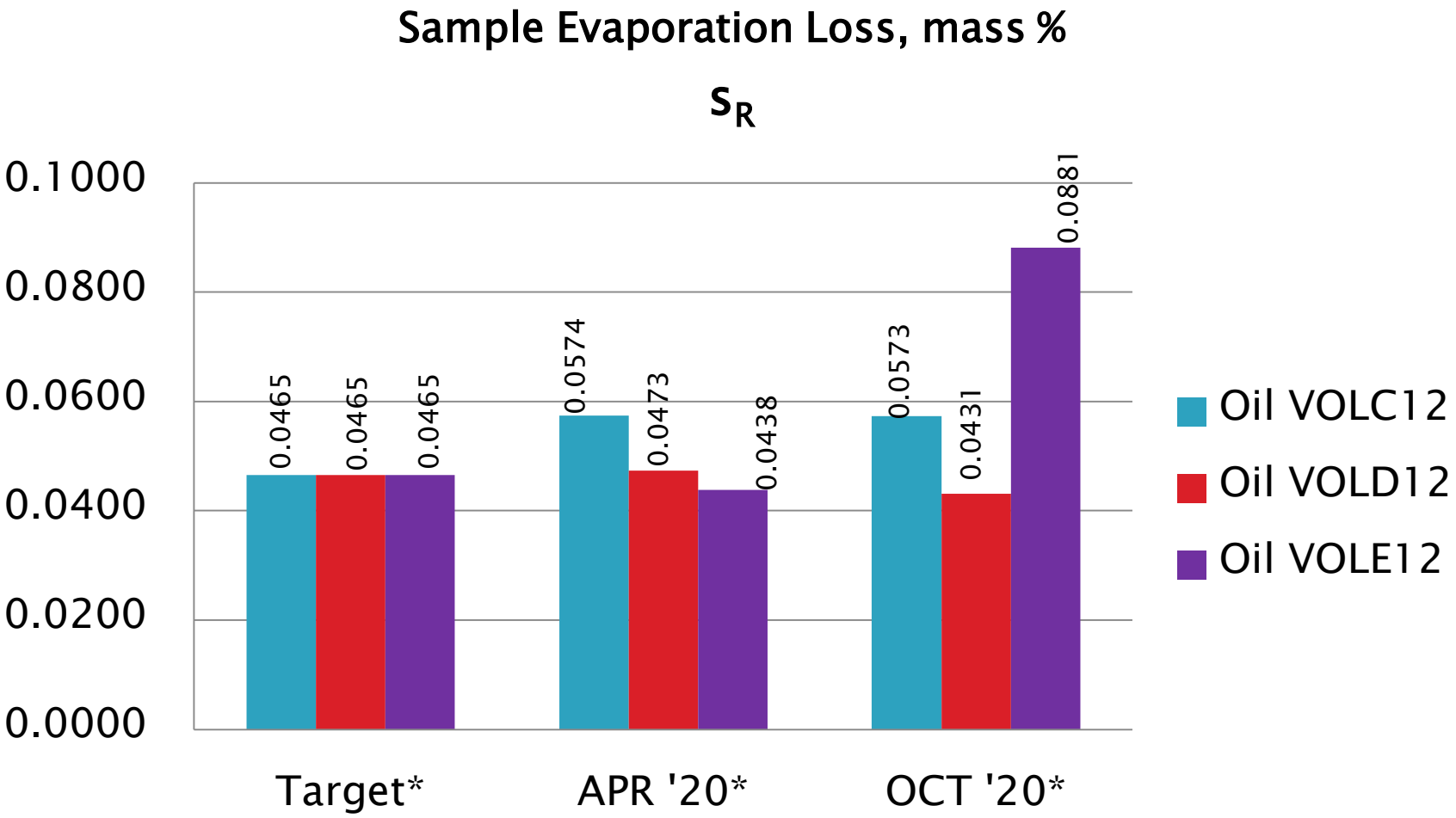


D5800 Performance by Oil



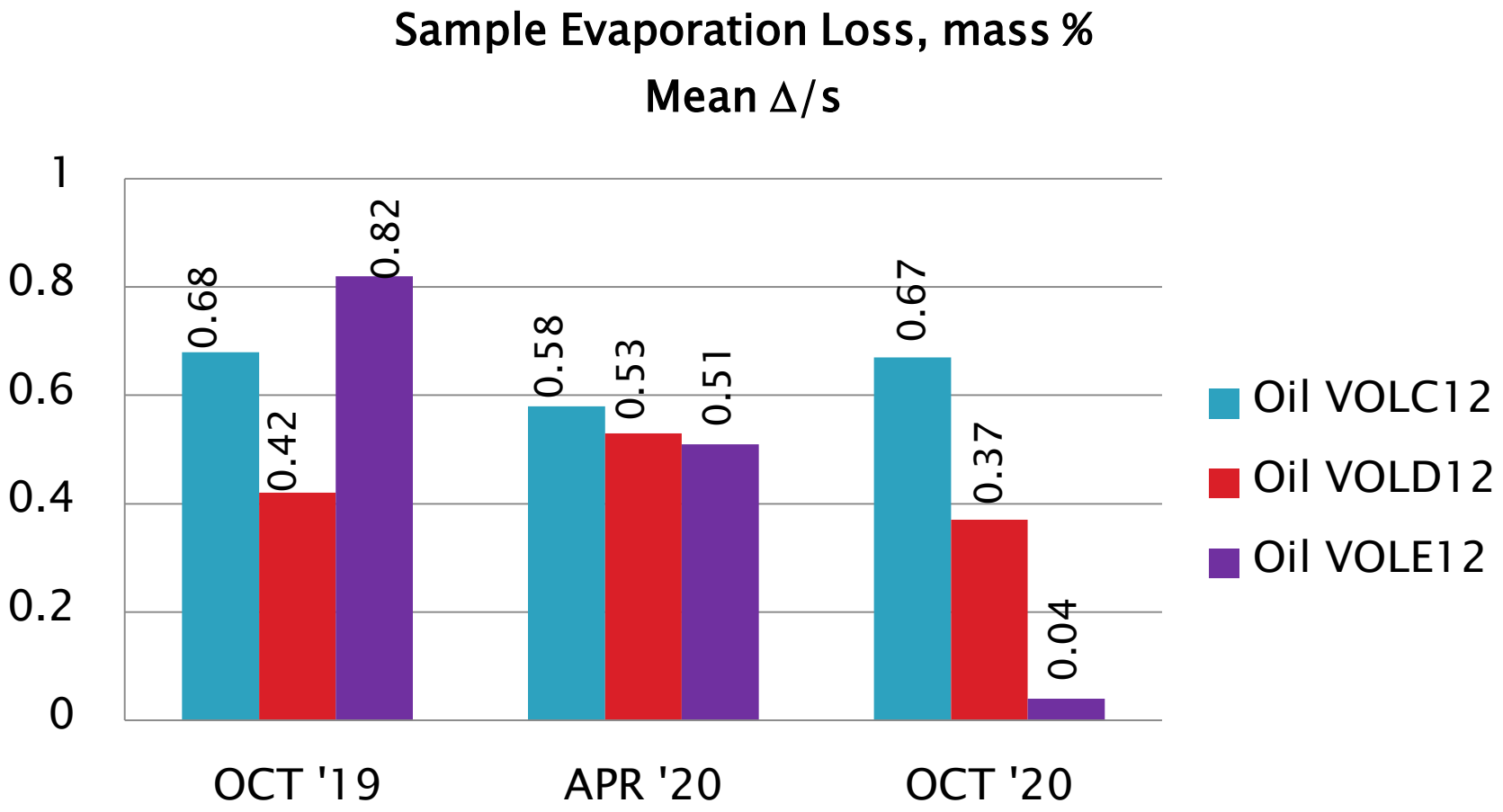
*Results transformed to natural log per updated LTMS 20200207

D5800 Performance by Oil



*Results transformed to natural log per updated LTMS 20200207

D5800 Performance by Oil



Return to Executive Summary

D5133: Gelation Index

Test Status	Validity Code	No. Tests
Acceptable Calibration Test	AC	43
Failed Calibration Test	OC	9
Operationally Invalidated by Lab	LC, XC	1
Operationally Invalidated After Initially Reported as Valid	RC	5
Industry Donated Run	AG	3
Instrument Shakedown	AN, ON	8
Total		**69**

Number of Labs Reporting Data: 9

Fail Rate of Operationally Valid Tests: 17%

D5133: Gelation Index

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

- .Six operationally invalid tests reported this period:
  - Two with seized heads, noted post-test (LC, RC)
  - Four with non-compliant internal calibrations on the heads (RC)

- Three industry information runs starting a round robin to evaluate performance of a potential new reference oil (GI ~10-12)

- Eight shakedown runs requested on a new bath (all heads).

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

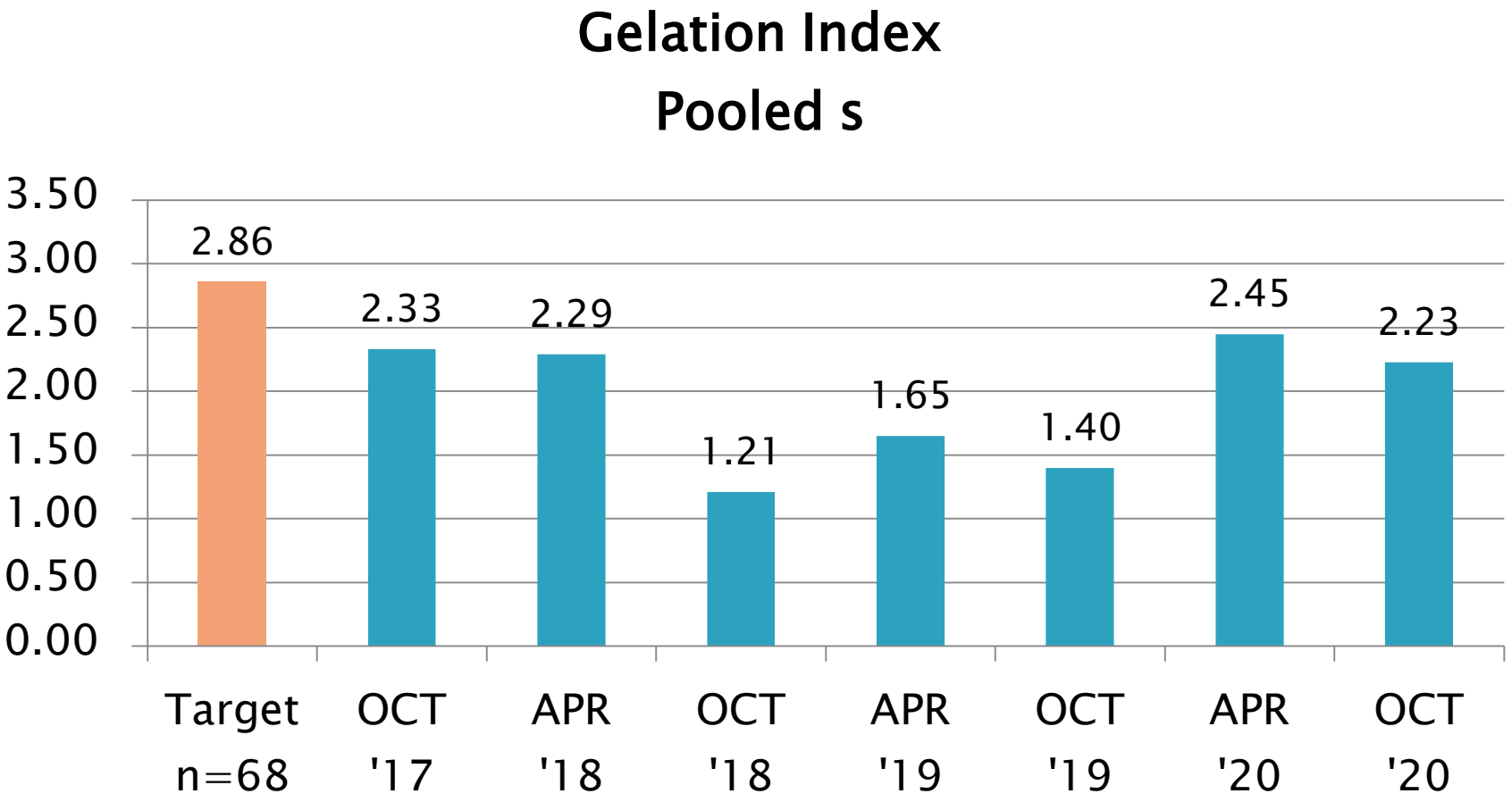
D5133: Gelation Index

Period Precision and Severity Estimates

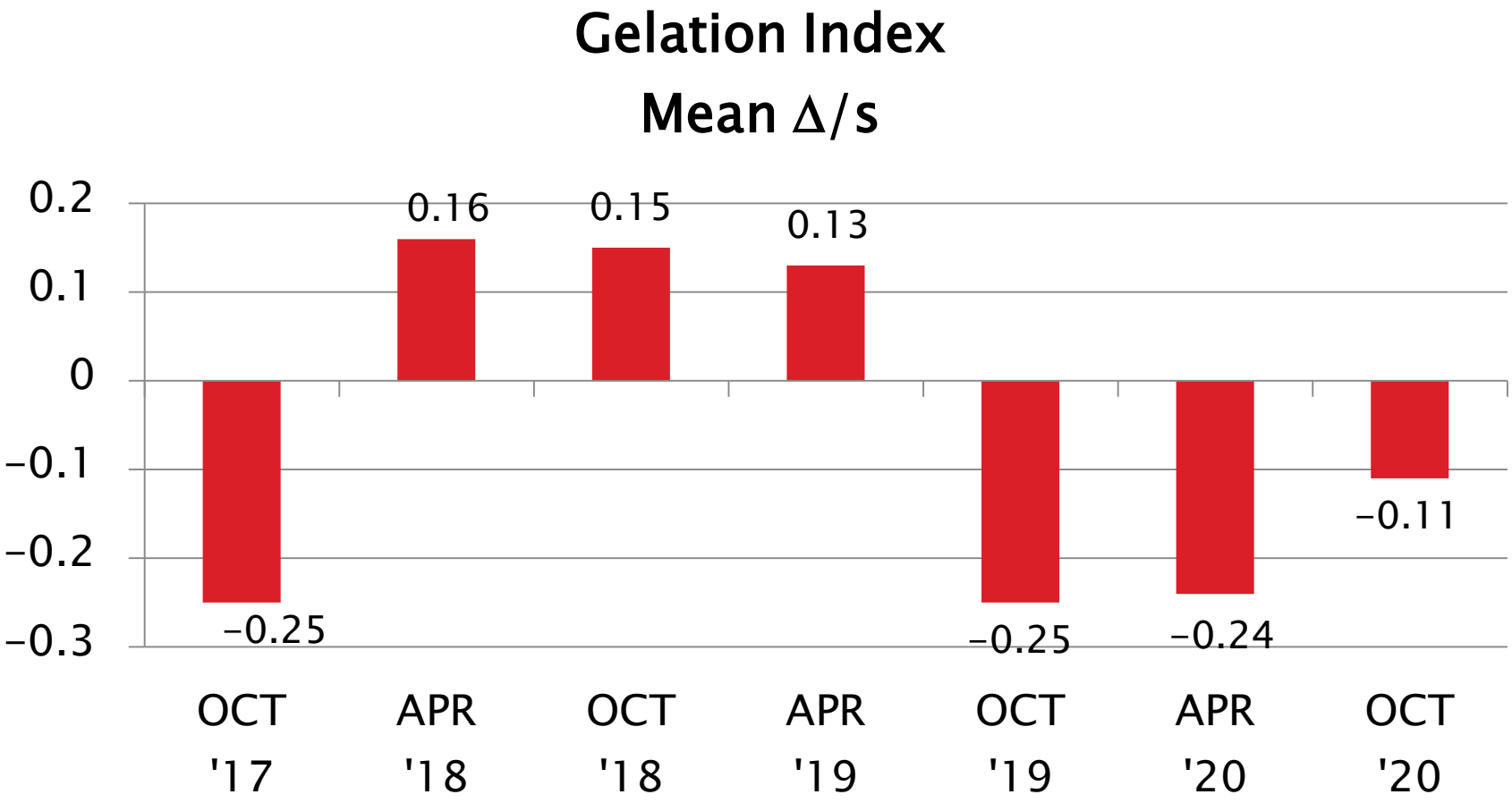
Gelation Index	n	df	Pooled s	Mean Δ/s
Current Targets 7/15/2003	68	65	2.86	-----
10/1/17 through 3/31/18	36	33	2.29	0.16
4/1/18 through 9/30/18* 4/1/18 through 9/30/18*	32 31	29 28	1.21 1.03	0.15 -0.02
10/1/18 through 3/31/19	27	24	1.65	0.13
4/1/19 through 9/30/19	47	44	1.40	-0.25
10/1/19 through 3/31/20	41	37	2.45	-0.24
4/1/20 through 9/30/20	52	48	2.23	-0.11

*Extreme OC results included and excluded

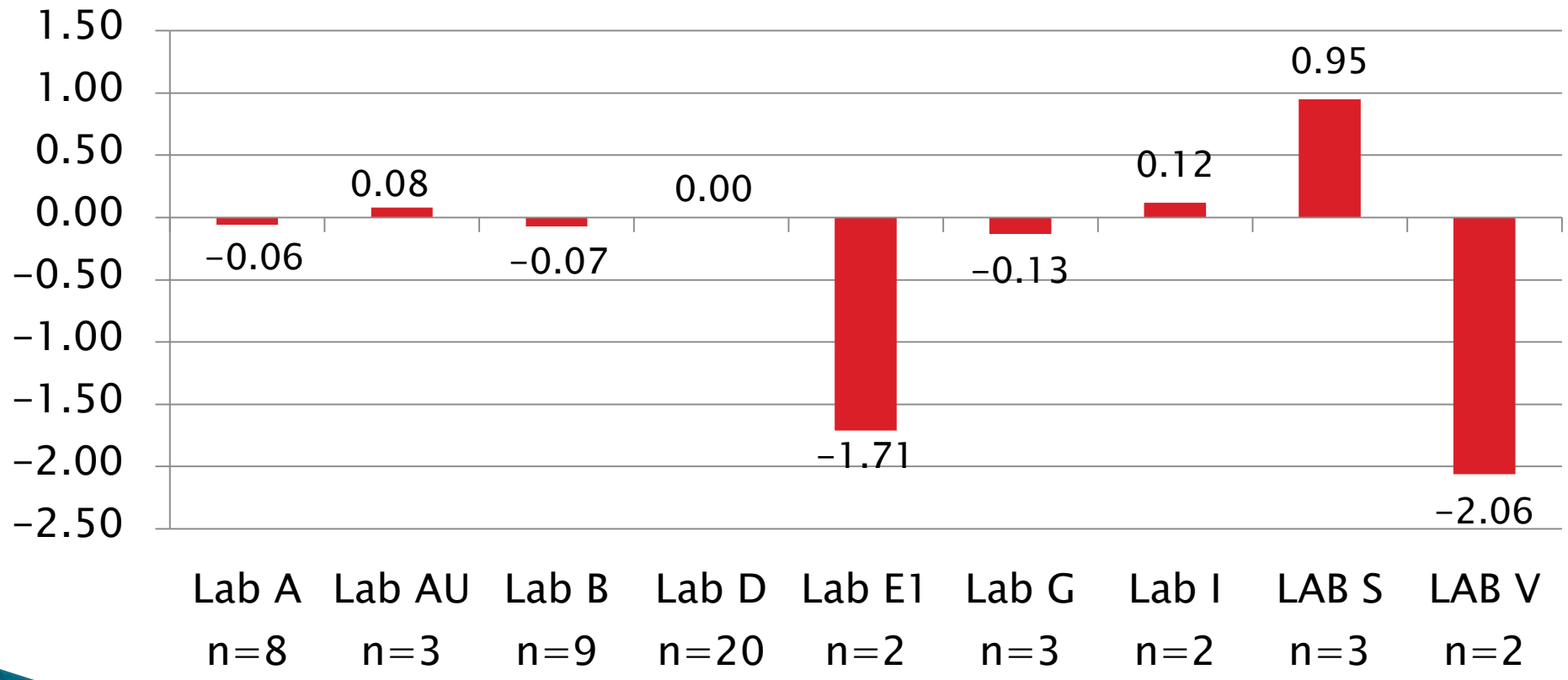
D5133 Precision Estimates



D5133 Severity Estimates



D5133 Lab Severity Estimates



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D5133: Gelation Index

- Fail rate of operationally valid tests is 17% this period
  - Up from 12% last period
  - Historic period fail rates have ranged between 6% and 26%
- Precision (Pooled s) is more precise than last period
  - More precise than target precision
- Performance (Mean Δ/s) is -0.11 s mild
- Only one of the nine statistically invalid (OC) results this period was on low/non-gelling oil 58, the others were on oils with expected measurable gelation index performance.
- First report period with significant sample population on reference oil GIA17 (replacing nearly depleted oil 62).

D5133 GELATION INDEX INDUSTRY OPERATIONALLY VALID DATA

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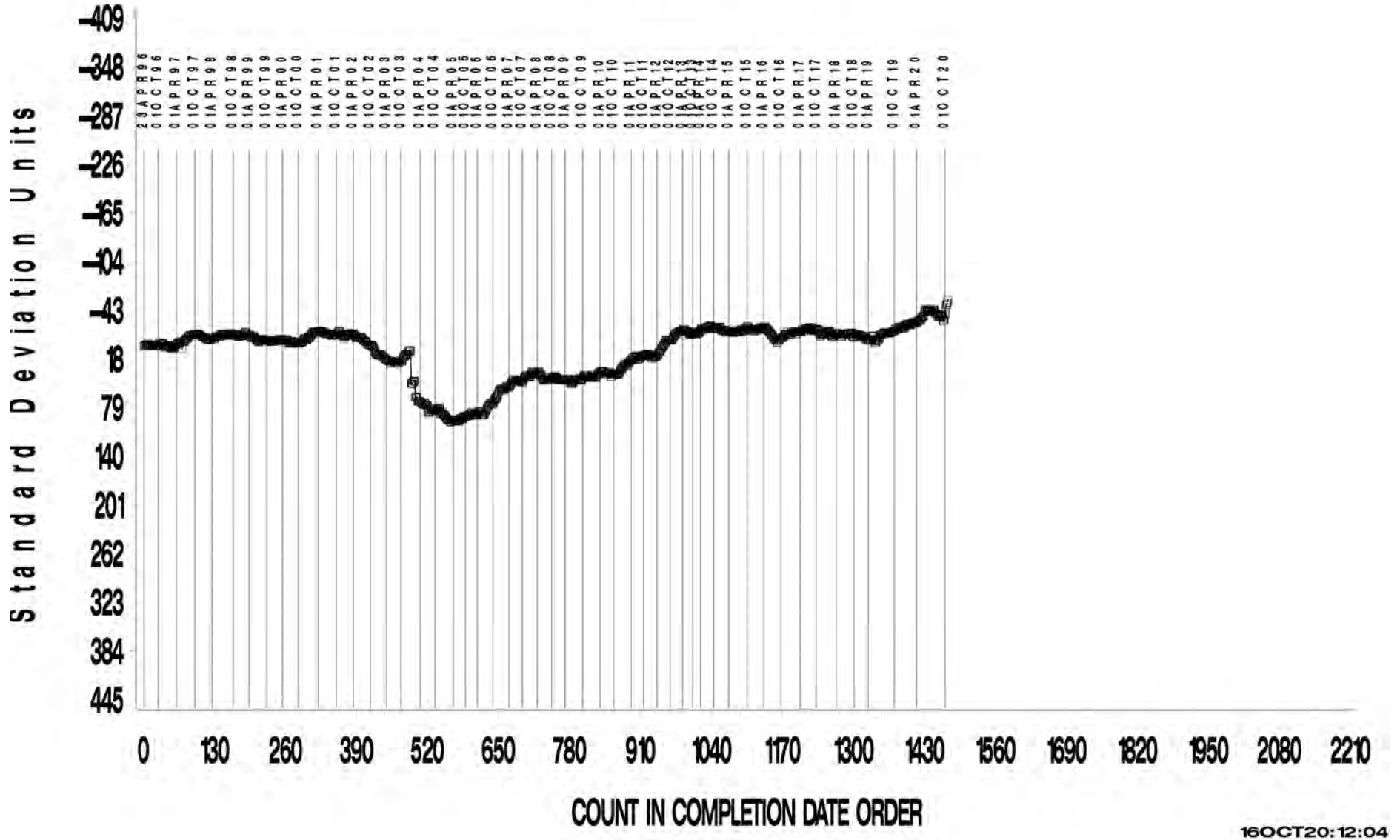
GELATION INDEX

CUSUM Severity Analysis



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D5133 GELATION INDEX INDUSTRY OPERATIONALLY VALID DATA

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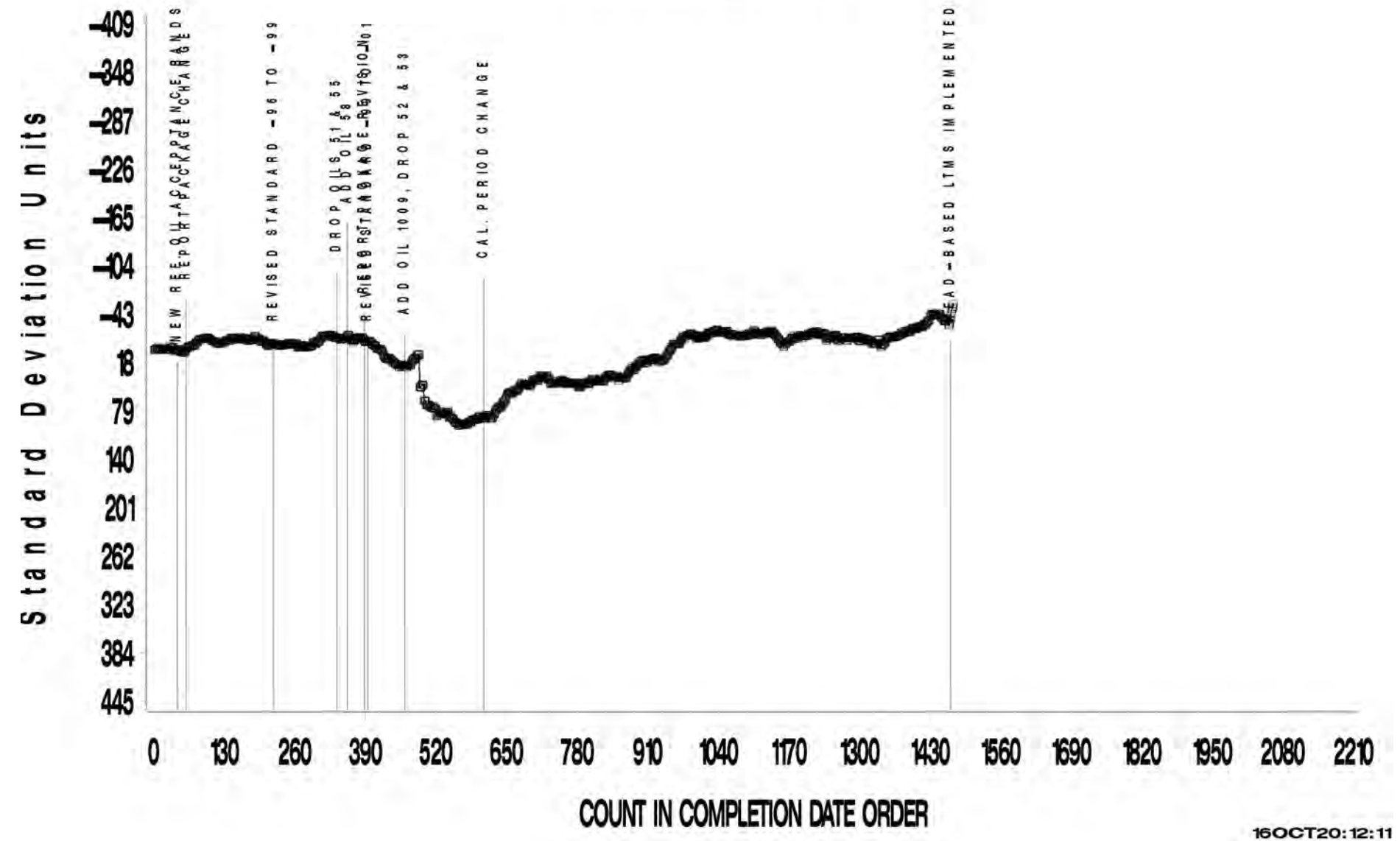
GELATION INDEX

CUSUM Severity Analysis



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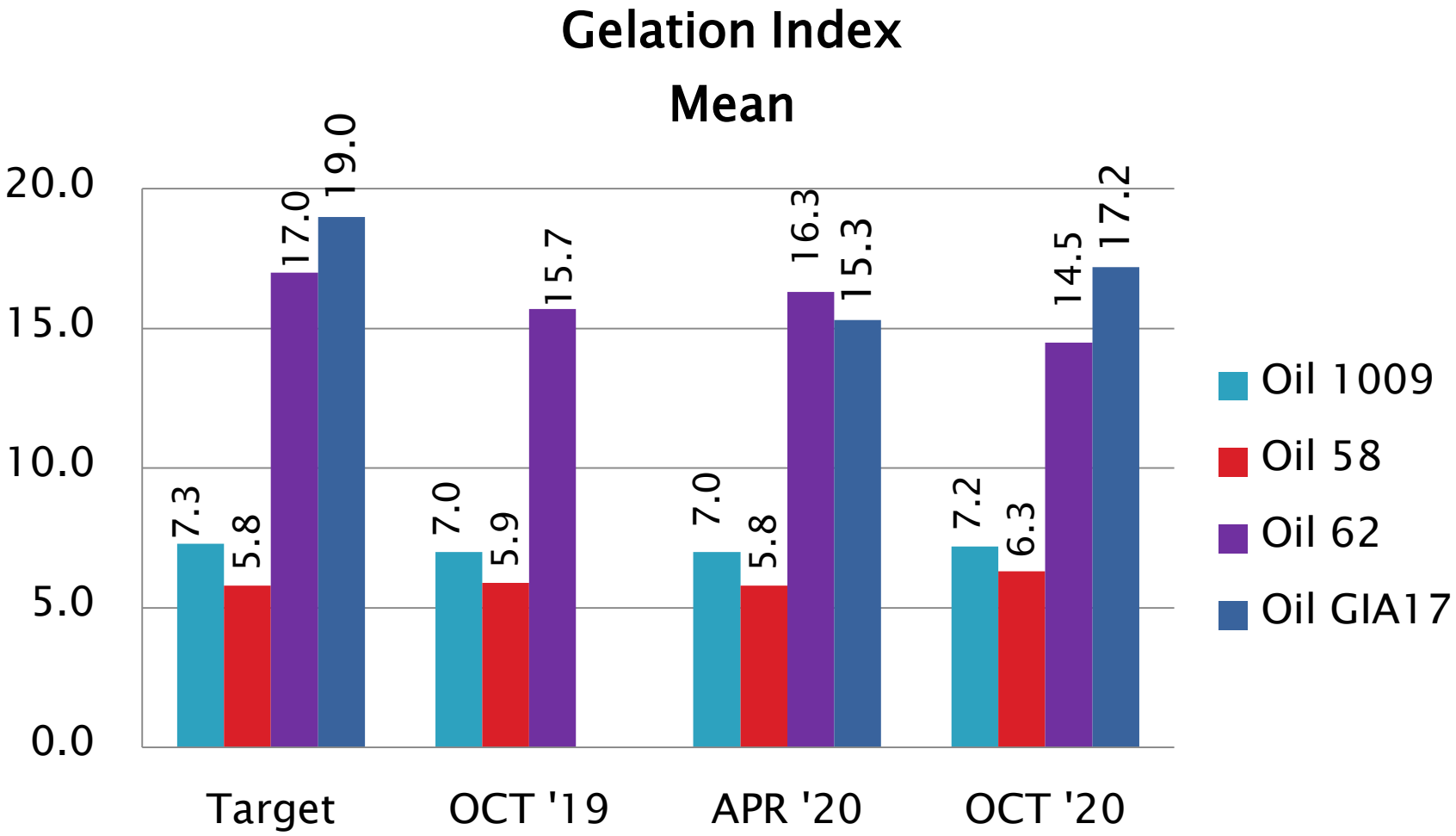
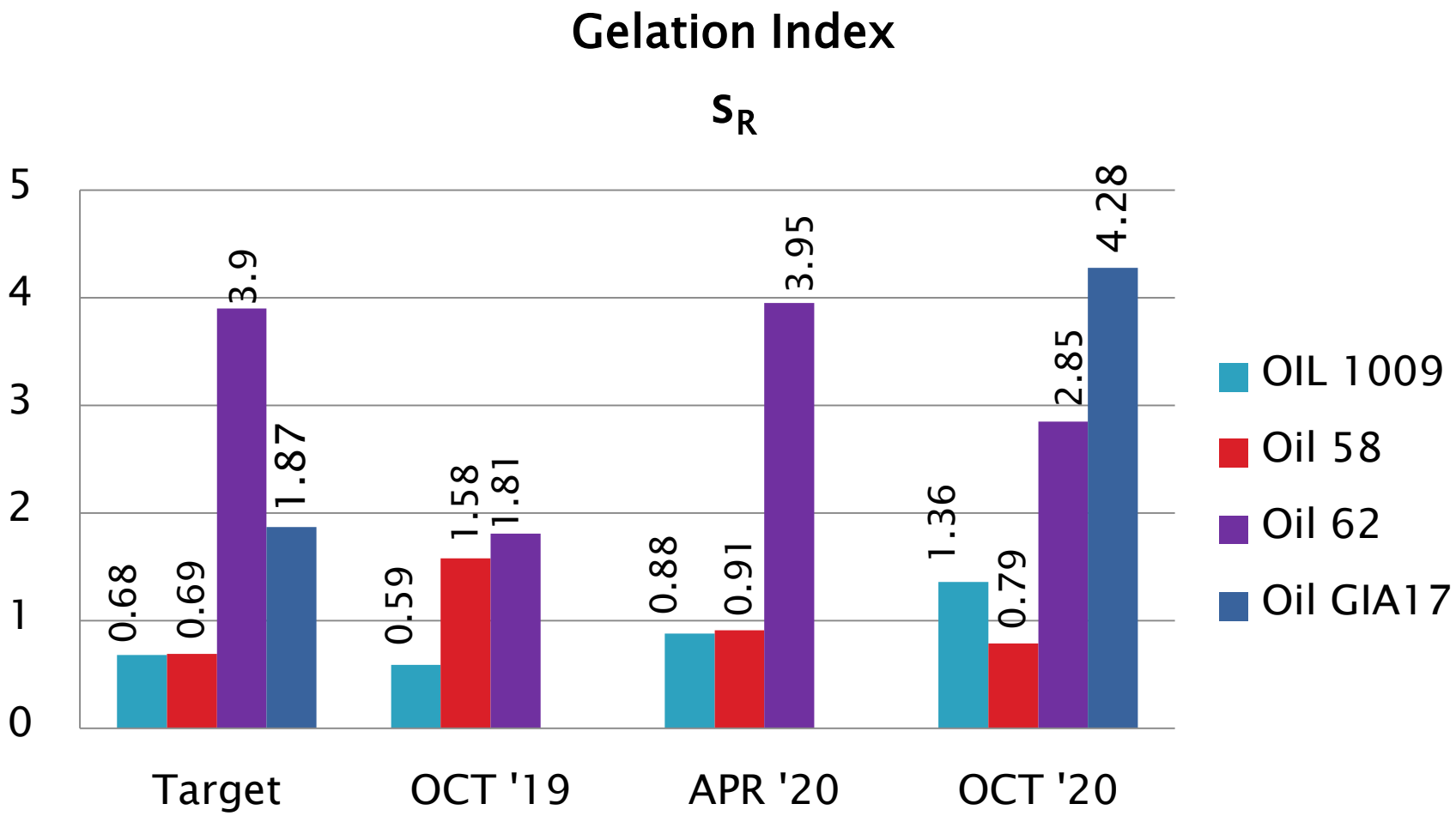
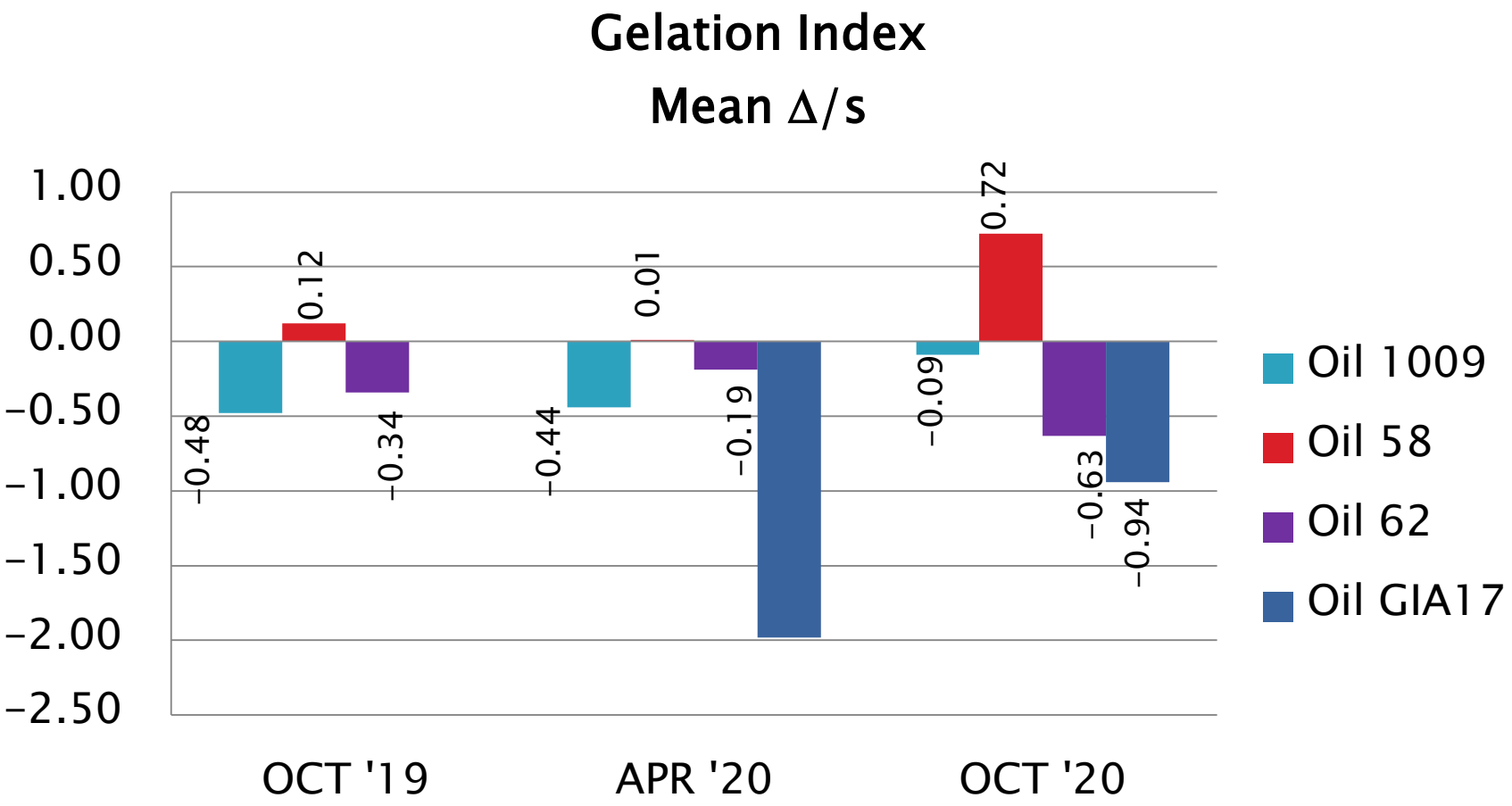
D5133 Performance by Oil



D5133 Performance by Oil



D5133 Performance by Oil



Return to Executive Summary

D6335: Deposits by TEOST-33C

Test Status	Validity Code	No. Tests
Acceptable Calibration Test	AC	20
Failed Calibration Test	OC	13
Operationally Invalidated by Lab	LC, XC	3
Operationally Invalidated After Initially Reported as Valid	RC	0
Total		**36**

Number of Labs Reporting Data: 7
Fail Rate of Operationally Valid Tests: 39%

D6335: Deposits by TEOST-33C

Statistically Unacceptable Tests (OC)	No. Of Tests
Total Deposits Mild	7
Total Deposits Severe	6

- One instrument (G2) accounts for six of the thirteen statistically failing runs (OC, severe and mild), and three tests more than ±4 s

- There were three operationally invalid tests reported this period:
  - Two tests invalidated due to airflow problems
  - One test aborted due to spilled EOT sample.

- 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

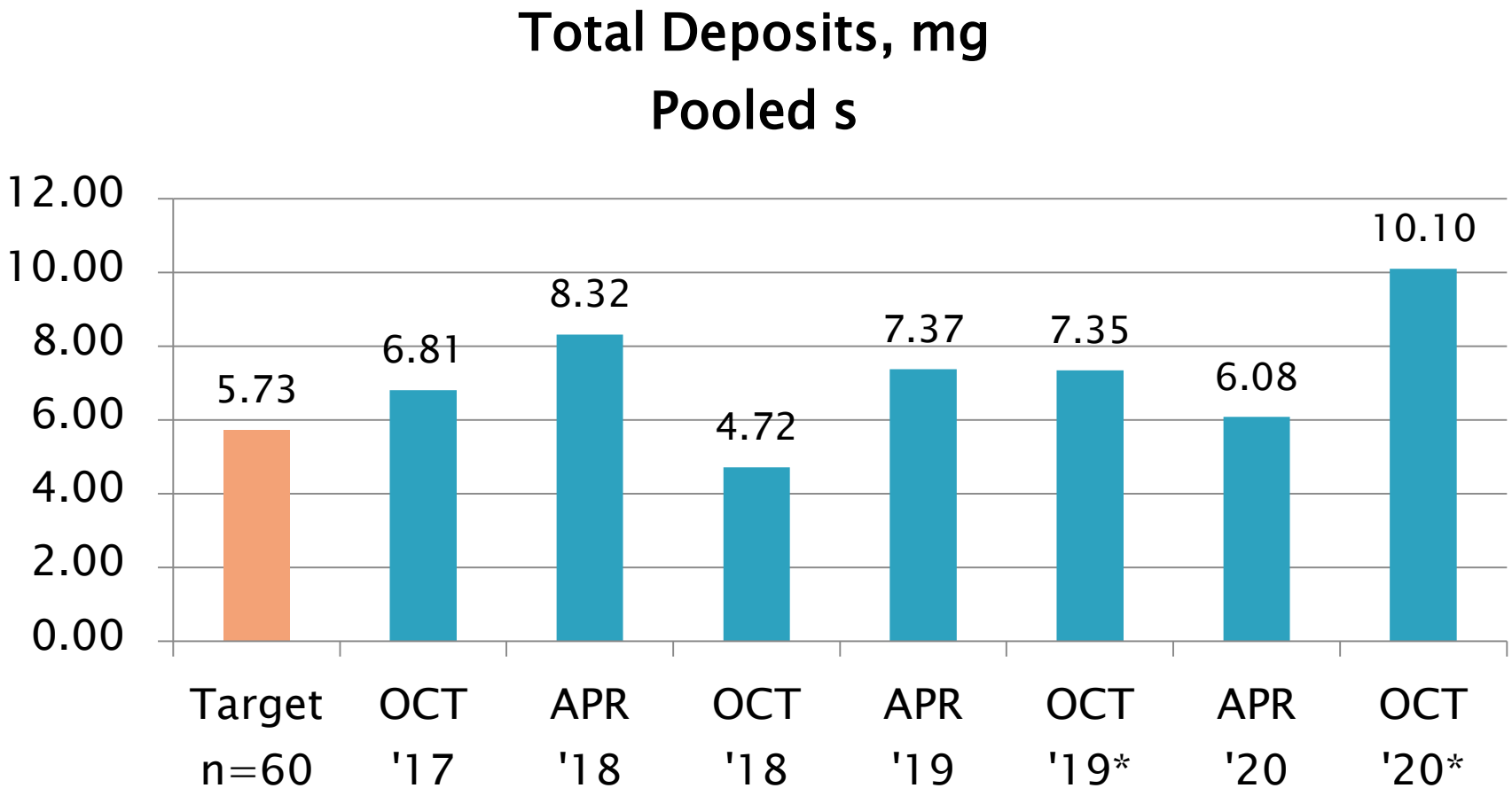
Total Deposits, mg	n	df	Pooled s	Mean Δ/s
Updated Targets 20130415	60	58	5.73	-----
10/1/17 through 3/31/18[1]	27	25	8.32	-0.61
10/1/17 through 3/31/18[1]	26	24	6.43	-0.45
4/1/18 through 9/30/18	21	19	4.72	-0.33
10/1/18 through 3/31/19	25	23	7.37	0.11
4/1/17 through 9/30/19[2]	30	28	12.66	0.47
4/1/17 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

[1]Single result of -4.6 s mild included and excluded

[2]Four consecutive OC results on same rig included and excluded.

[3]Rig with six OC results included and excluded.

D6335 Precision Estimates



*Multiple OC results from single excessively failing rig excluded.

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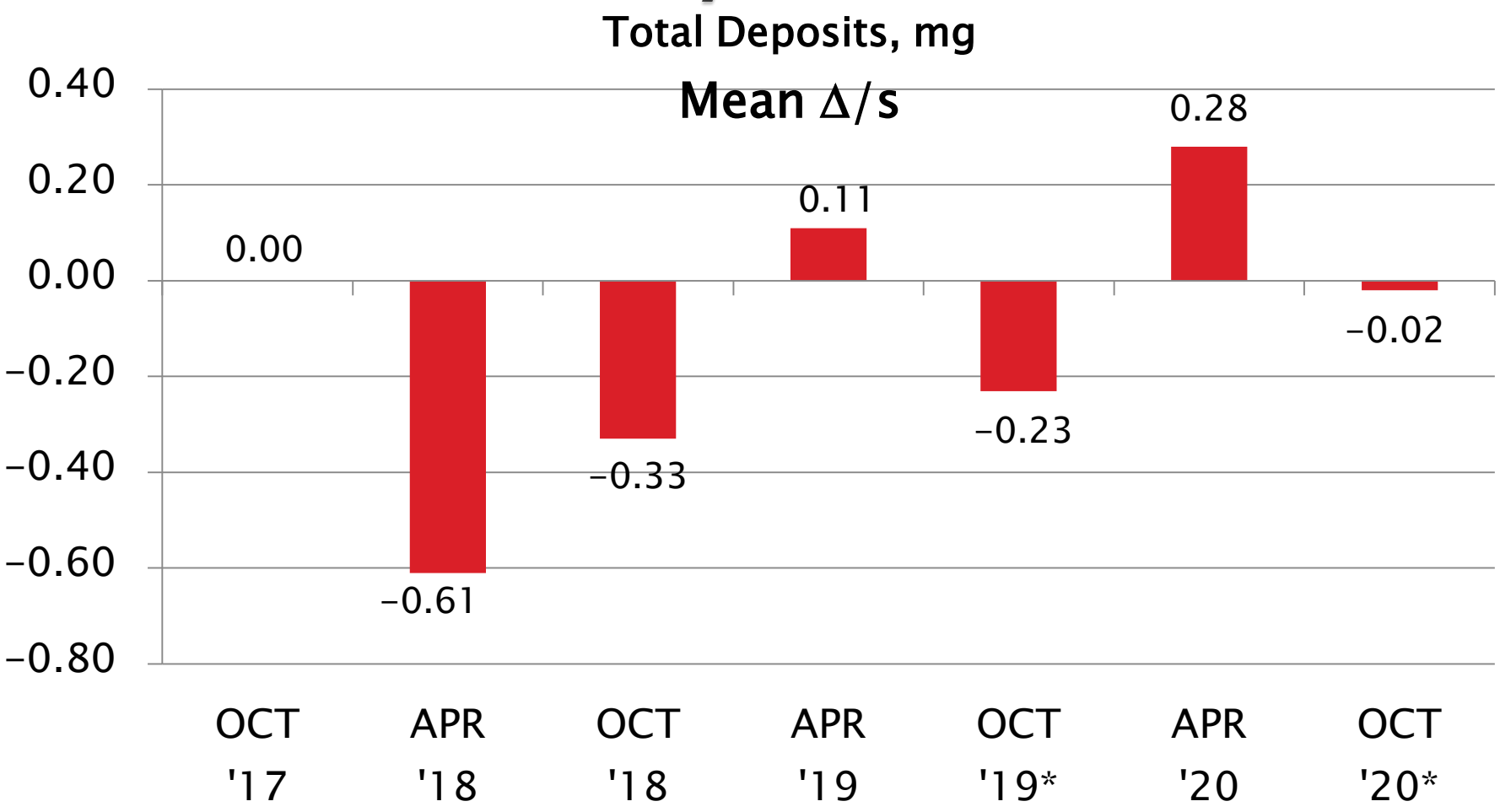
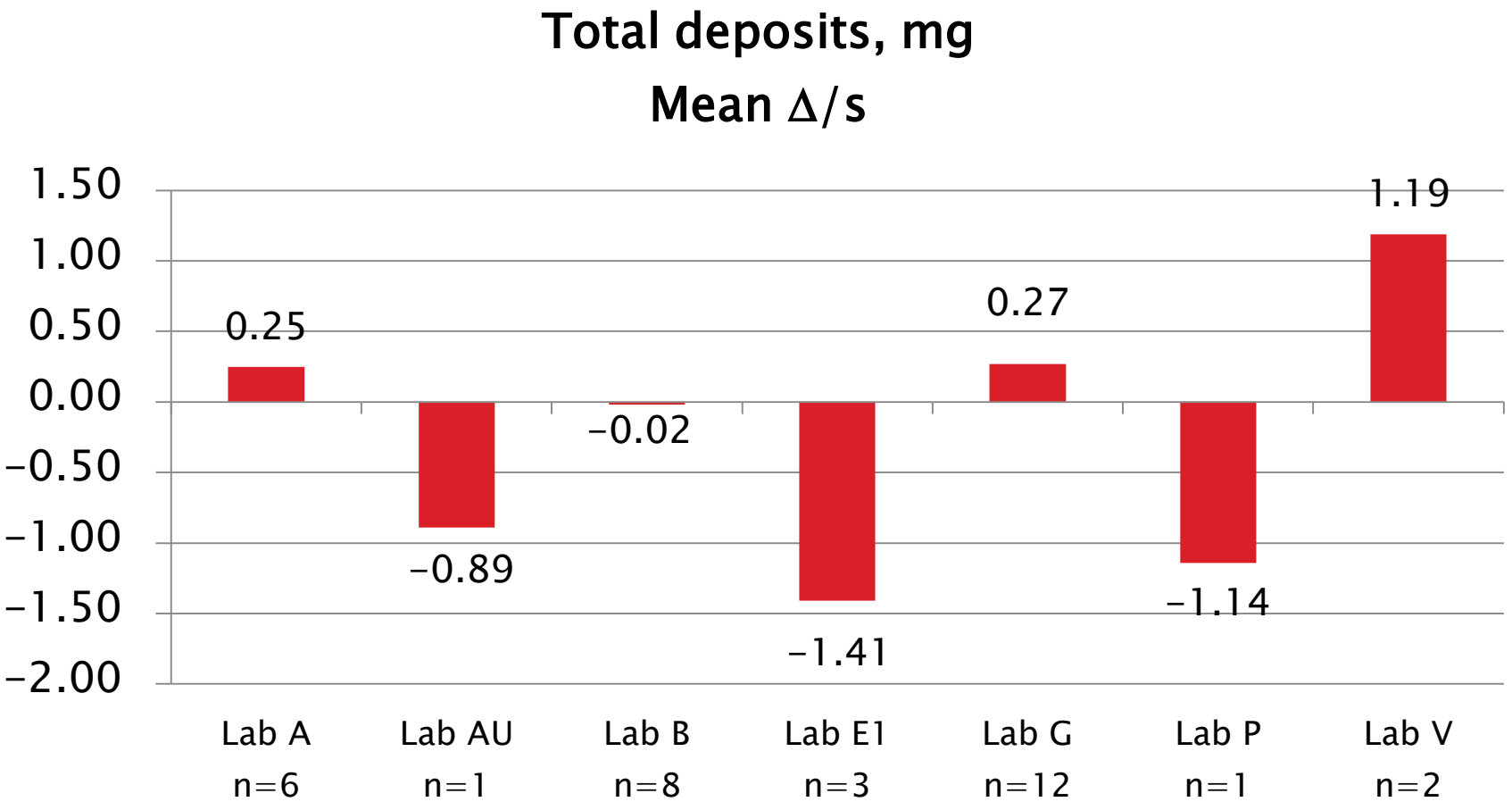
D6335 Severity Estimates



*Multiple OC results from single excessively failing rig excluded.

D6335 Lab Severity Estimates



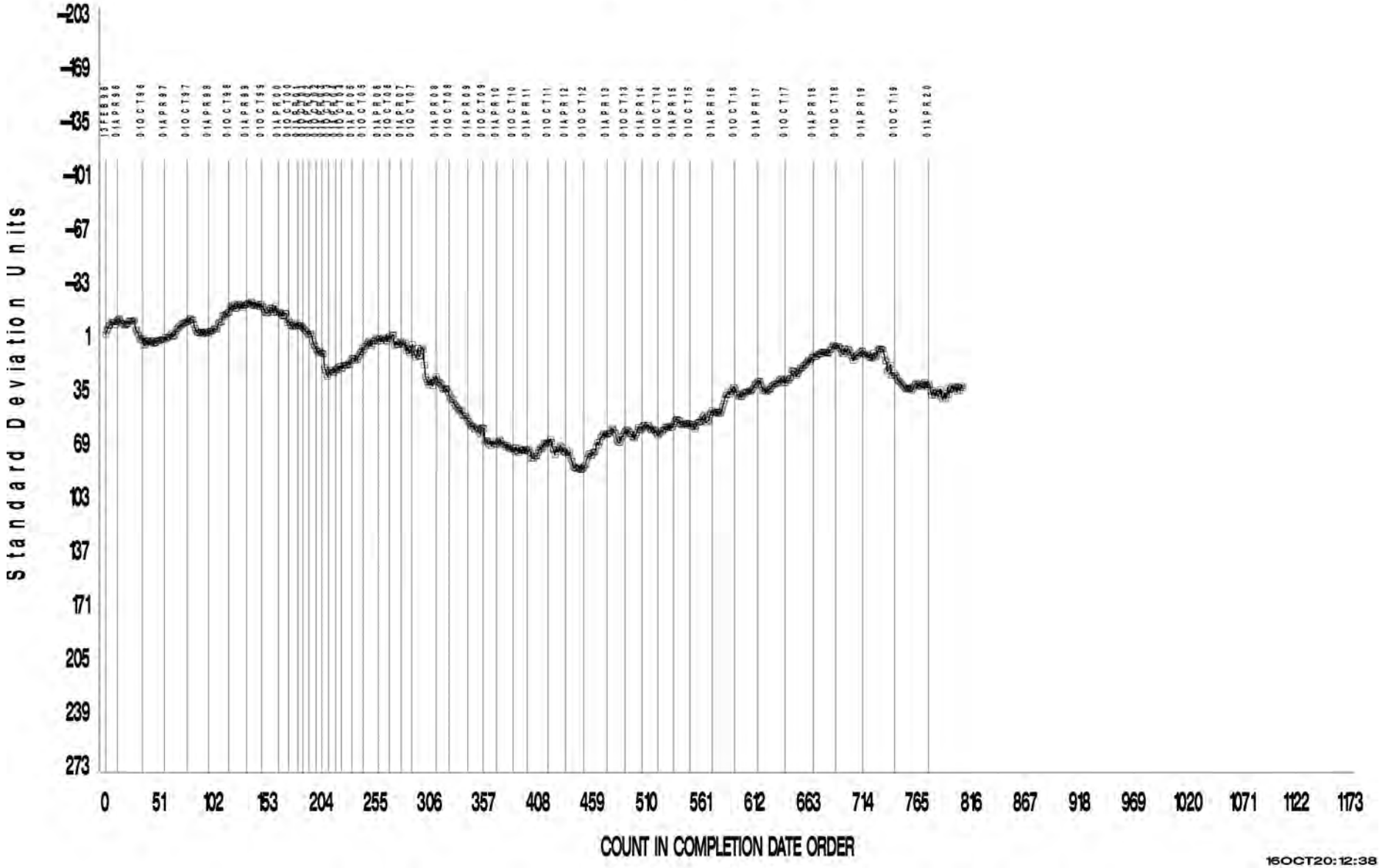
D6335: Deposits by TEOST-33C

- Even with problematic rig excluded, precision (Pooled s) is significantly less precise than prior periods
  - Much less precise than target precision
- Performance (Mean Δ/s) is on-target (-0.02 s)
- Period fail rate of 39%
  - Six of the thirteen statistically failing runs (OC) are from one rig
  - Compared to 0% fail rate last period, but 20% and 23% before that, and similarly high in prior periods
- All tests this period report using Rod Batch M.
- First report period with significant sample population on reference oil 75-1 (reblend of depleted oil 75).

TEOST—83C INDUSTRY OPERATIONALLY VALID DATA

TOTAL DEPOSITS MG

CUSUM Severity Analysis



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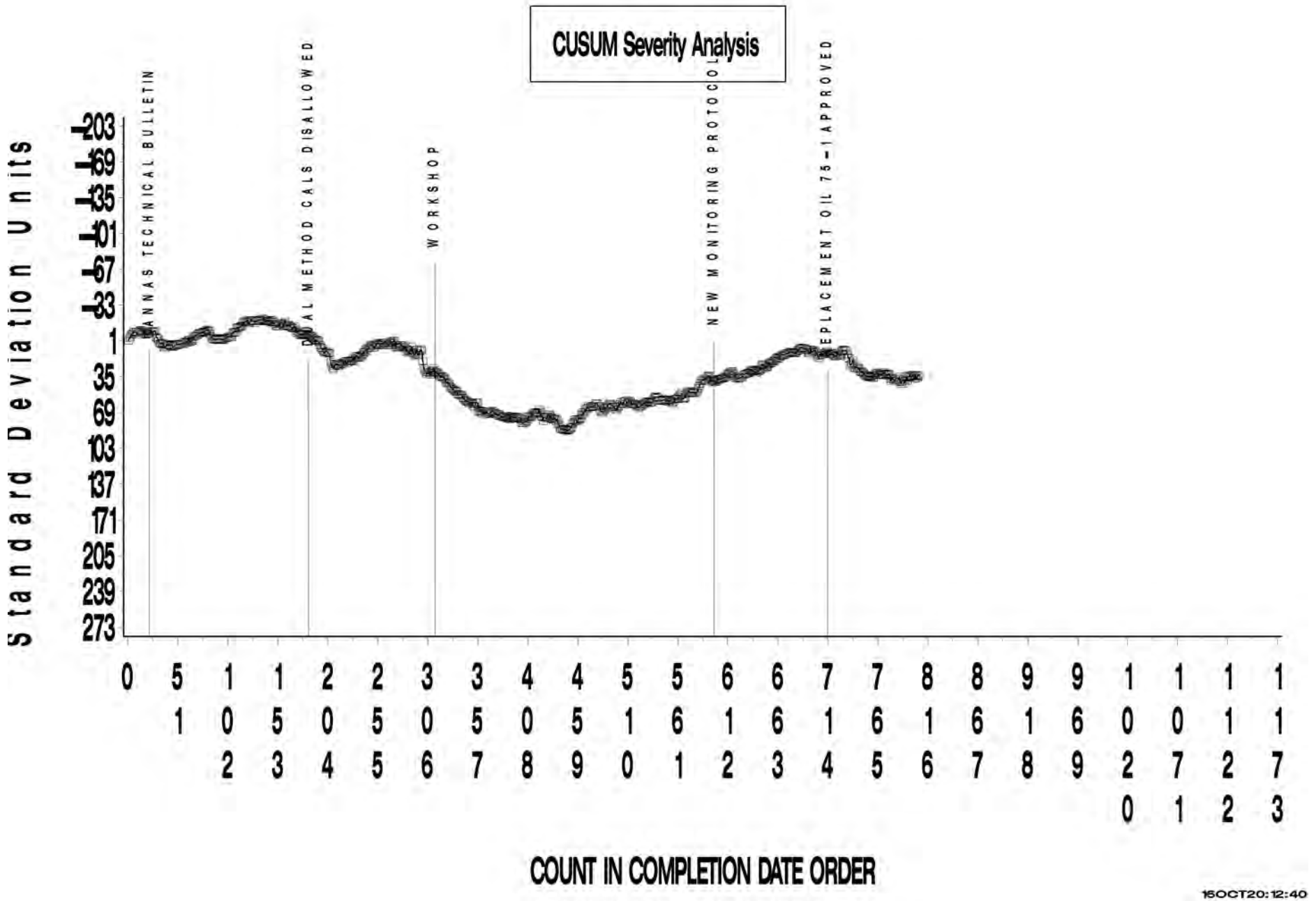
TEOST—33C INDUSTRY OPERATIONALLY VALID DATA

TOTAL DEPOSITS MG



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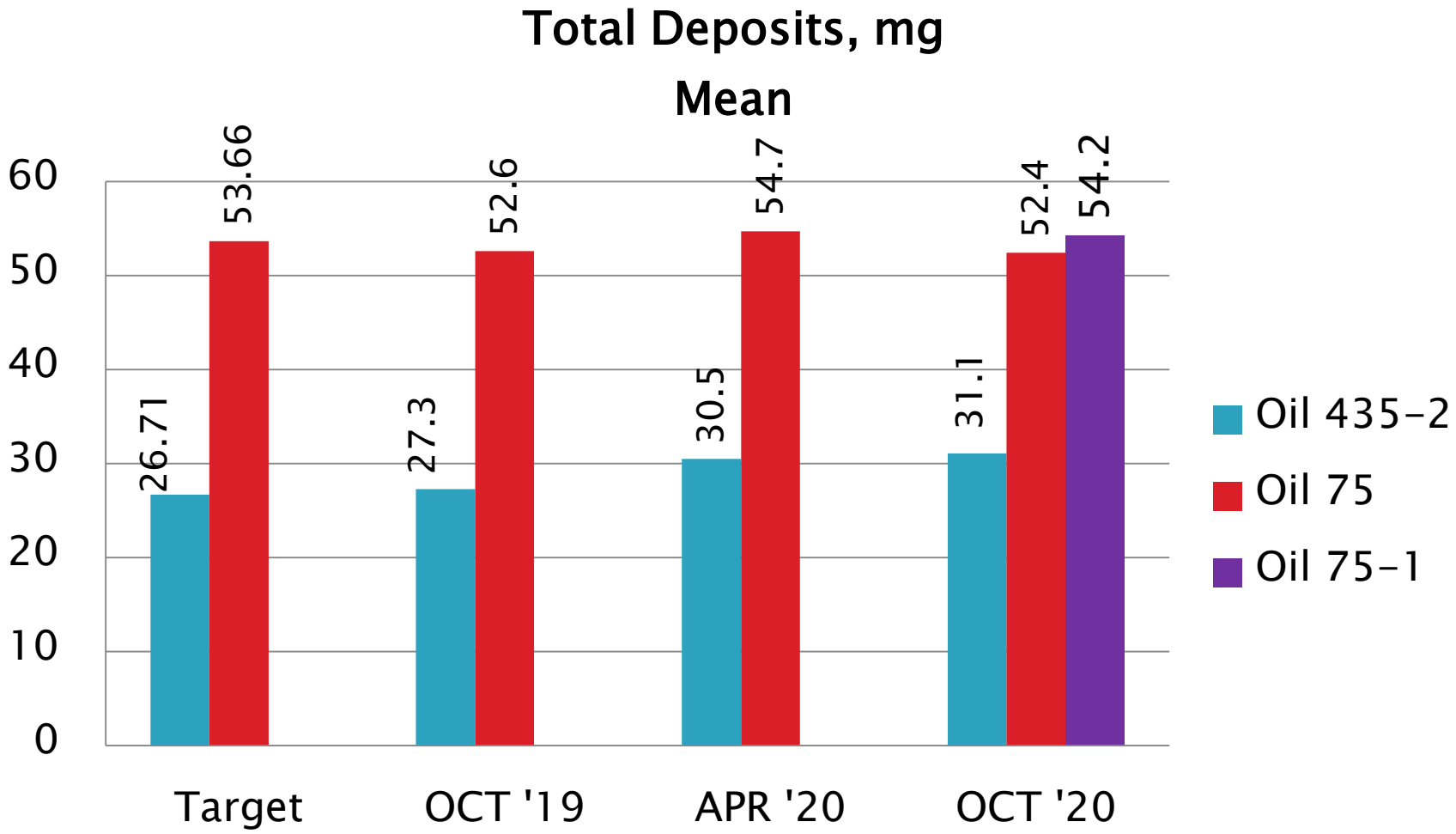
D6335 Performance by Oil



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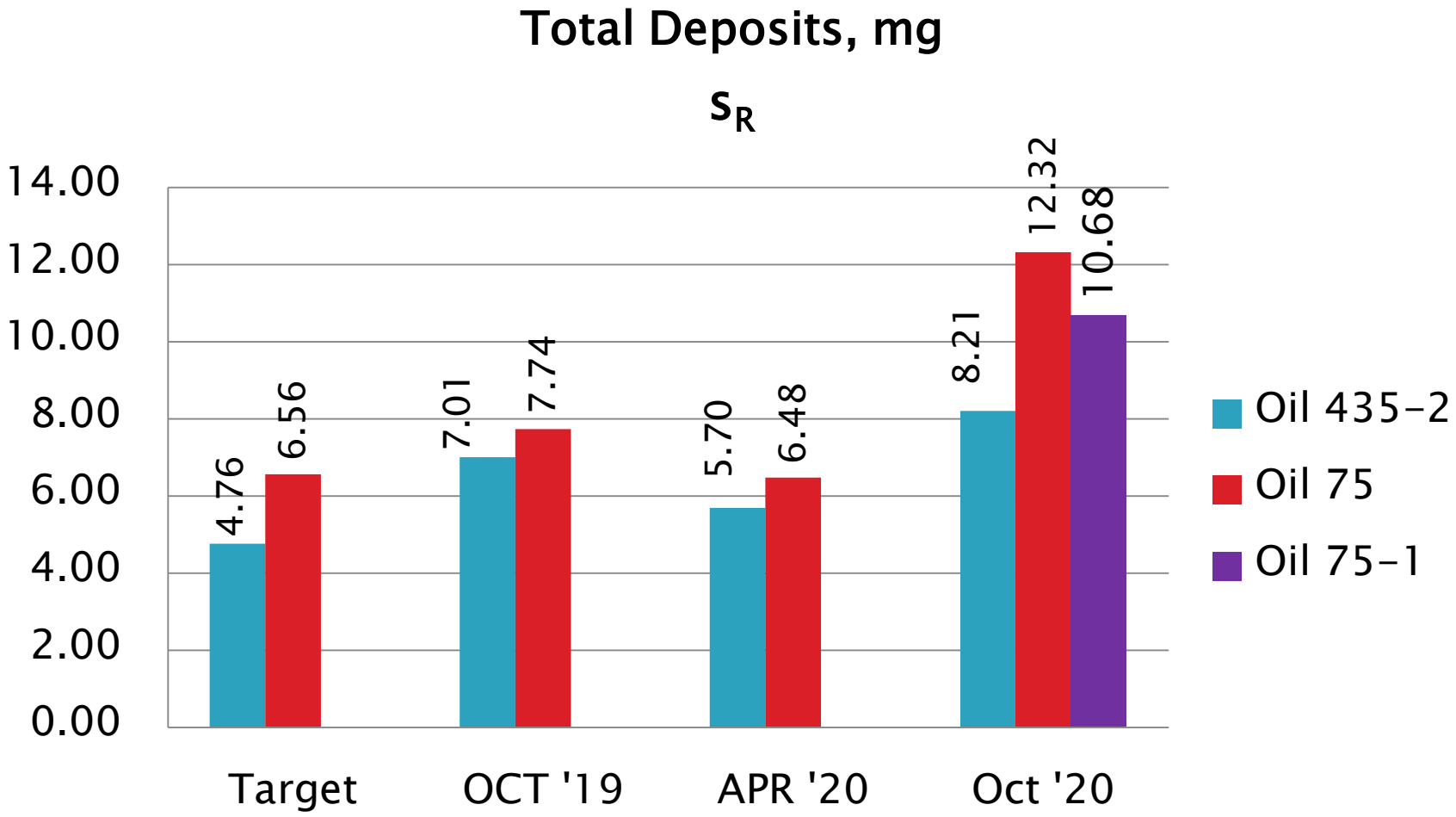
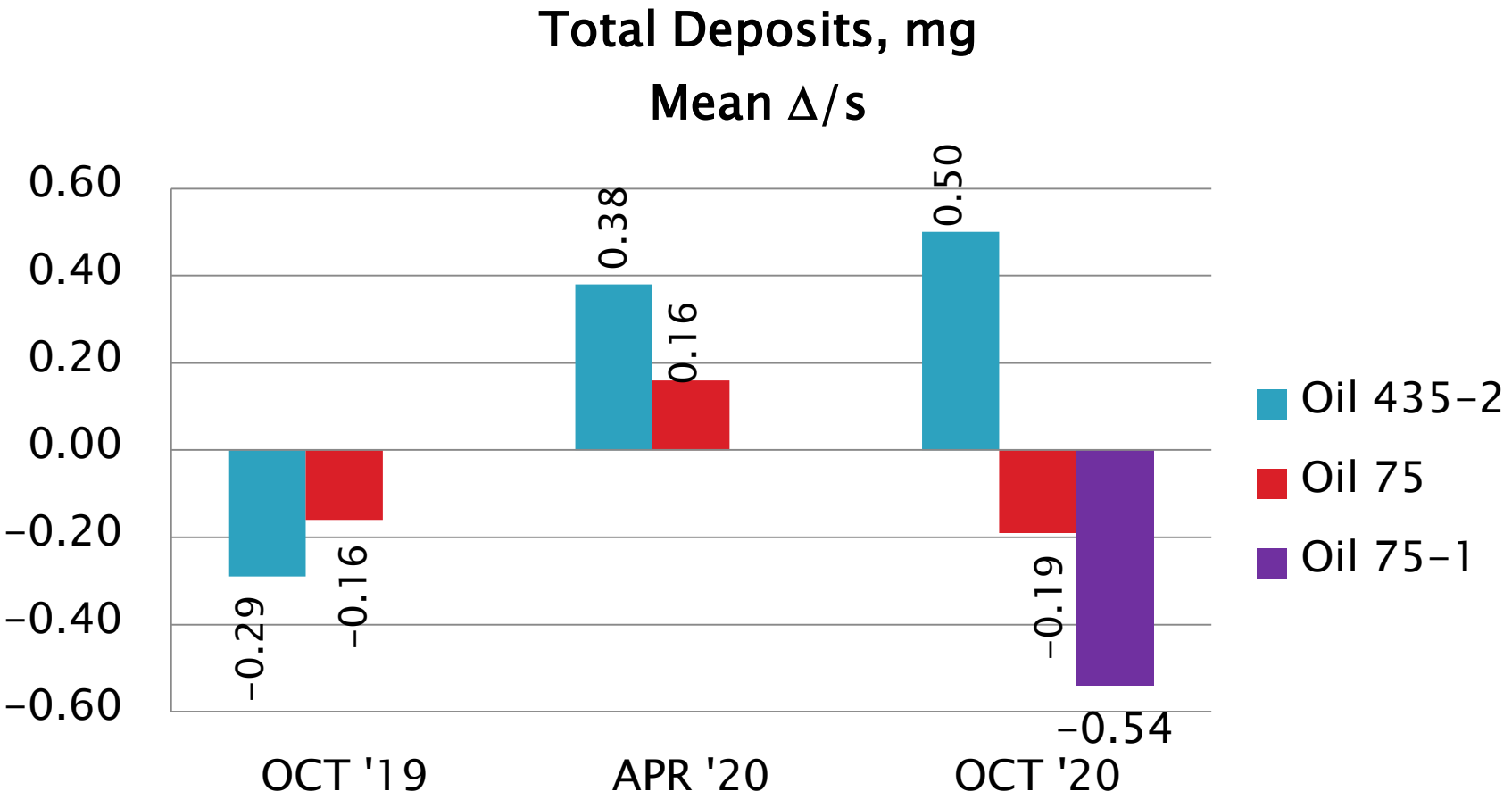
D6335 Performance by Oil



D6335 Performance by Oil



Return to Executive Summary

D7097: Deposits by MHT TEOST

Test Status	Validity Code	No. Tests
Acceptable Calibration Test	AC	72
Failed Calibration Test	OC	0
Operationally Invalidated by Lab	LC, XC	2
Operationally Invalidated After Initially Reported as Valid	RC	0
Total		**74**

Number of Labs Reporting Data: 10
Fail Rate of Operationally Valid Tests: 0%

D7097: Deposits by MHT TEOST

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

- Two operationally invalid calibration test reported this period:
  - One test invalidated due to pump failure
  - One test aborted due to off-spec thermocouple depth.
- There were no MTEOS technical updates issued this report period.
- Calibration requirement updates are issued as LTMS document updates.

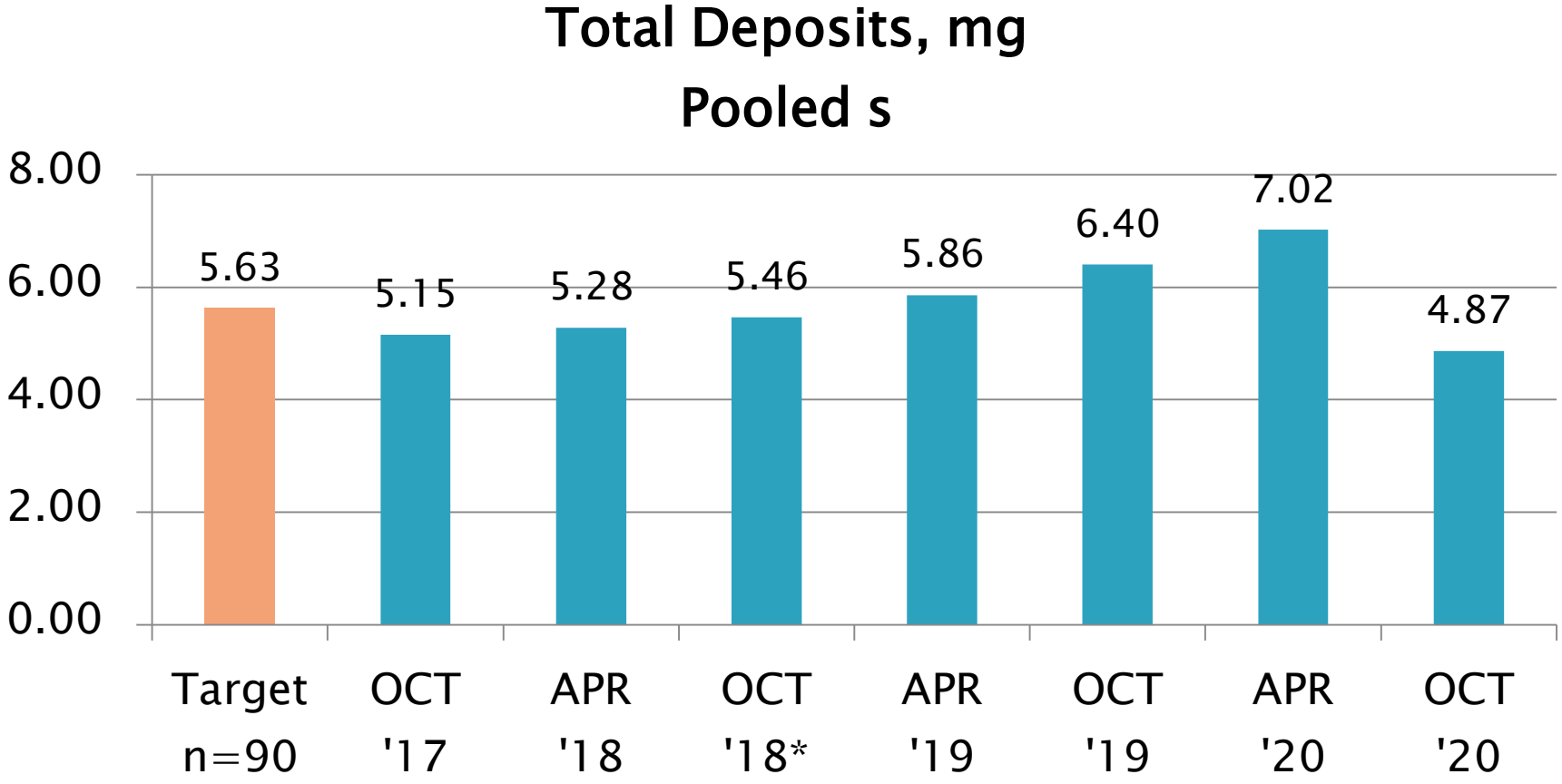
D7097: Deposits by MHT TEOST

Period Precision and Severity Estimates

Total Deposits, mg	n	df	Pooled s	Mean Δ/s
Current Targets 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
4/1/20 through 9/30/20	72	70	4.87	-0.22

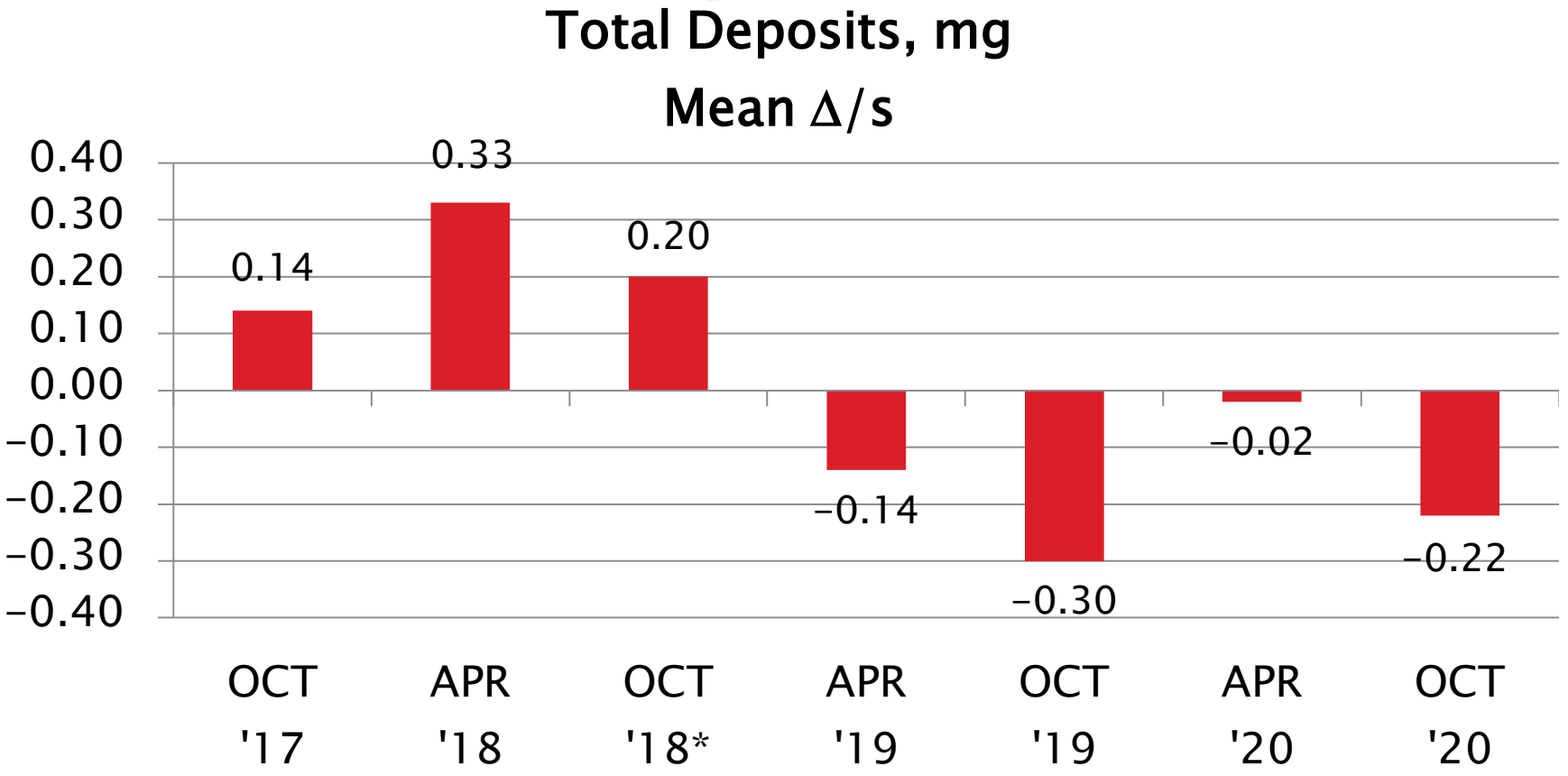
*One severe OC test from instrument G5 included and excluded (8.9 s)

D7097 Precision Estimates



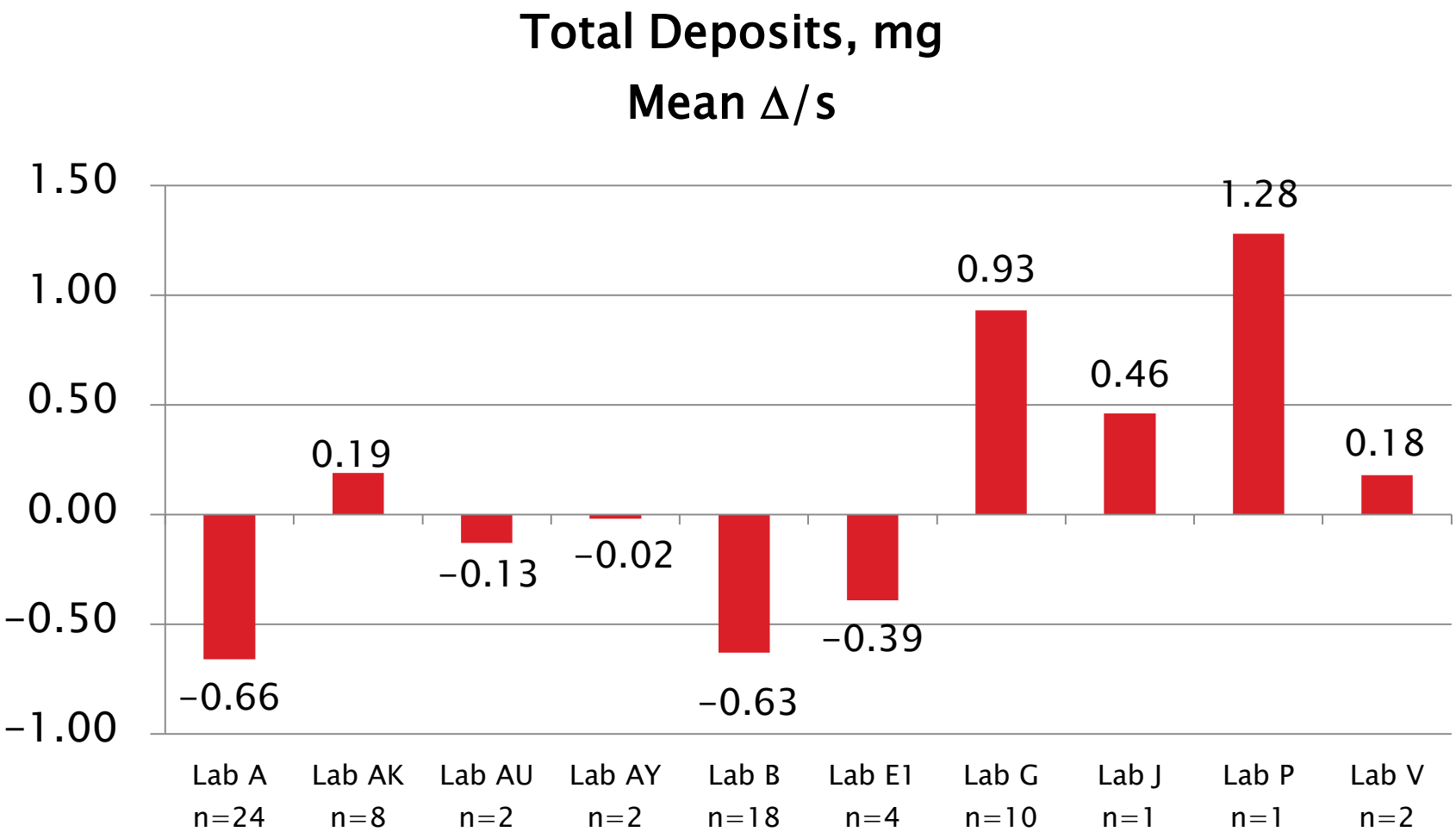
*One severe OC test from instrument G5 excluded (8.9 s)

D7097 Severity Estimates



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

D7097 Lab Severity Estimates



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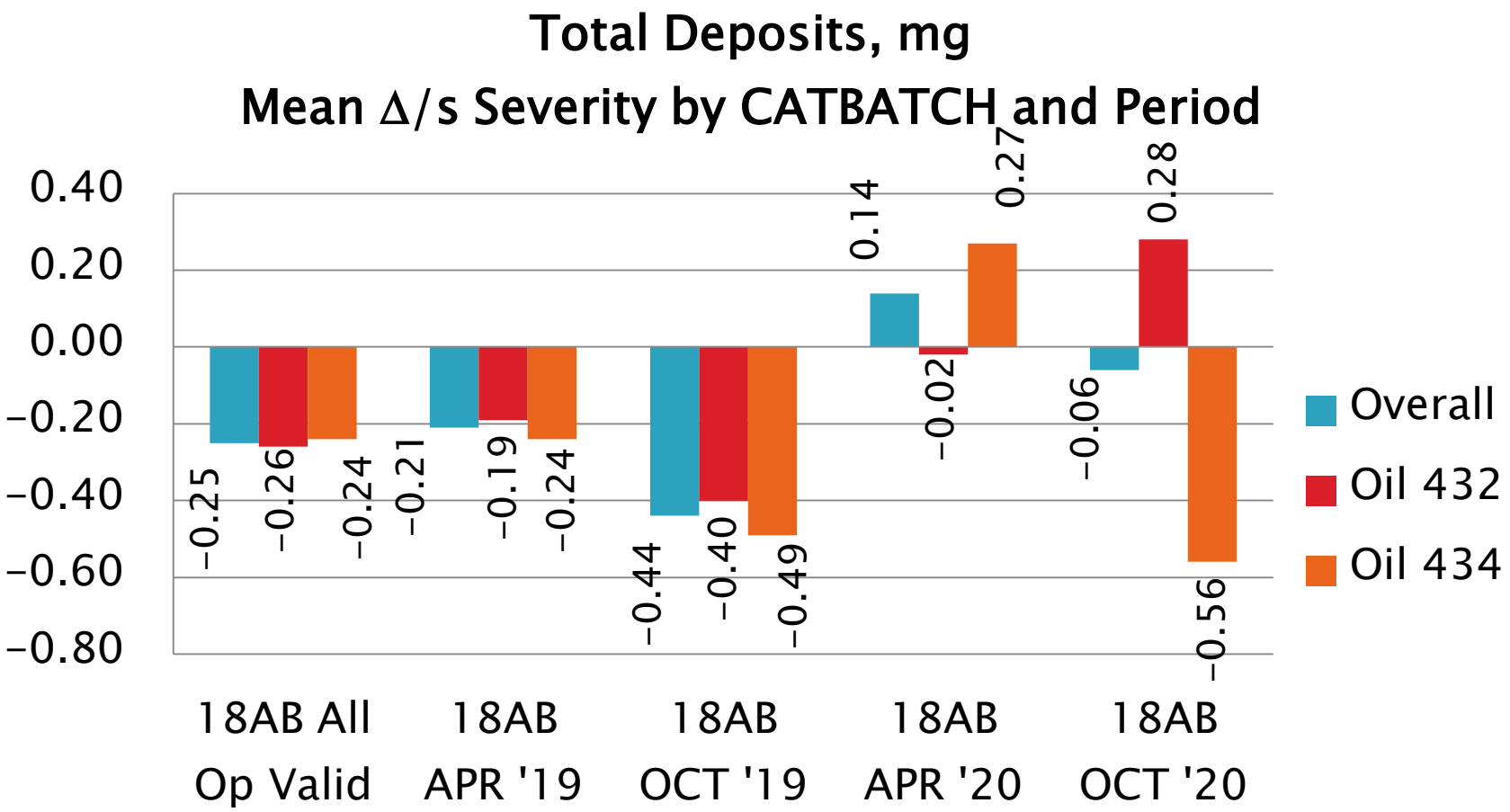
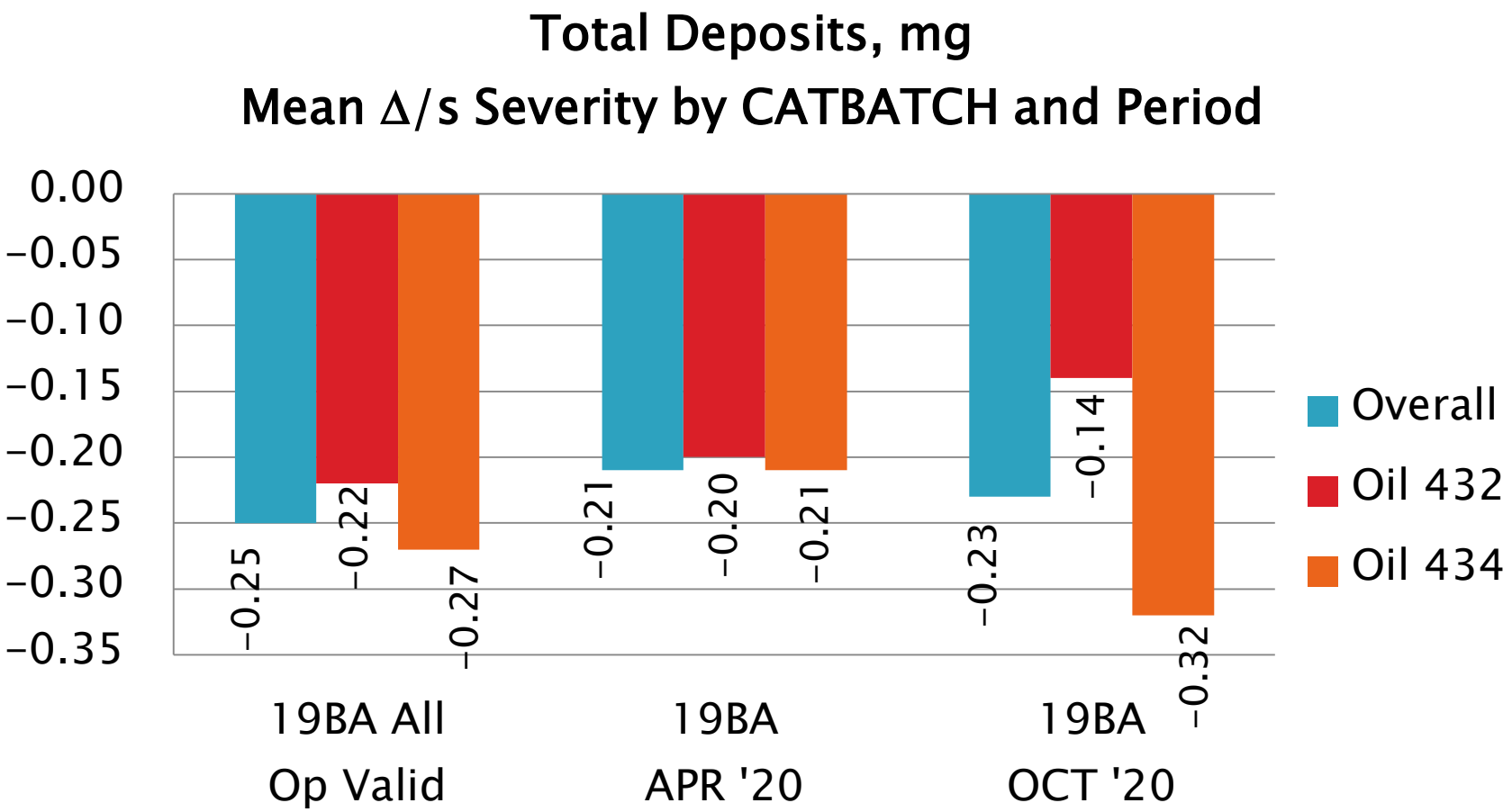
D7097: Deposits by MHT TEOST



D7097: Deposits by MHT TEOST

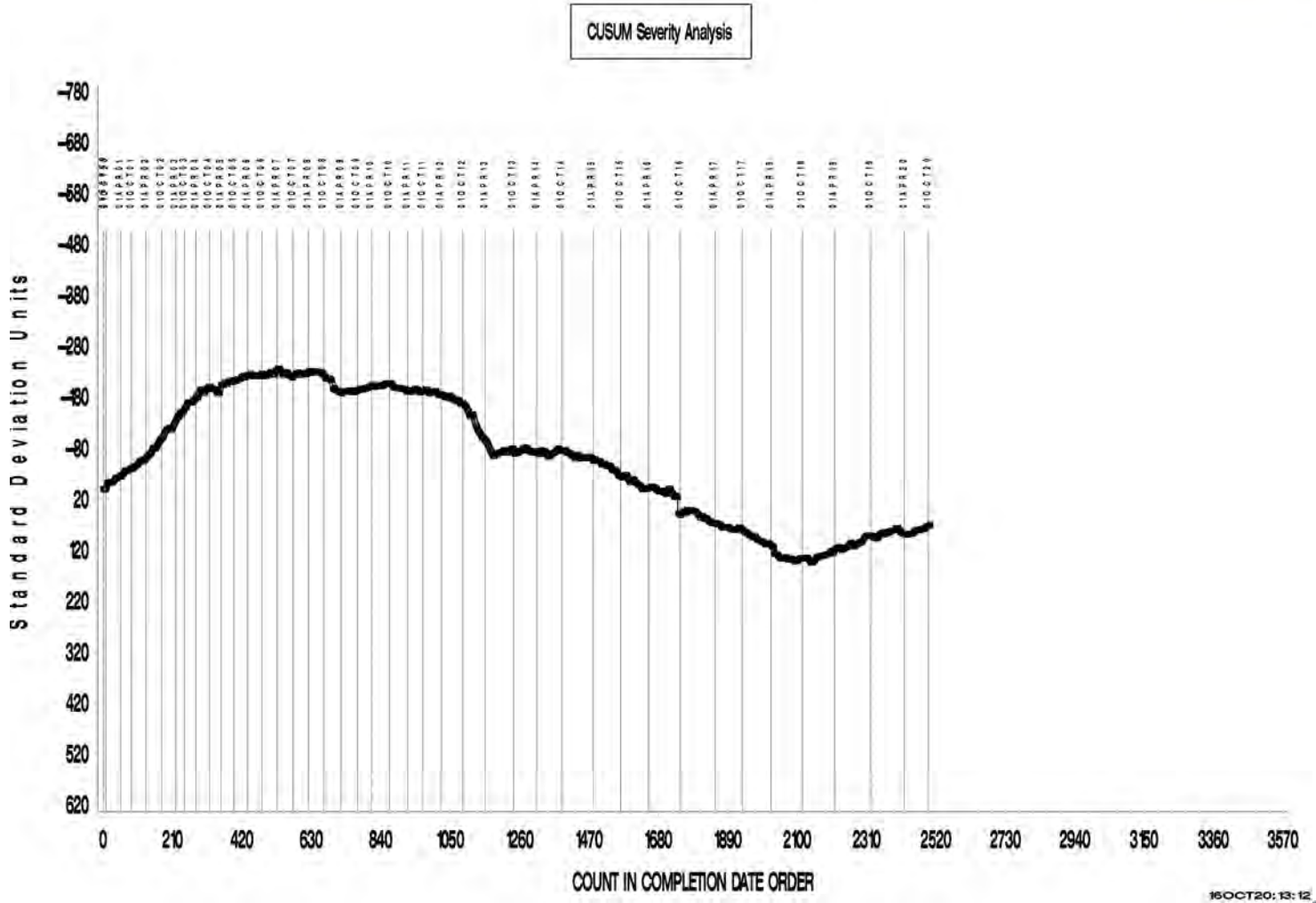


D7097: Deposits by MHT TEOST

- Precision (Pooled s) is more precise than the prior report period
  - More precise than target precision
- Performance (Mean Δ/s) is -0.22 s mild
  - No statistically unacceptable runs reported this period.
- All operationally valid tests this period report using Rod Batch M
- All operationally valid calibration tests this period report using Catalyst Batch 18AB (n=5) or 19BA (n=67)
- Overall severity on catalyst batch 19BA (n=122) appears to be about -0.25 s mild, and comparably mild on both reference oils.
  - Catalyst Batch 18AB is, overall, performing similarly mild (n=247)

MHT—4 TEOST INDUSTRY OPERATIONALLY VALID DATA

TOTAL DEPOSITS MG



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MHT—4 TEOST INDUSTRY OPERATIONALLY VALID DATA

TOTAL DEPOSITS MG

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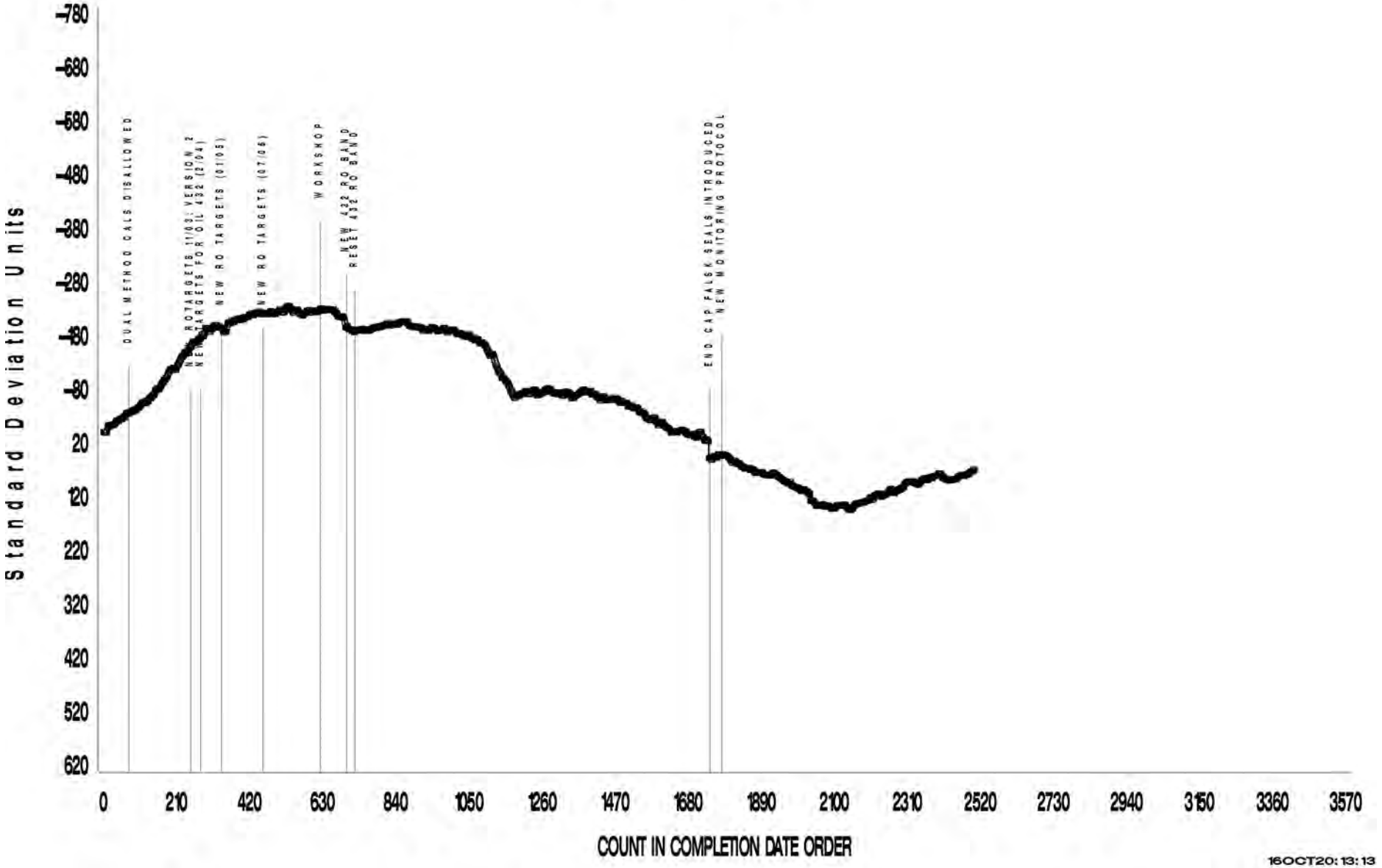
CUSUM Severity Analysis



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MHT—4 TEOST INDUSTRY OPERATIONALLY VALID DATA

TOTAL DEPOSITS MG

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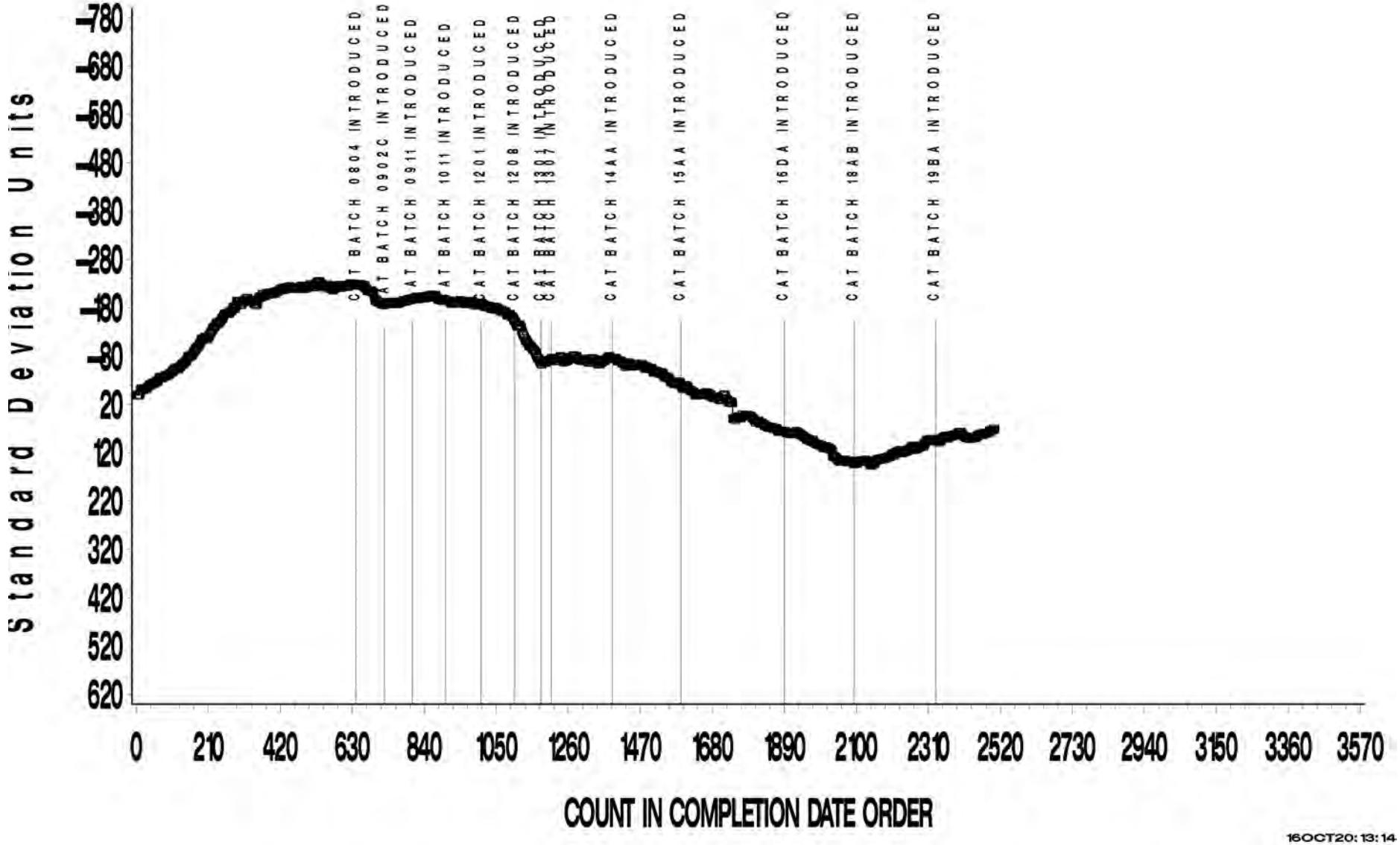
CUSUM Severity Analysis



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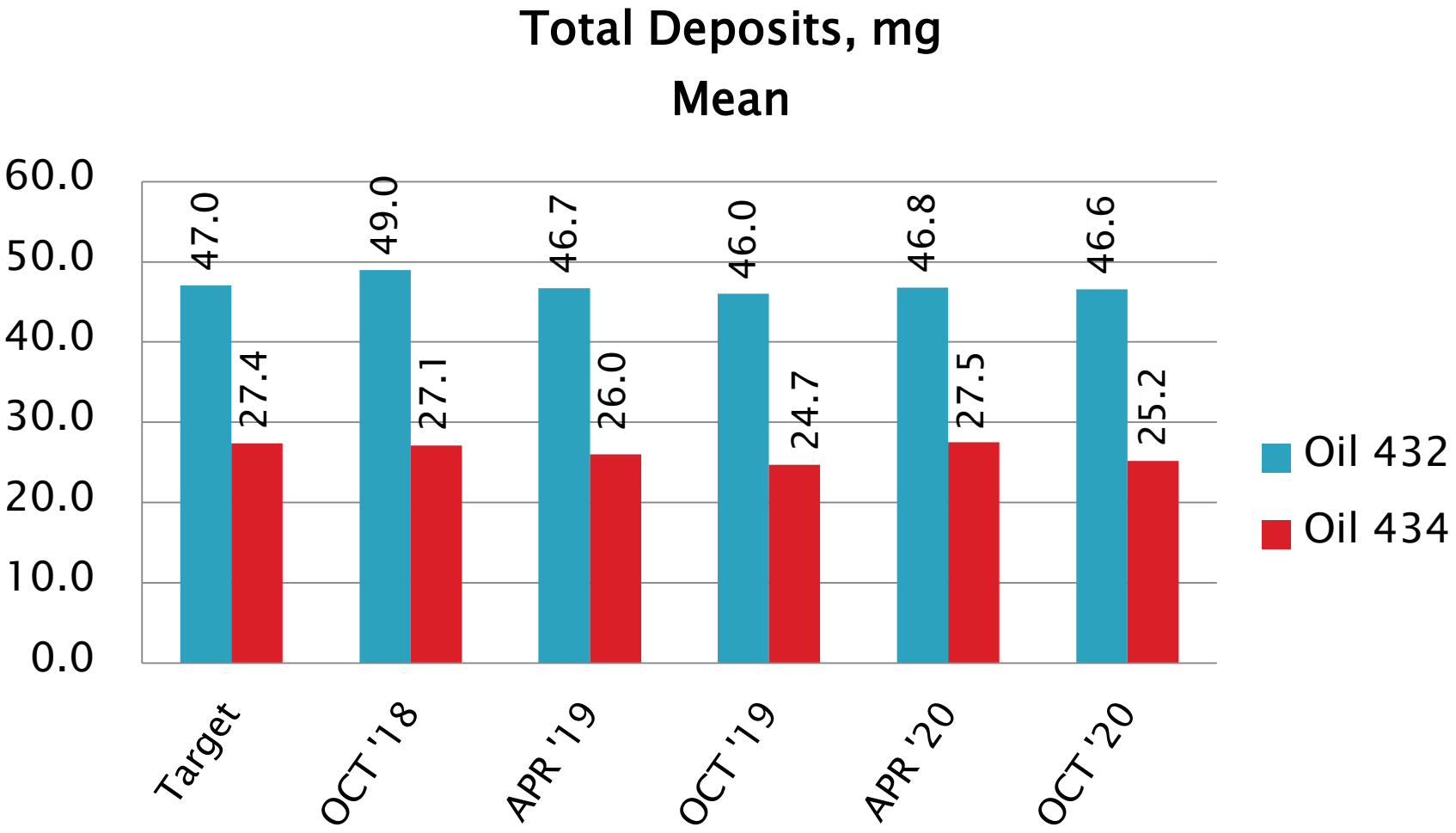
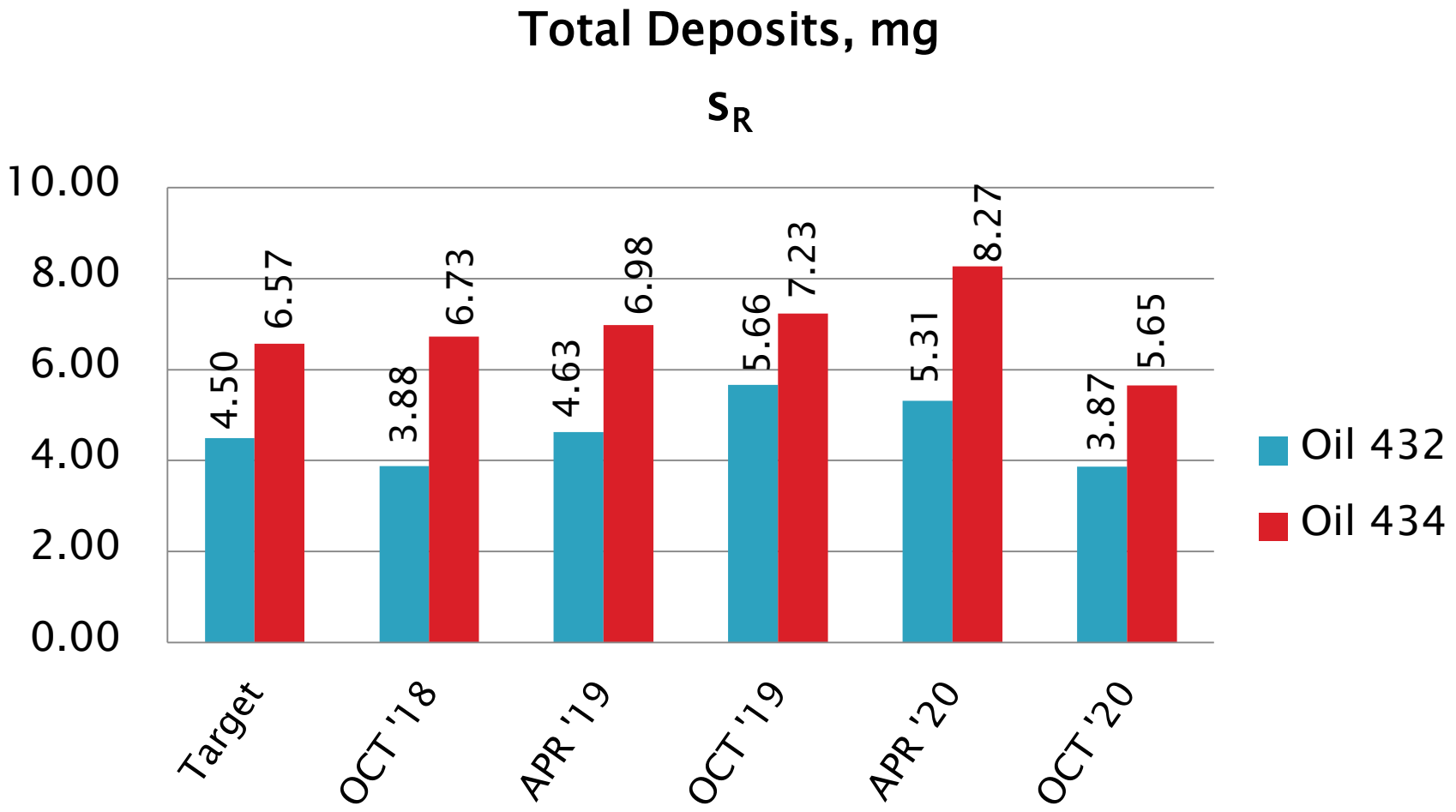
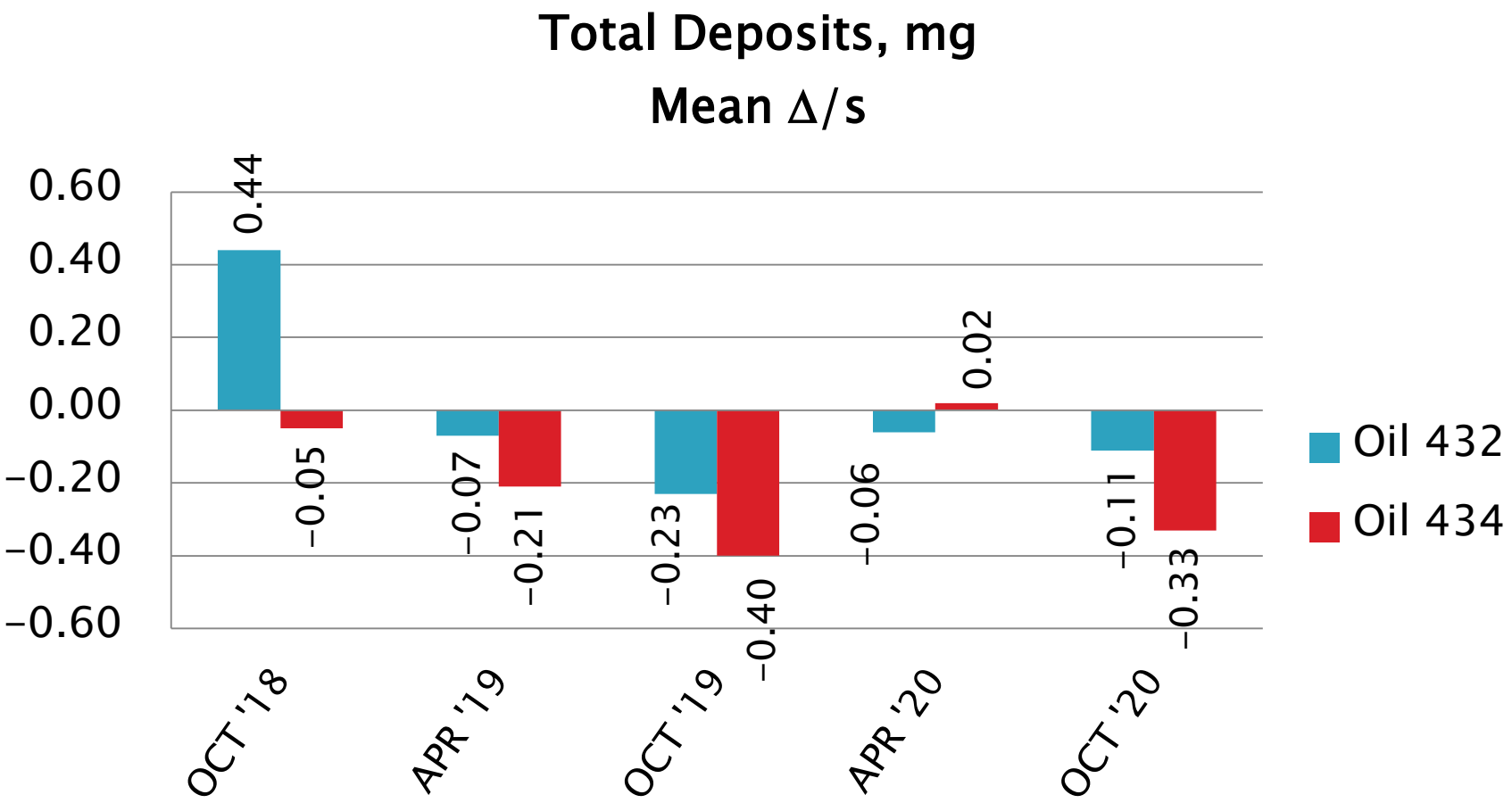
D7097 Performance by Oil



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	13
Acceptable Discrimination Test	AS	5
Failed Statistically	OC	0
Operationally Invalidated by Lab	LC, XC	0
Total		**18**

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.
- 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	-----
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
4/1/20 through 9/30/20	13	11	8	-0.85

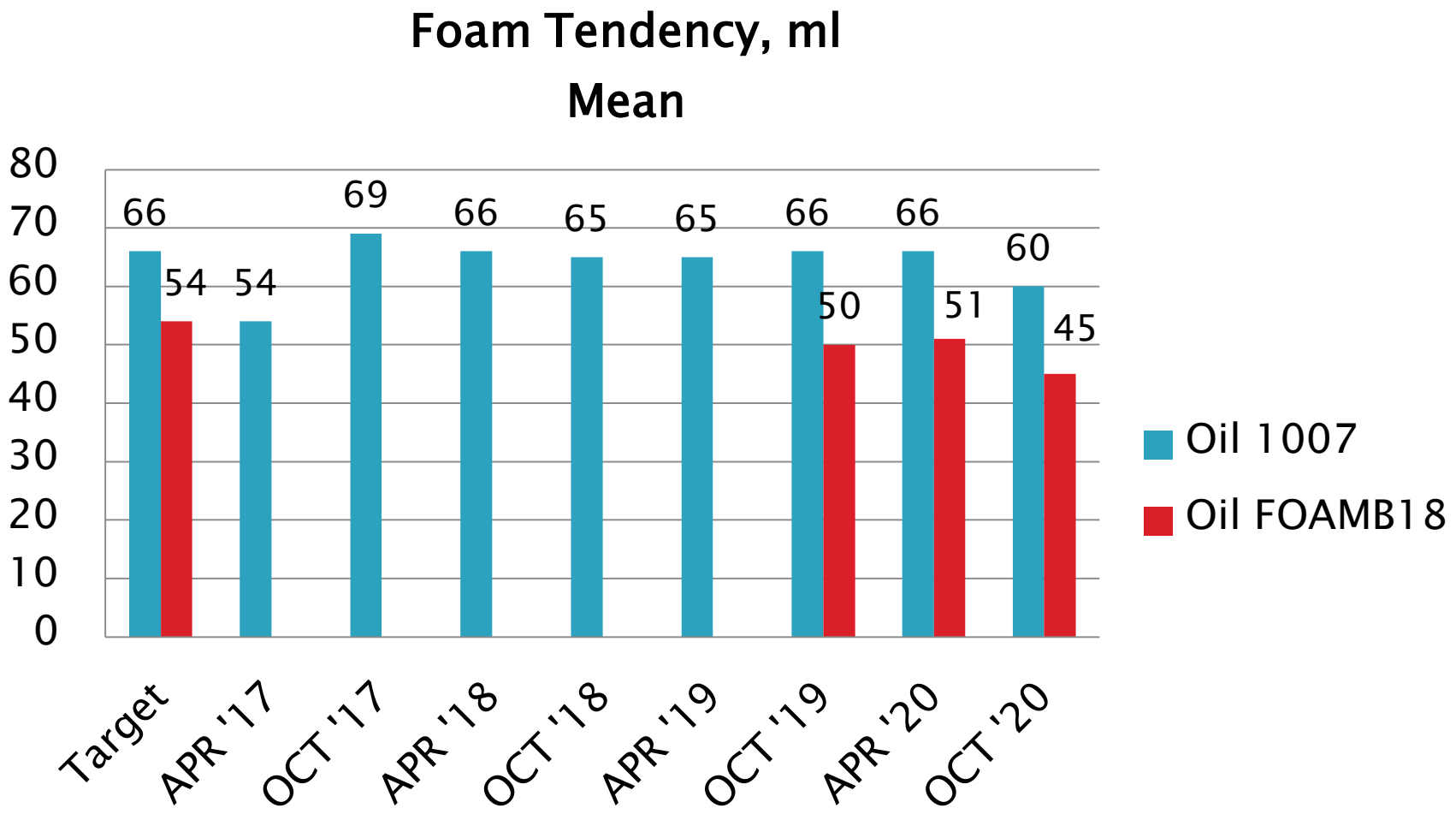
*Single OC result Yi=2.3 s severe included and excluded

D6082: High Temperature Foam

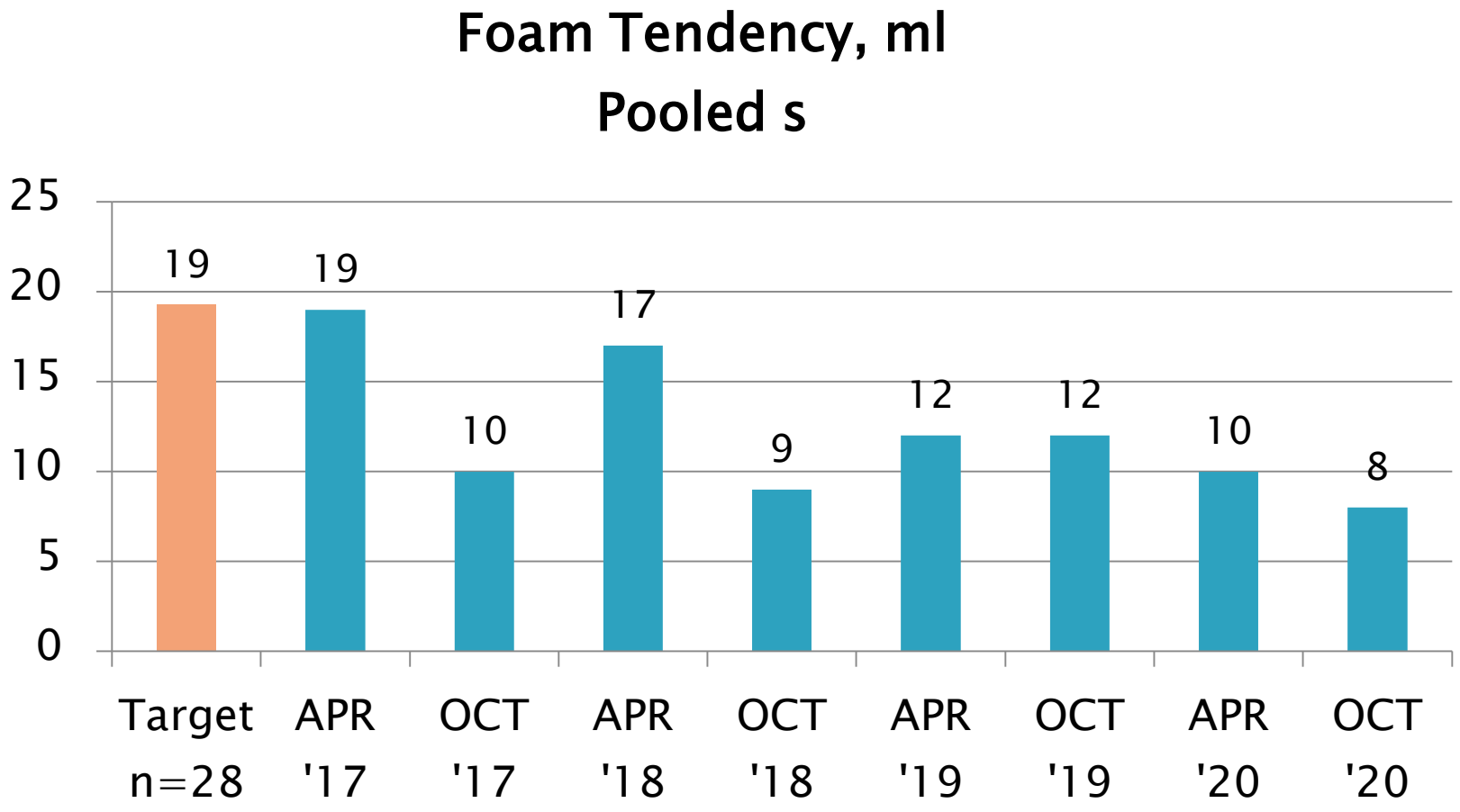
Period Precision and Severity Estimates

Foam Stability @ 1 min, ml	n	Mean	s
Current Targets	28	0.00	0.00
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	
4/1/20 through 9/30/20	13	No non-zero occurrences	

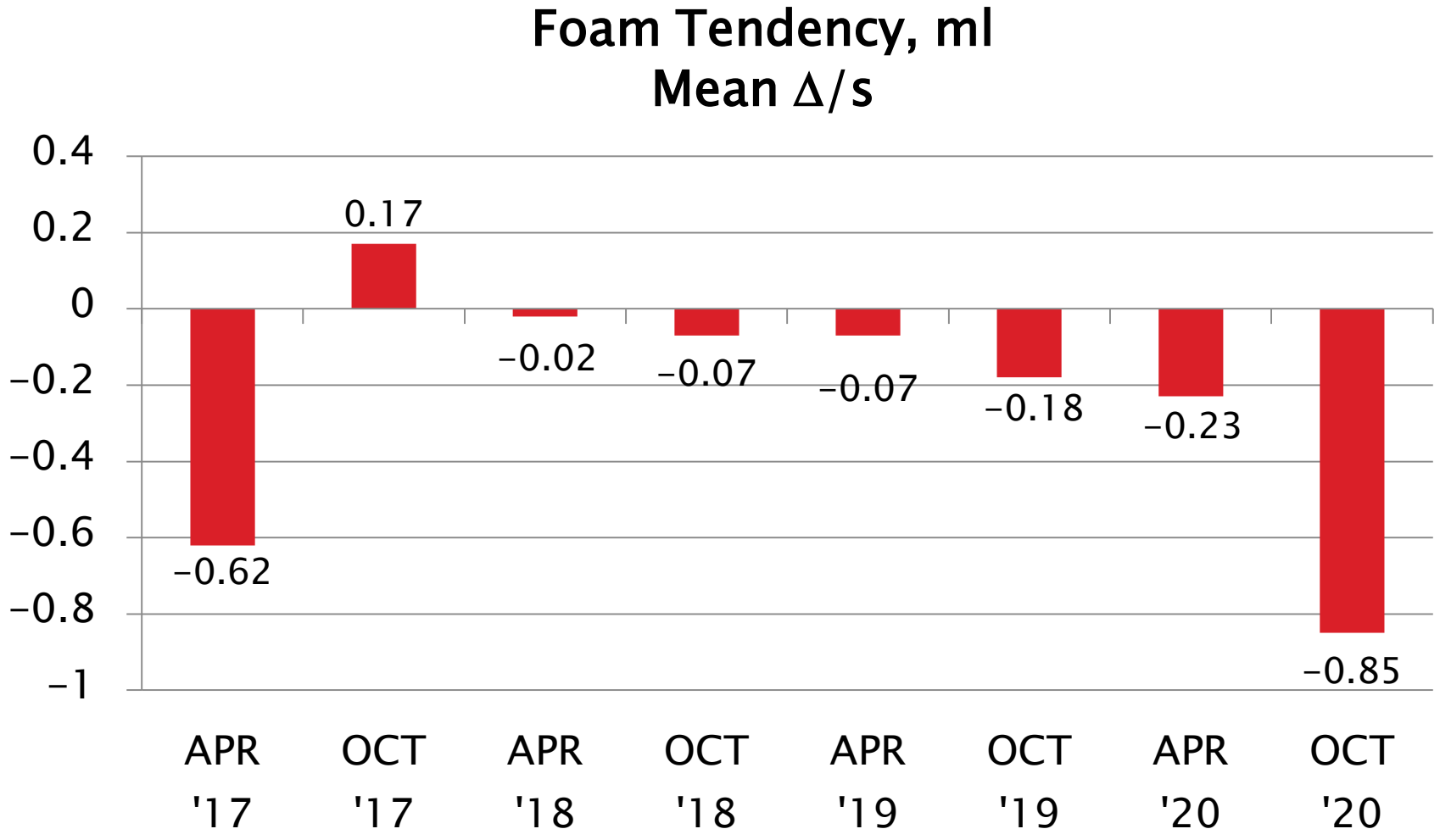
D6082 Performance by Oil



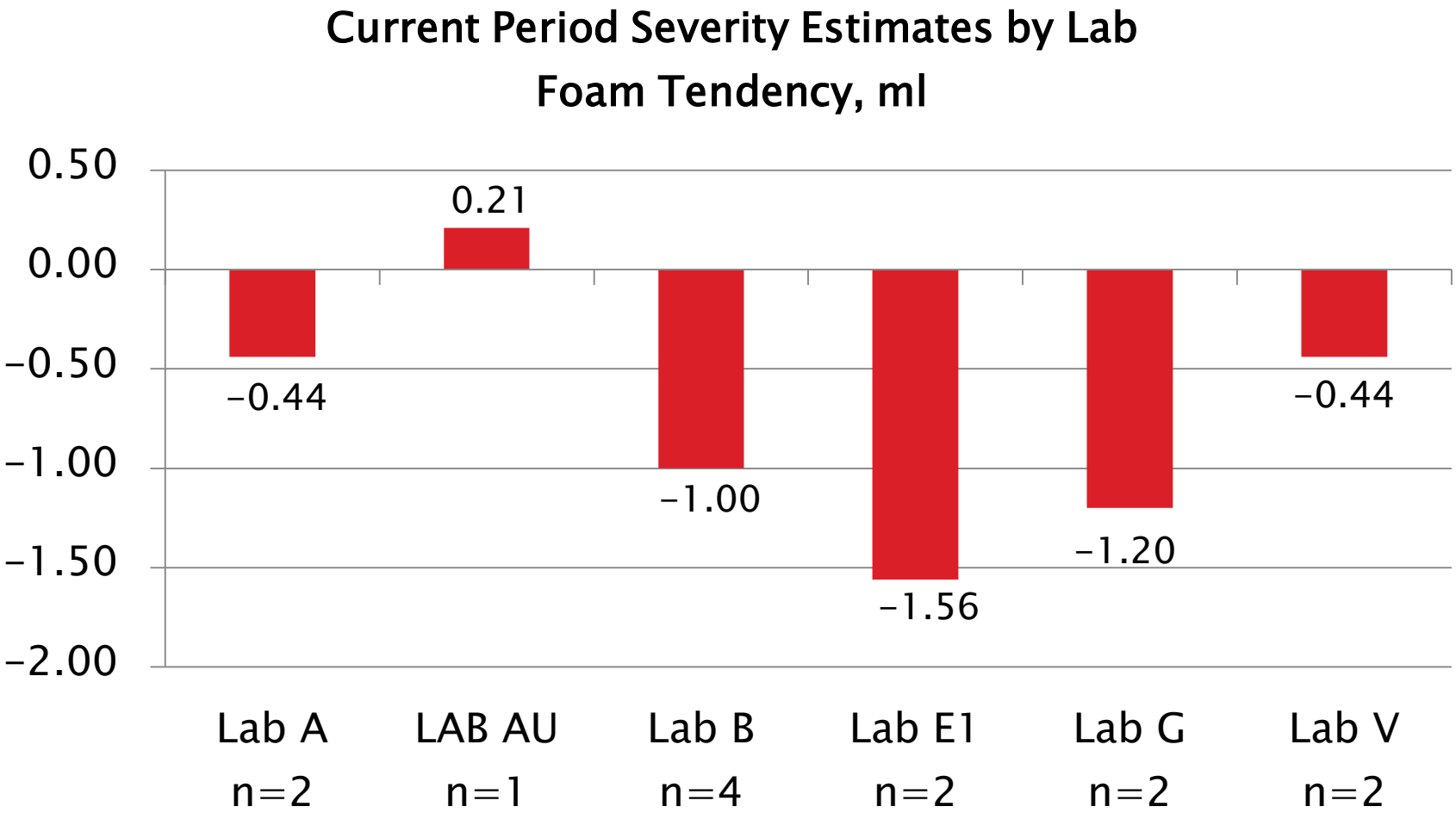
D6082: High Temperature Foam



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 -0.85 s mild
  - Replacement reference oil FOAMB18 performing at -0.95 s mild (n=11)
  - Third consecutive period of mild performance on the new reference oil.
    - Target performance, set on 18 runs in a RR, may need revisited.

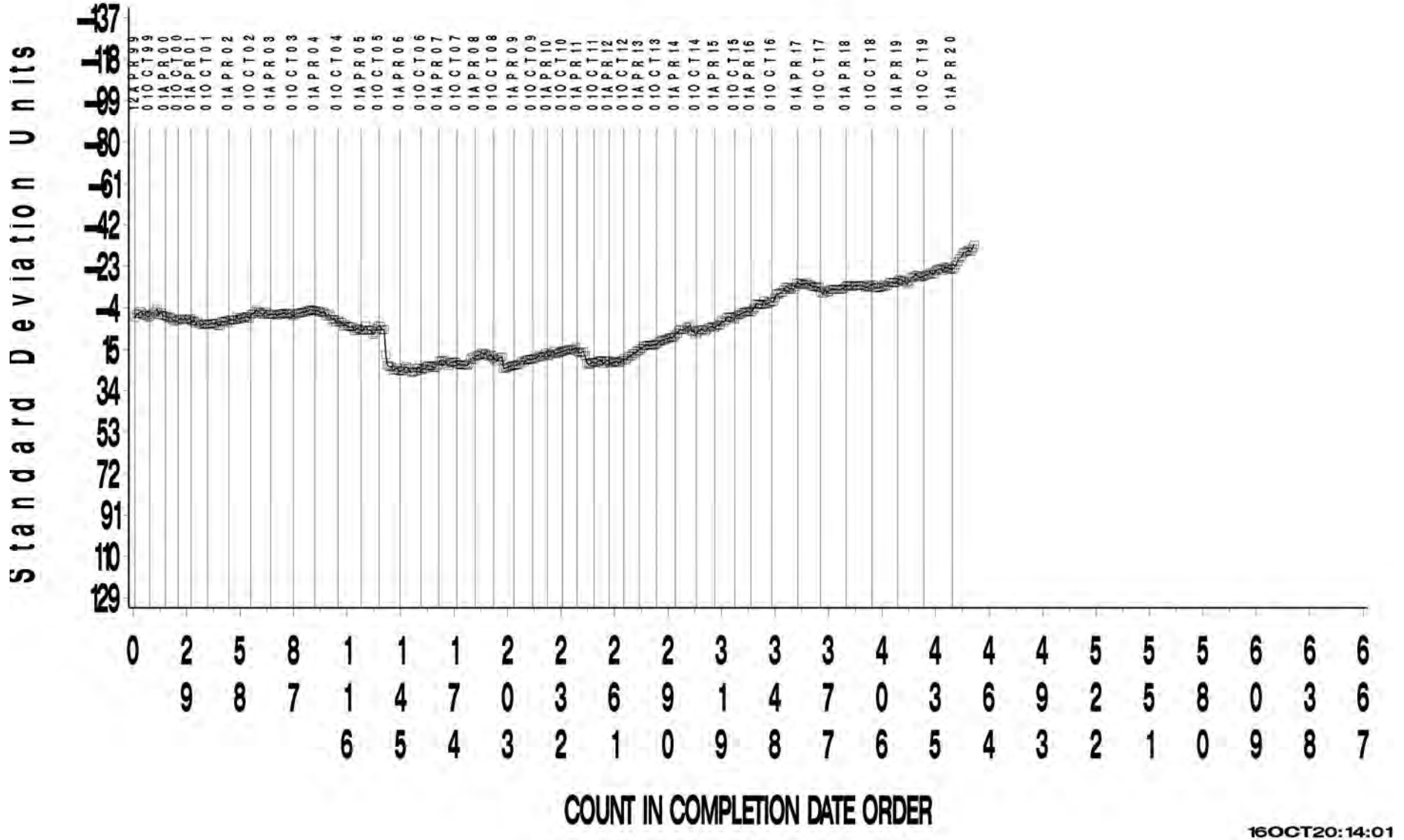
- No non-zero occurrences of Foam Stability

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

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

CUSUM Severity Analysis

Return to Executive Summary



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D874: Sulfated Ash

Test Status	Validity Code	No. Tests
Acceptable Calibration Test	AC	8
Failed Calibration Test	OC	0
Operationally Invalidated by Lab	LC, XC	0
Operationally Invalidated After Initially Reported as Valid	RC	0
Total		**8**

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

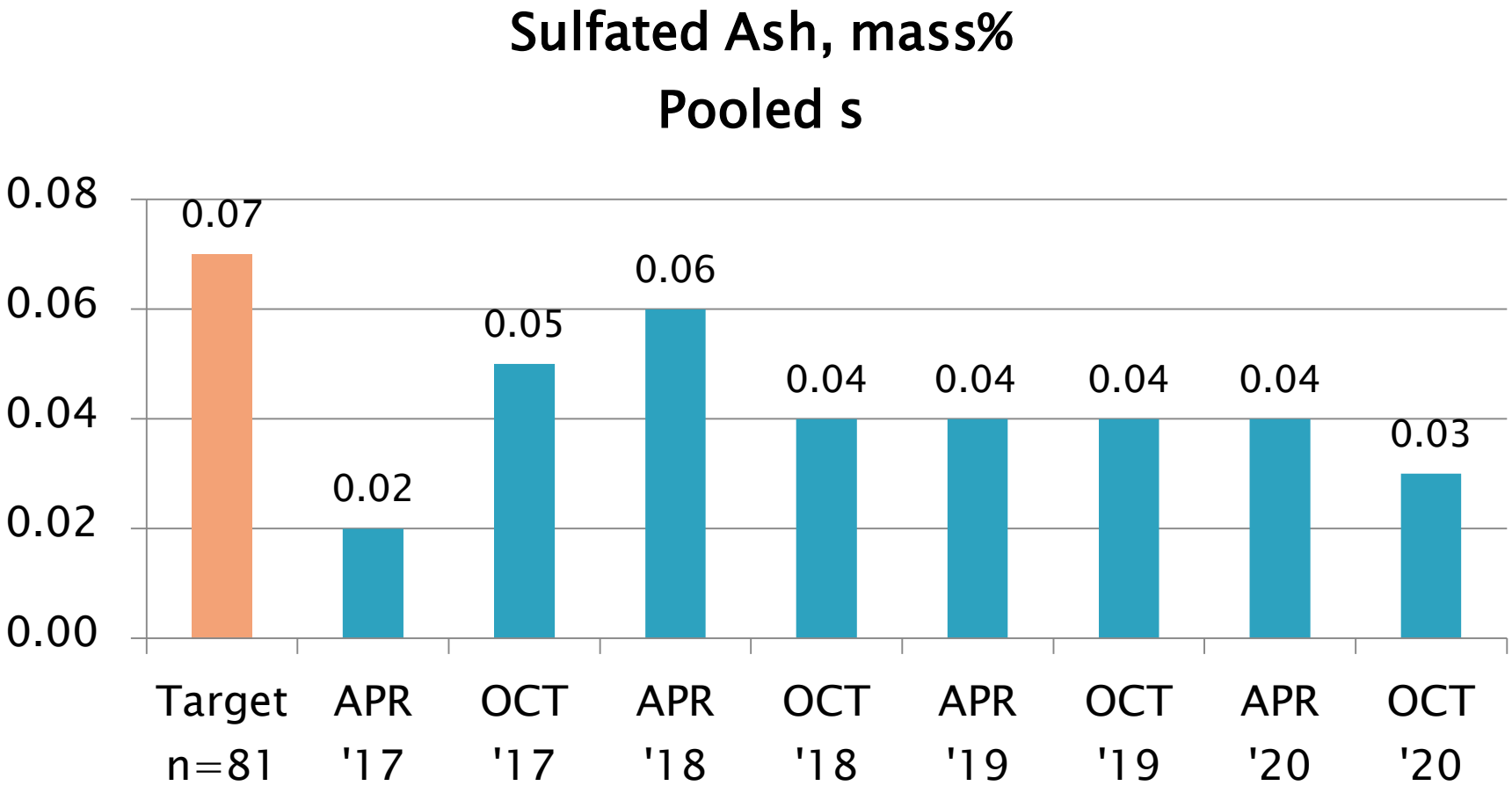
- No statistically or operationally invalid tests reported this period
- No TMC technical updates issued this period

D874: Sulfated Ash

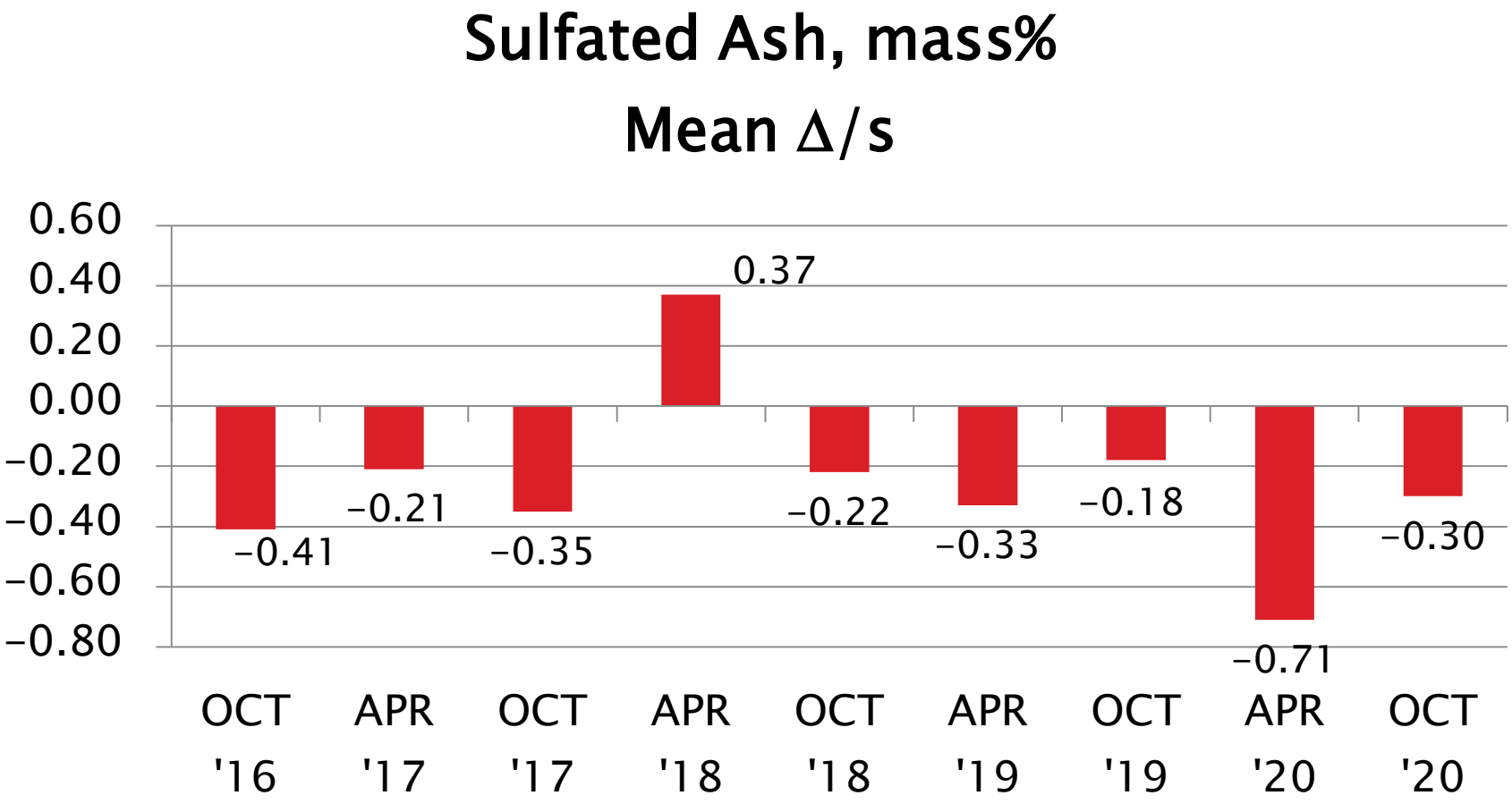
Period Precision and Severity Estimates

Total Deposits, mg	n	df	Pooled s	Mean Δ/s
Current Targets	81	78	0.07	-----
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
4/1/20 through 9/30/20	8	5	0.03	-0.30

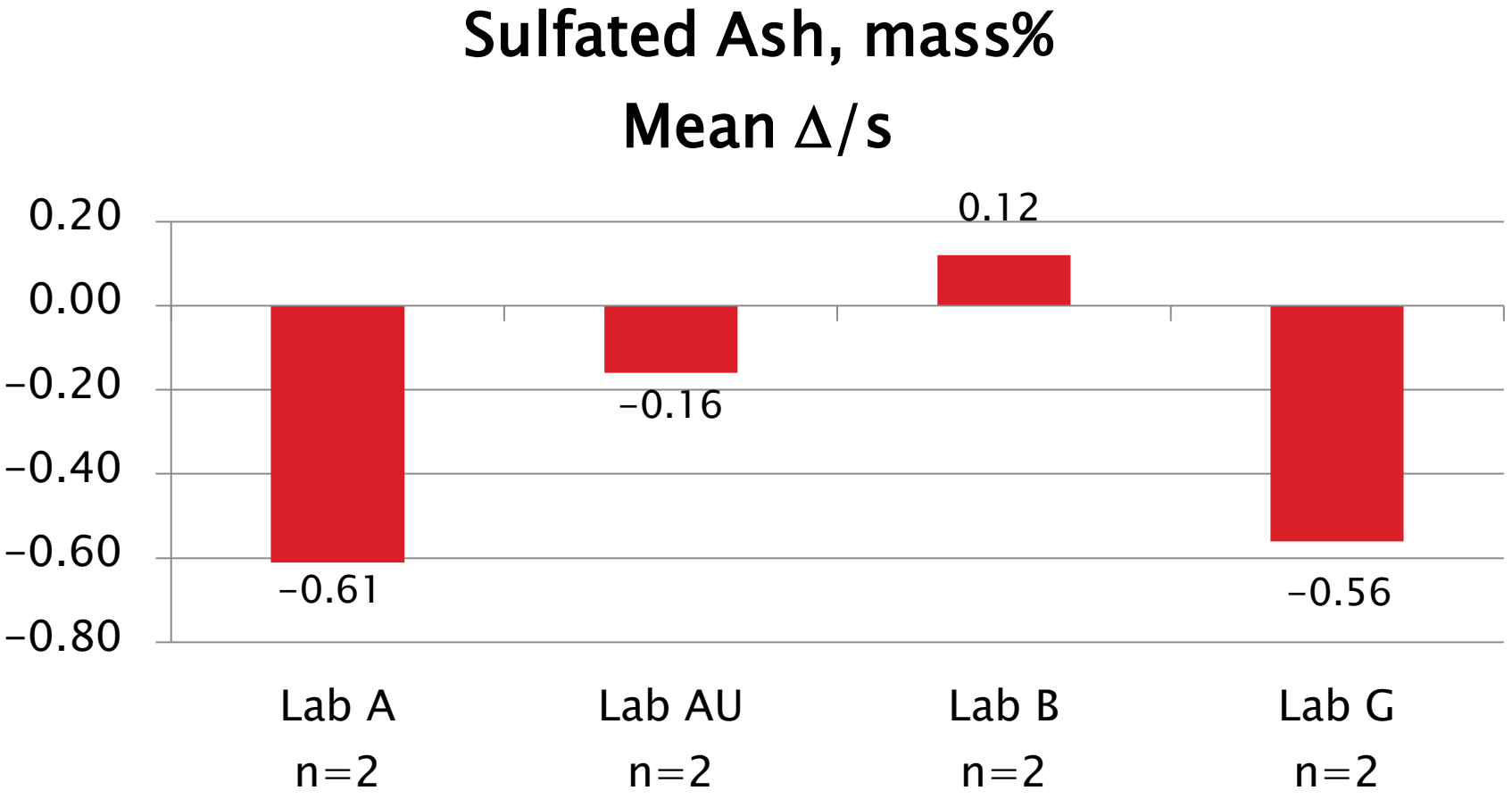
D874: Sulfated Ash



D874: Sulfated Ash



D874: Sulfated Ash



D874: Sulfated Ash

- Precision (Pooled s) is more precise than prior periods
  - More precise than target precision
- Performance (Mean Δ/s) is -0.30 s mild

D874 INDUSTRY OPERATIONALLY VALID DATA

TEST SAMPLE PERCENT SULFATED ASH

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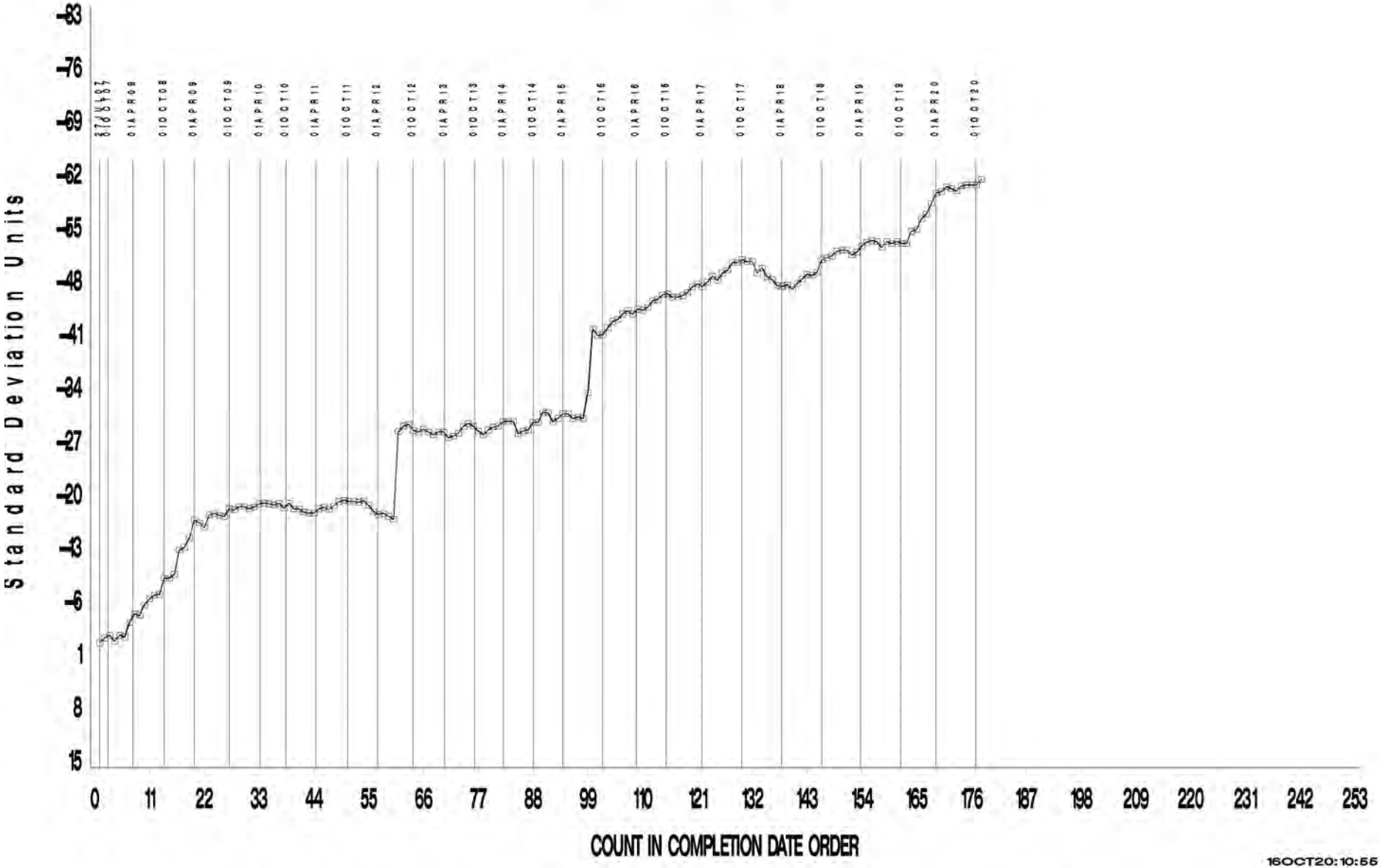
CUSUM Severity Analysis



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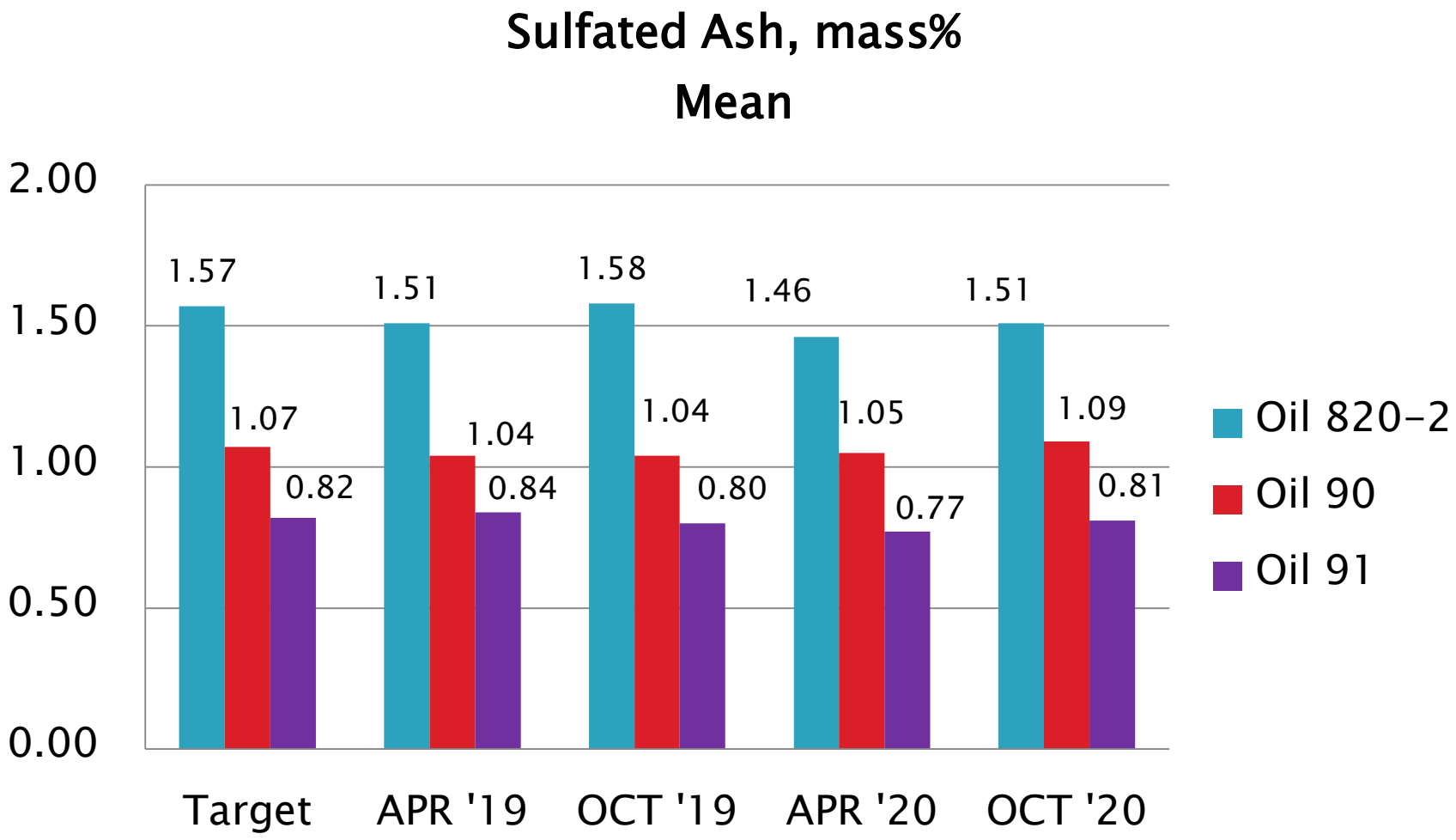
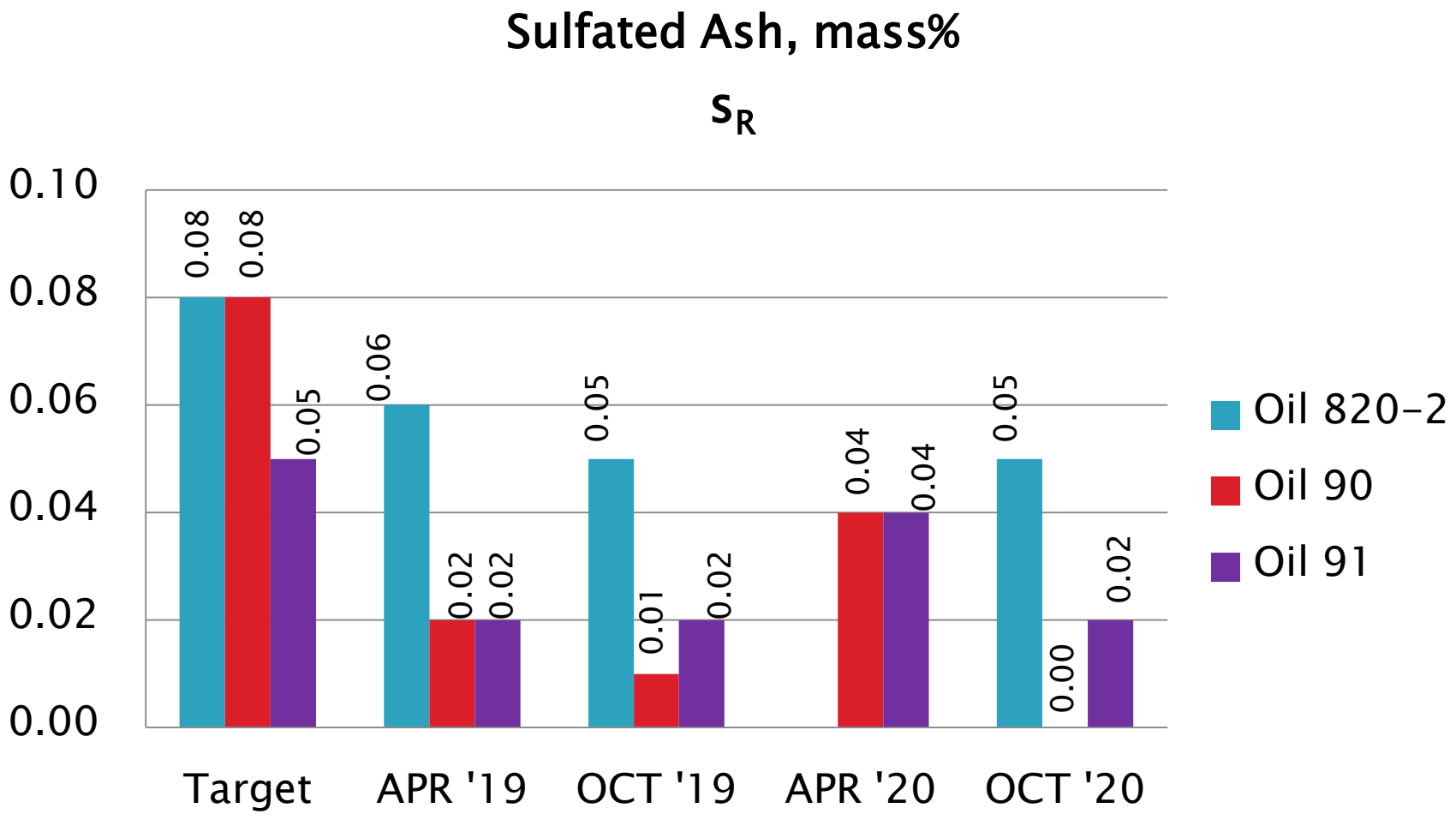
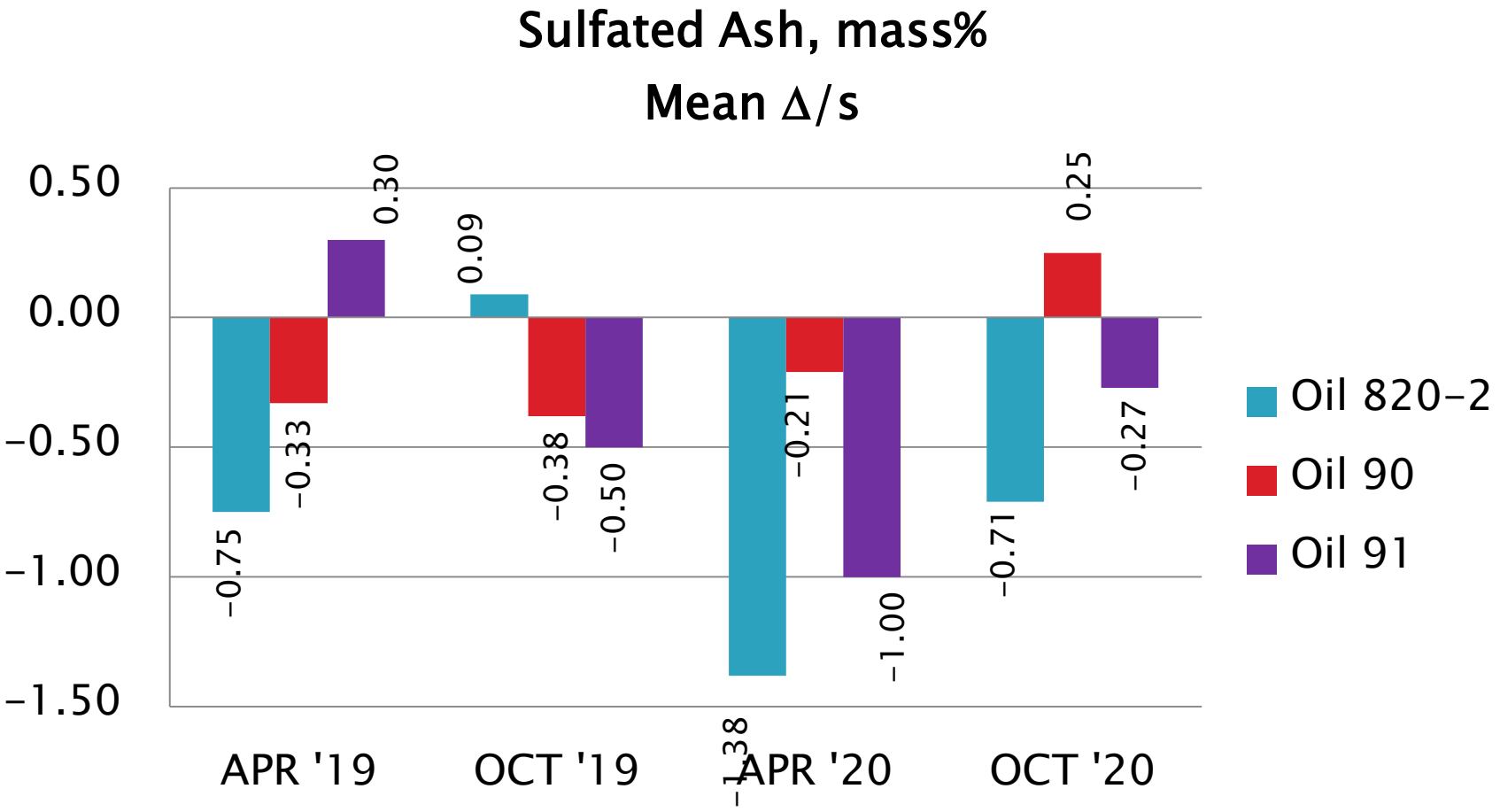
D874: Sulfated Ash



D874: Sulfated Ash



D874: Sulfated Ash



Return to Executive Summary

D7528: Oxidation by ROBO

Test Status	Validity Code	No. Tests
Acceptable Calibration Test	AC	102
Failed Calibration Test	OC	17
Operationally Invalidated by Lab	LC, XC	26
Operationally Invalidated After Initially Reported as Valid	RC	1
Held out of statistics (new rigs, failed to calibrate)	MC	5
Industry Information Run (436 RR)	AG	2
Non-Blind Instrument Shakedown	_N	19
Total		**172**

Number of Labs Reporting Data: 8

Fail Rate of Operationally Valid Tests: 14%

D7528: Oxidation by ROBO

Operationally Invalid Calibration Tests

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

Other Tests

- 5 tests held out of statistics (MC), failed to demonstrate passing calibrations on new rigs
- 2 industry information tests (AG) on proposed new oil 436
- 19 Rig shakedown run (AN, ON, LN, XN)
  - Some required on new rigs, LTMS updated mid-report period to drop this requirement

D7528: Oxidation by ROBO

Statistically Unacceptable Tests (OC)	No. Of Tests
Natural Log (MRV Viscosity) Mild	16
Natural Log (MRV Viscosity) Severe	1

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

- There were no technical update issued this period.

- Calibration requirement updates are issued as LTMS document updates

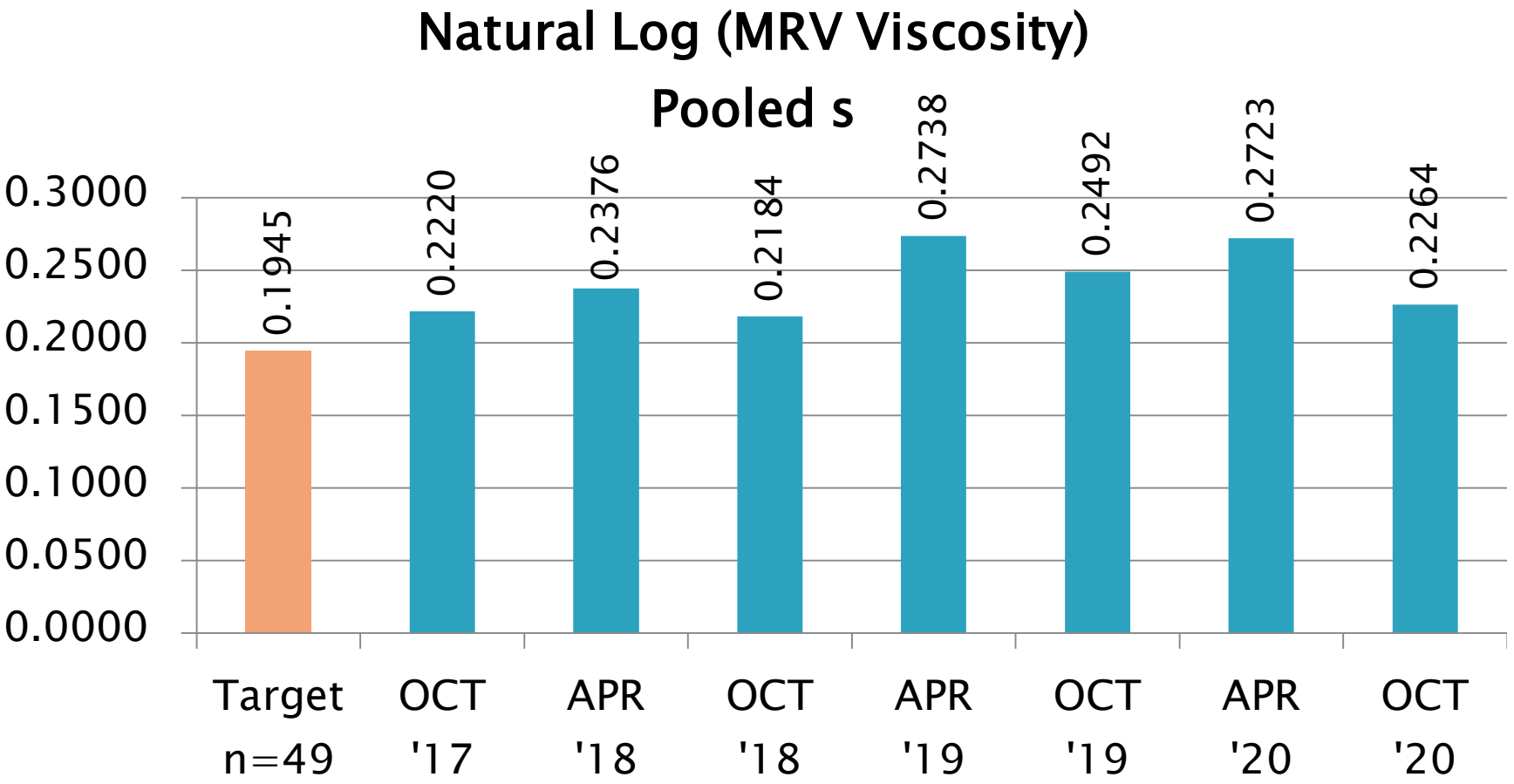
D7528: Oxidation by ROBO

Period Precision and Severity Estimates

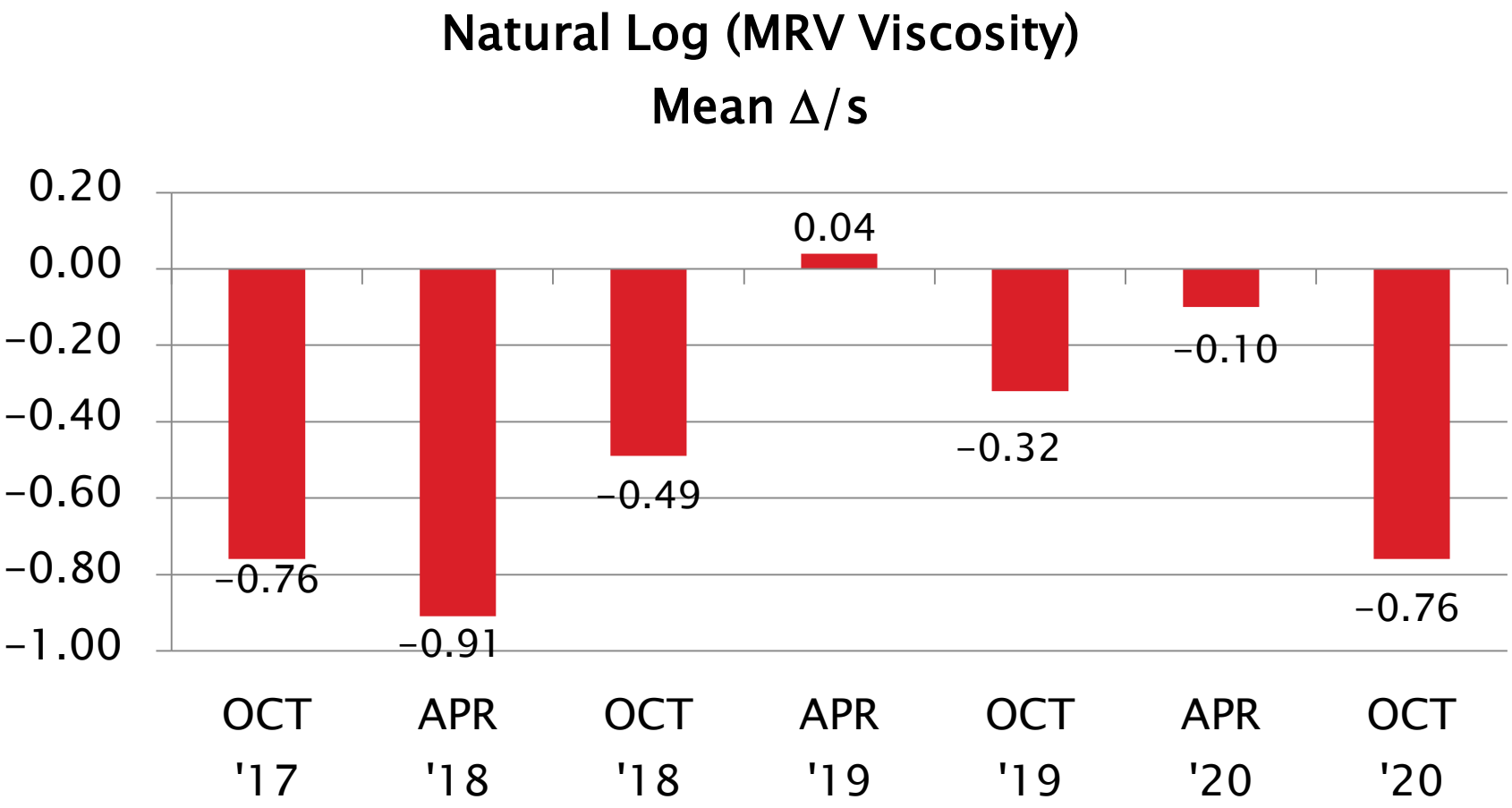
Natural Log (MRV Viscosity)	n	df	Pooled s	Mean Δ/s
Current Targets	49	46	0.1945	-----
4/1/17 through 9/30/17	99	95	0.2220	-0.76
10/1/17 through 3/31/18*	90	86	0.2376	-0.91
10/1/17 through 3/31/18*	83	79	0.2076	-0.74
4/1/18 through 9/30/18	126	122	0.2184	-0.49
10/1/18 through 3/31/19	100	96	0.2738	0.04
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
4/1/20 through 9/30/20	119	113	0.2264	-0.76

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

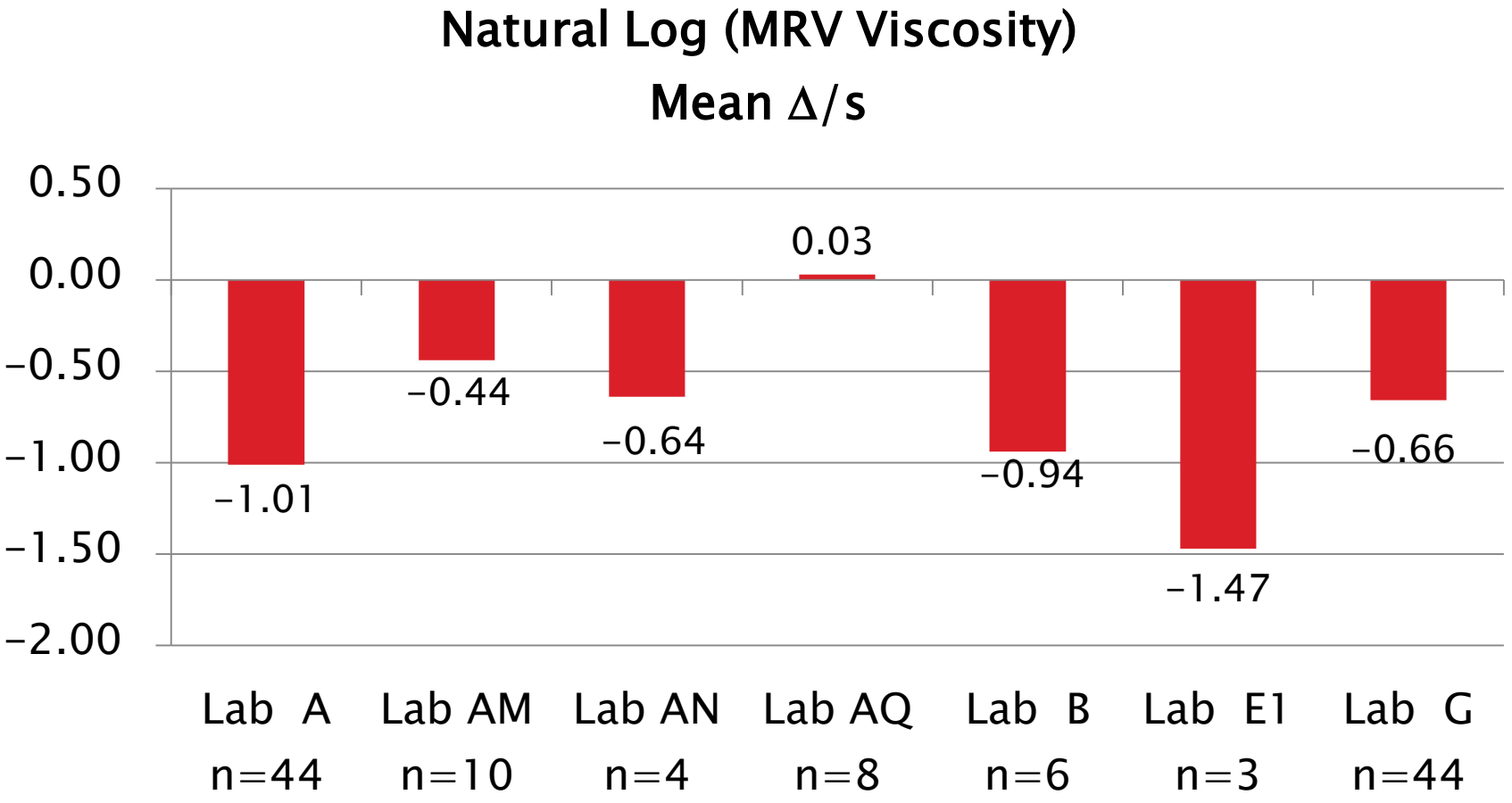
D7528: Oxidation by ROBO



D7528: Oxidation by ROBO



D7528: Oxidation by ROBO



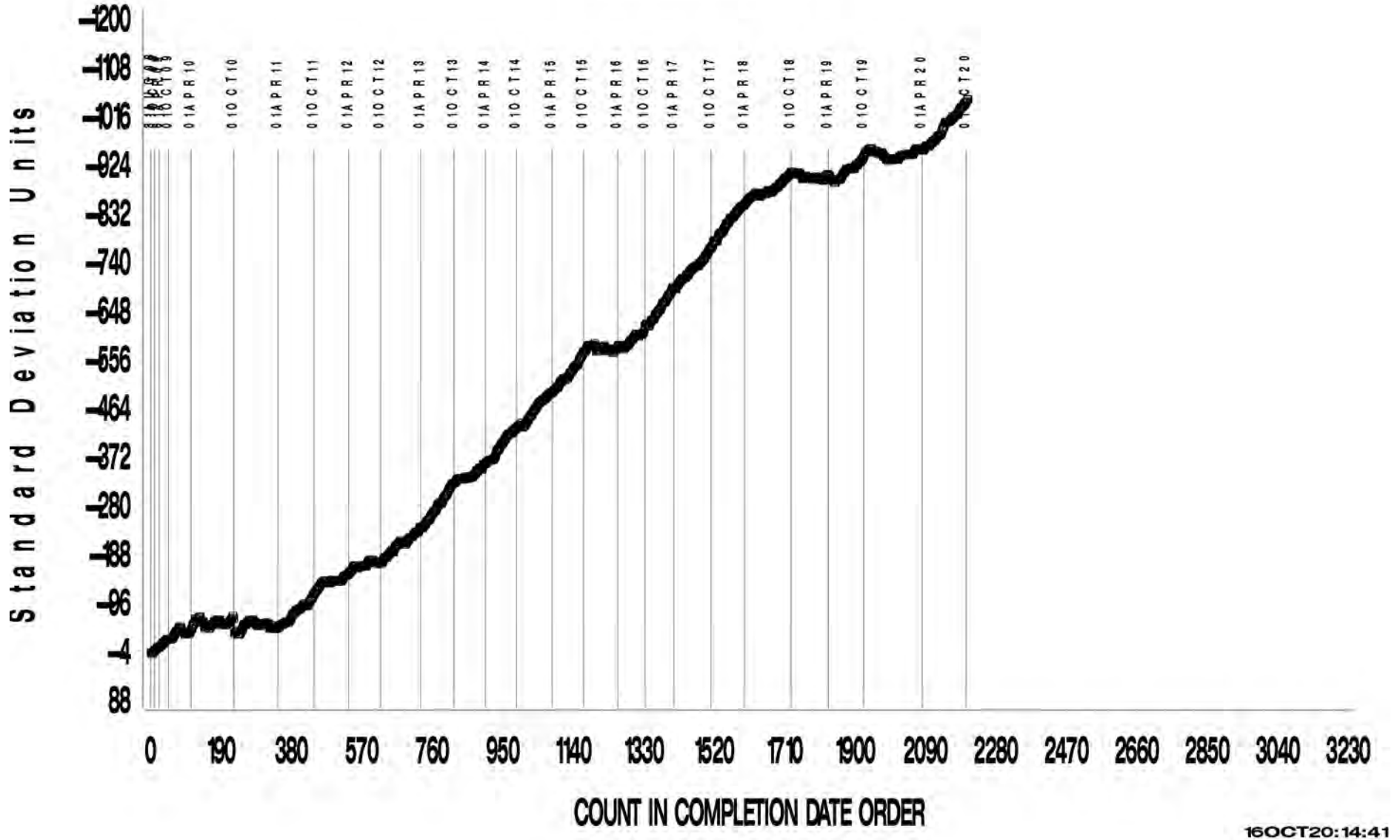
D7528: Oxidation by ROBO

- Precision (Pooled s) is more precise than last period
  - Continues to be less precise than target
- Performance (Mean Δ/s) is -0.76 s mild for this report period
- CUSUM severity plot shows variable performance past three report period

ROBO TEST INDUSTRY OPERATIONALLY VALID DATA

AGED OIL MRV APPARENT VISCOSITY

CUSUM Severity Analysis



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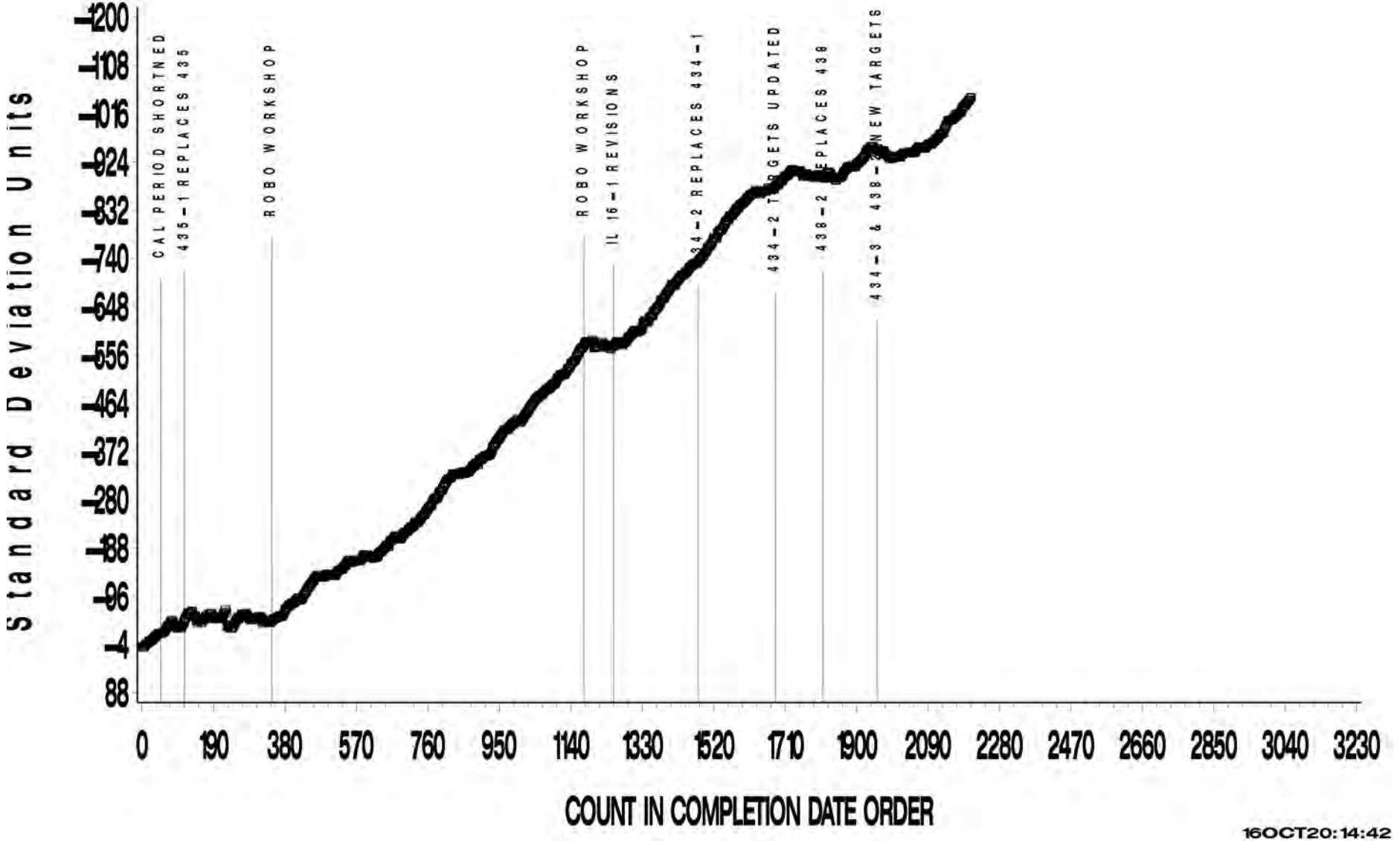
ROBO TEST INDUSTRY OPERATIONALLY VALID DATA

AGED OIL MRV APPARENT VISCOSITY

CUSUM Severity Analysis



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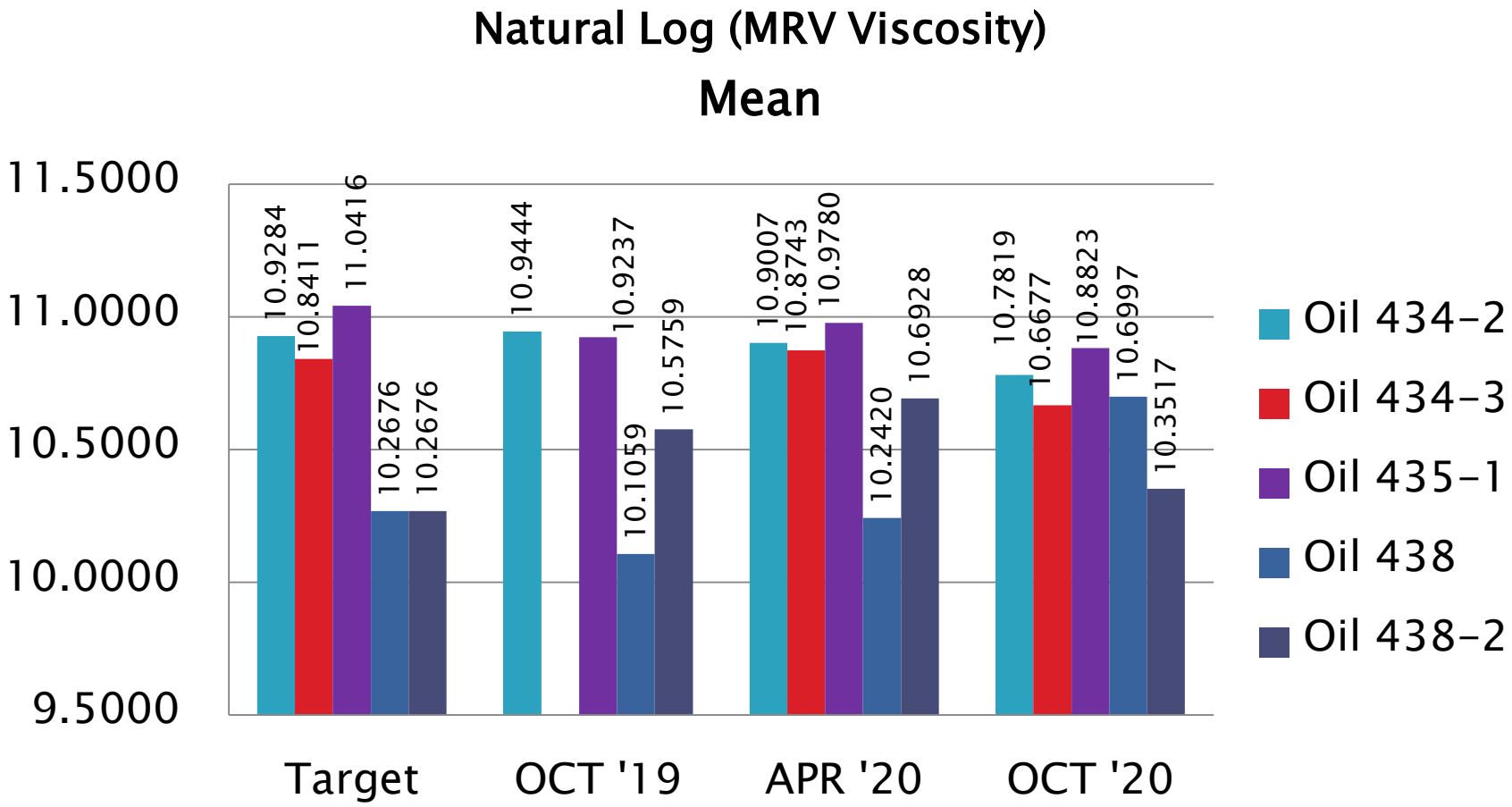
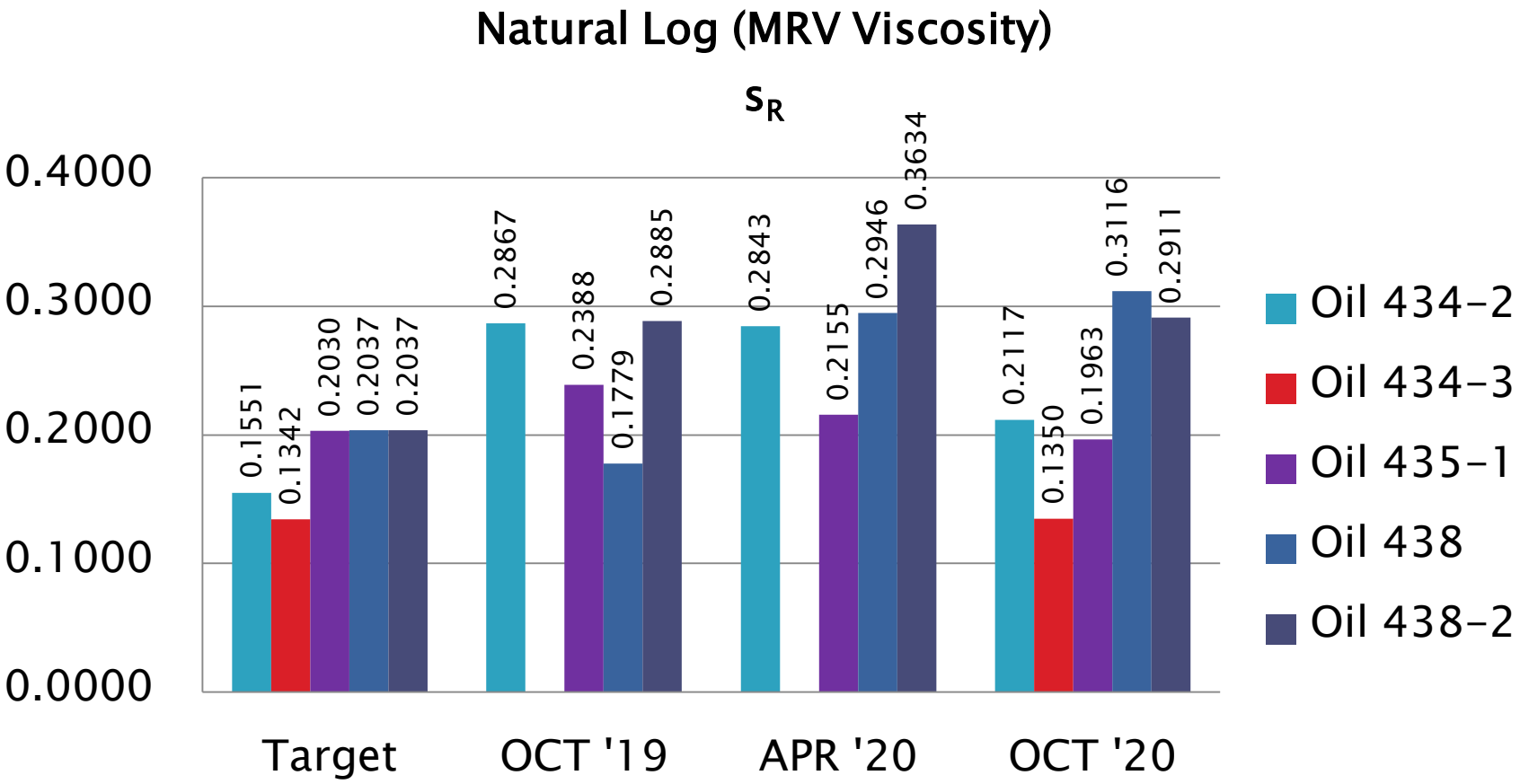


D7528: Oxidation by ROBO



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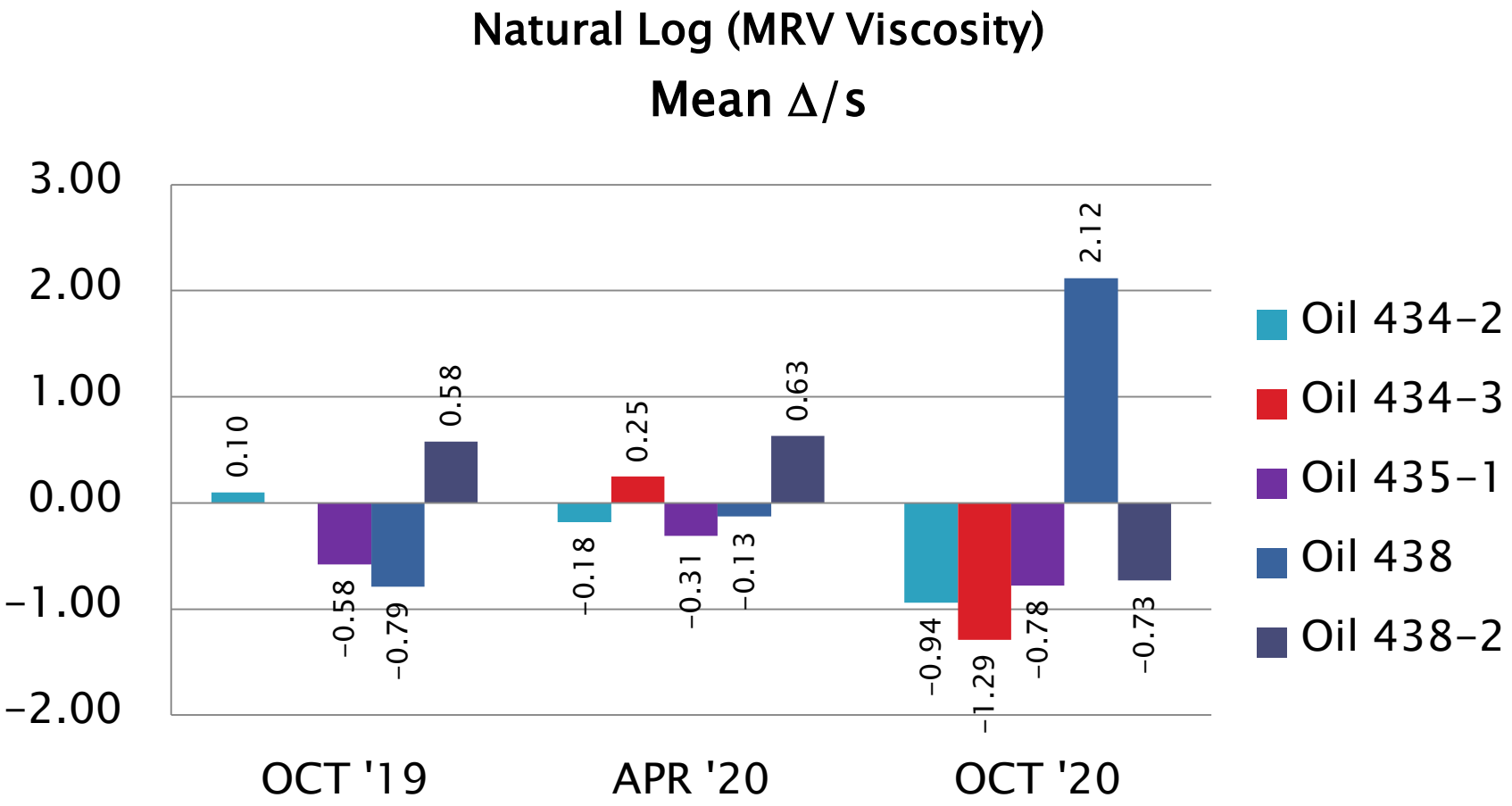

Return to Executive Summary

Reference Oil Inventory

- As of 9/30/2020

Reference Oil Inventory

D5800

Oil	Year Rec'd By TMC[A]	Tests	TMC Inventory, gallons	Gallons Shipped last 12 months
VOLC12	2013	D5800	29.4	3.3
VOLD12	2013	D5800	27.8	3.0
VOLE12	2013	D5800	25.5	3.5
VOLD18	2018	D5800QC	916	115

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

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	0.02
58	1998	D6417, D6417QC, GI	114.0	1.3
GIA17[B]	2017	GI	9.0	0.8
1009	2002	GI	37.0	0.9

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

[B]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	103.2	0.5
75-1	2016	TEOST	6.0	1.5
435-2[B]	2010	TEOST	40.4	0.6
434-3[B,C]	2017	ROBO/MTEOS	44.6	1.5
435-1	2008	ROBO	371	23.5
438-2[B]	2017	ROBO	38.4	3.6

[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.

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

Reference Oil Inventory

D6082 & D874

Oil	Year Rec'd By TMC[A]	Tests	TMC Inventory, gallons	Gallons Shipped last 12 months
FOAMB18	2018	D6082	88.7	3.6
66	2002	D6082	75.4	1.4
820-2	2001	D874	8.9	0.0
90	2005	D874/D874QC	15.5	2.1
91	2006	D874	3.5	0.0

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

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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