Test Monitoring Center

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

D6417, D5133 (GI), D5800, D6335 (TEOST), D7097(MTEOS), D6082, D874, D7528 (ROBO), and D7216 (EOEC/LDEOC)

October 2019

B0.07 Bench Testing
Executive Summary

- D6417 (Volatility by GC)
- Precision (Pooled s) is more precise than prior period
  - More precise than target precision
- Performance (Mean Δ/s) is 0.10 s severe (on-target)
- CUSUM plot shows overall slight severe performance with leveling to nearly on-target this report period.

B0.07 Bench Testing Executive Summary

- D5800 (Volatility by Noack)

- Precision (Pooled s) is less precise than the target LTMS pooled precision of 0.73 mass %, but comparable to the prior report period.
- Performance (Mean Δ/s) is 0.65 s severe.
- Two tests exceeded 3 s from targets (rig G6 +3.5 s; rig J5 +4.2 s)
- Fail rate of operationally valid tests (AC & OC) has increased to 10% this period, and was 7% last period (much influenced both periods by Lab J failing test results). The fail rate had dropped to 5% or less for the prior four report periods using EWMA LTMS, compared to approximately 26% under the Shewhart severity only system.
- CUSUM plot shows a continuing (and increasing) overall severe trend with reference testing.

B0.07 Bench Testing Executive Summary

- D5133 (Gelation Index)
- Fail rate of operationally valid tests is 9% this period. Historic period fail rates have ranged between 6% and 26%.
- Performance (Mean Δ/s) is -0.25 s mild
- Precision (Pooled s) is more precise than prior report period, and more precise than target precision.
- Two labs each reported very extreme results as operationally valid, but subsequently found the heads to be bad and in need of service. Another lab reports a result of 6.8 s severe as operationally valid. Also, two of the three mild failing results (OC) were on oil 58, presently with a lower limit set below GI 6.0. These results lend additional support to moving to a head-based calibration system, and reclassifying oil 58 as a discrimination oil with no lower limit.

B0.07 Bench Testing Executive Summary

- D5133 (Gelation Index, continued)
- Erratic calibration performance of certain heads should raise concerns about the adequacy of the current 'single-test' Shewhart monitoring system.
  - Industry might be better served if an LTMS EWMA based monitoring system was considered for this test, much like what is currently done in D5800.
  - **Forward progress on a revised monitoring system, and adding a D5133 GI monitoring protocol to the LTMS document is stalled due to inaction.**

B0.07 Bench Testing Executive Summary

- D6335 (TEOST-33C)

- Precision (Pooled s) is less precise than prior period, and less precise than target precision.
  - Comparable to prior period with four results from rig G1 excluded, but still less precise than target precision.
- Performance (Mean Δ/s) is 0.47 s severe.
  - -0.27 s mild excluding four results from rig G1.
- Fail rate of 23% is high again for the period.
  - Comparable to last period (20%).
- 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.

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

- Performance (Mean Δ/s) is -0.30 s mild.

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

- All operationally valid calibration tests this period report using Catalyst Batch 16DA (n=11) or 18AB (n=98).

- Overall severity of catalyst batch 18AB (n=199) appears to be about -0.3 s mild, and comparably mild on both reference oils.

B0.07 Bench Testing Executive Summary

- D6082 (High Temperature Foam)

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

- Performance (Mean Δ/s) is on target (slight mild bias)

- 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 this 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 -0.18 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 -0.32 s mild for this report period

Calibrated Labs and Stands*

Test	Labs	Stands
D6417	7	9
D5800	9	22
D5133 (GI)	8	12
D6335 (TEOST)	6	9
D7097 (MTEOS)	11	47
D6082	6	7
D874	4	--
D7528 (ROBO)	5	17

*As of 9/30/2019

D02.B0.07
TMC Monitored Tests

- April 1, 2019 –
  September 30, 2019

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D6417: Estimation of Engine Oil Volatility by Capillary GC

Test Status	Validity Code	No. Tests
Acceptable Calibration Test	AC	19
Failed Calibration Test	OC	0
Operationally Invalidated by Lab	LC, XC	0
Operationally Invalidated After Initially Reported as Valid	RC	0
Total		**19**

Number of Labs Reporting Data: 8
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 invalidated D6417 tests reported this period.

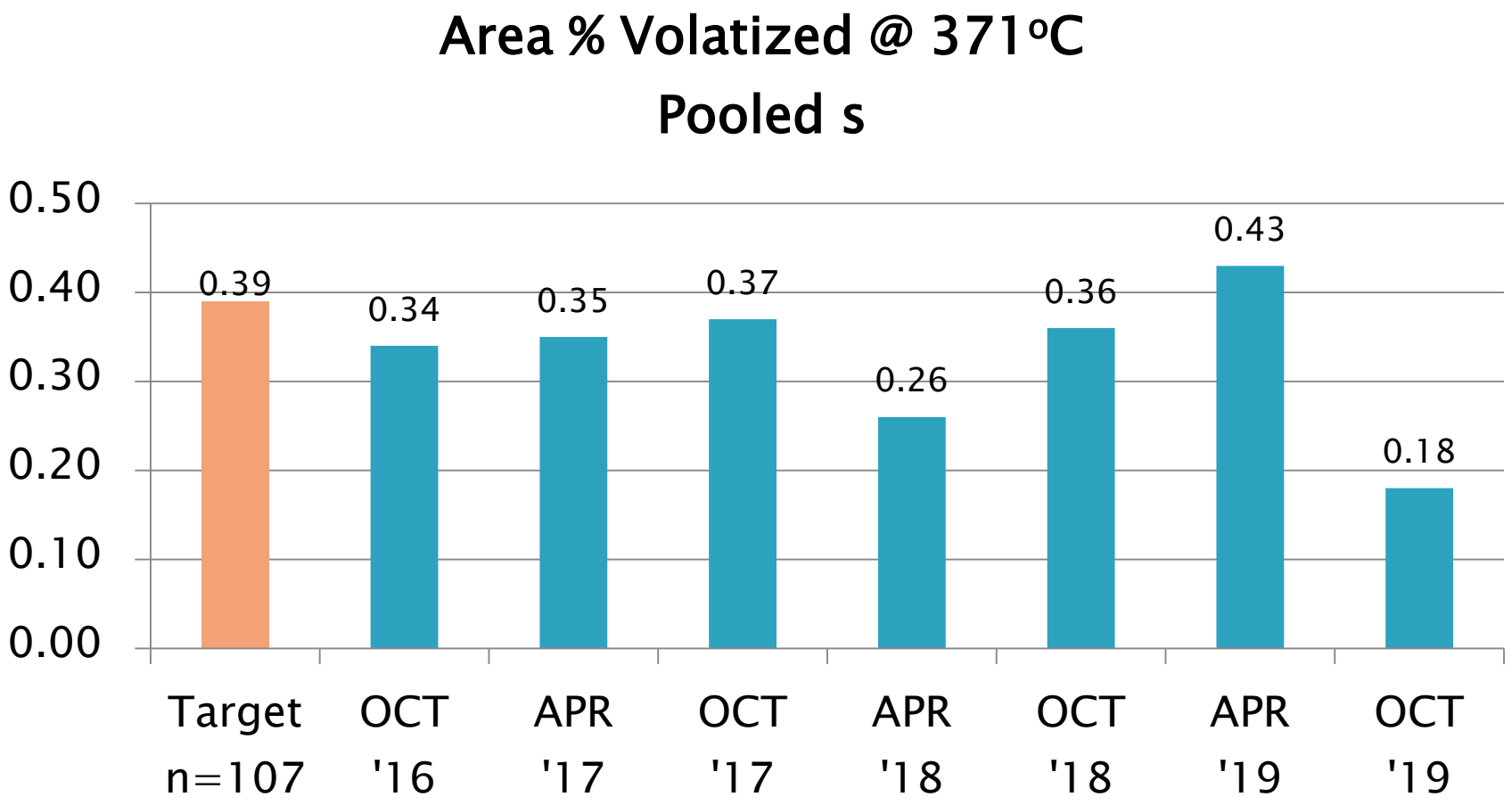
- Calibration requirement updates are issued as LTMS document updates

D6417: Estimation of Engine Oil Volatility by Capillary GC

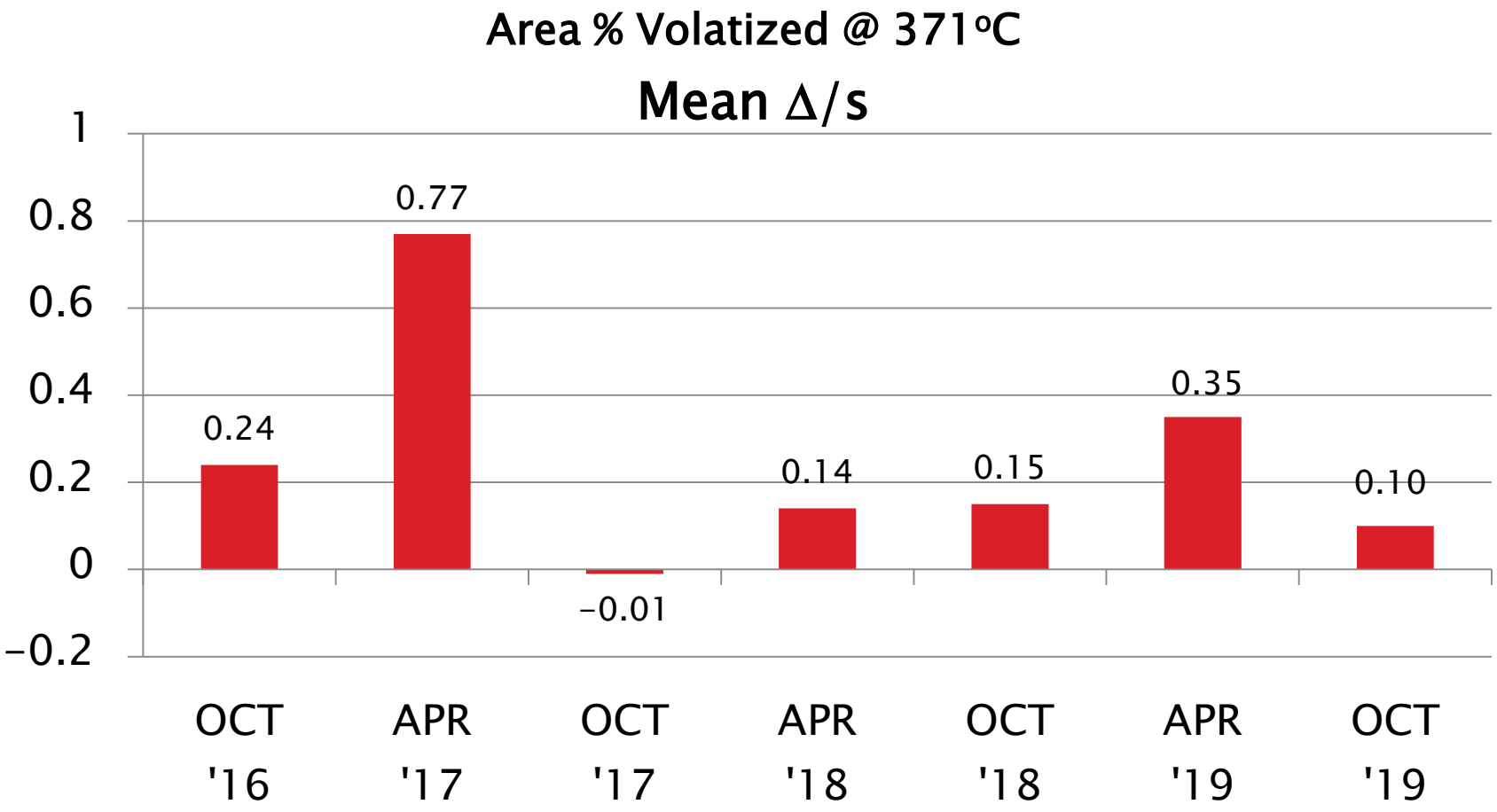
Period Precision and Severity Estimates

Area % Volatized @ 371°C	n	df	Pooled s	Mean Δ/s
Initial Selected Oils from RR	54	51	0.39	-----
4/1/16 through 9/30/16	11	8	0.34	0.24
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

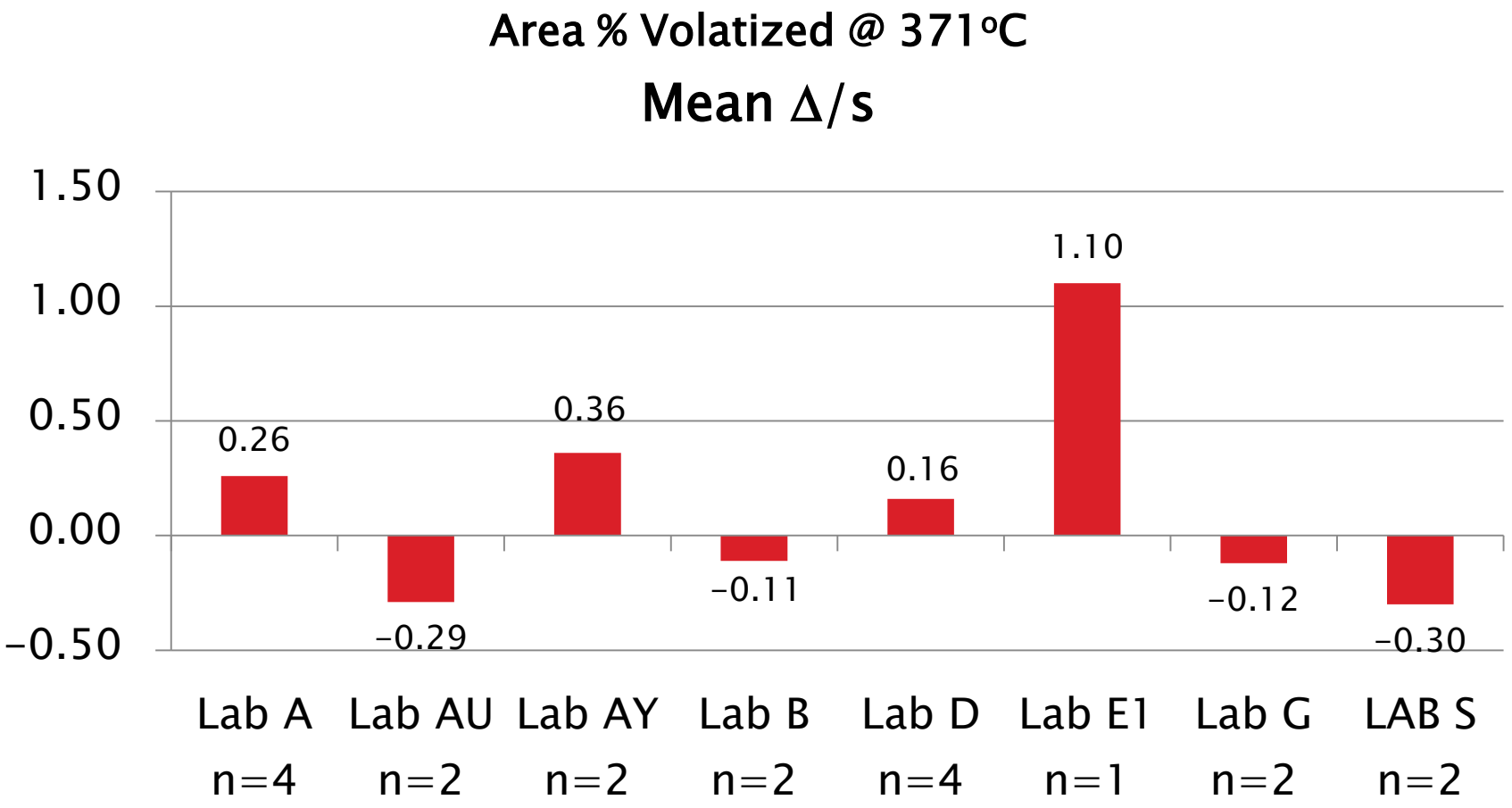
D6417 Precision Estimates



D6417 Severity Estimates



D6417 Lab Severity Estimates



D6417: Estimation of Engine Oil Volatility by Capillary GC

- Precision (Pooled s) is more precise than prior period
  - More precise than target precision
- Performance (Mean Δ/s) is 0.10 s severe (on-target)
- CUSUM plot shows overall slight severe performance with leveling to nearly on-target this report period.

D6417 VOLATILITY BY GC INDUSTRY OPERATIONALLY VALID

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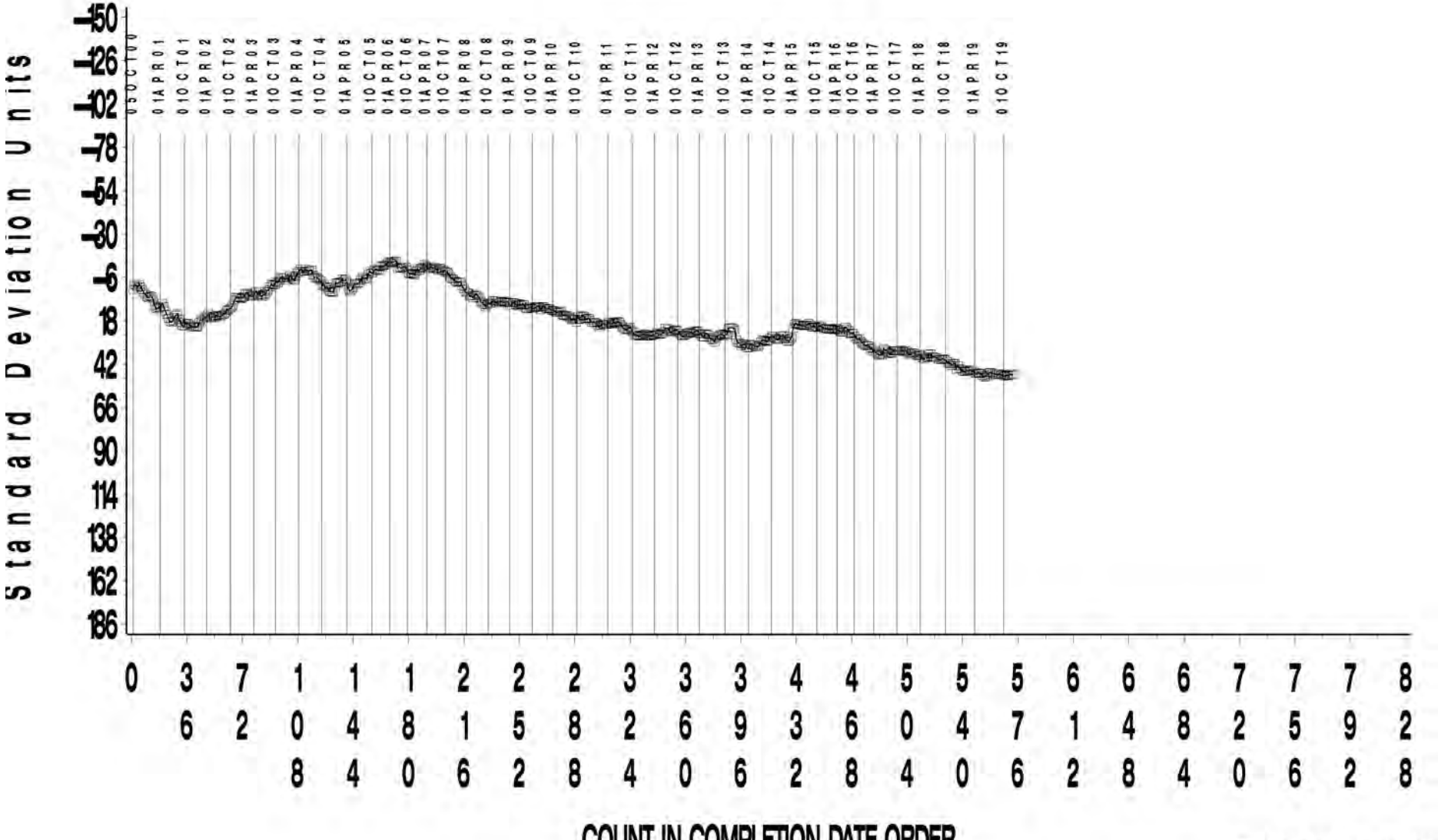
SAMPLE AREA % VOLATIZED

CUSUM Severity Analysis



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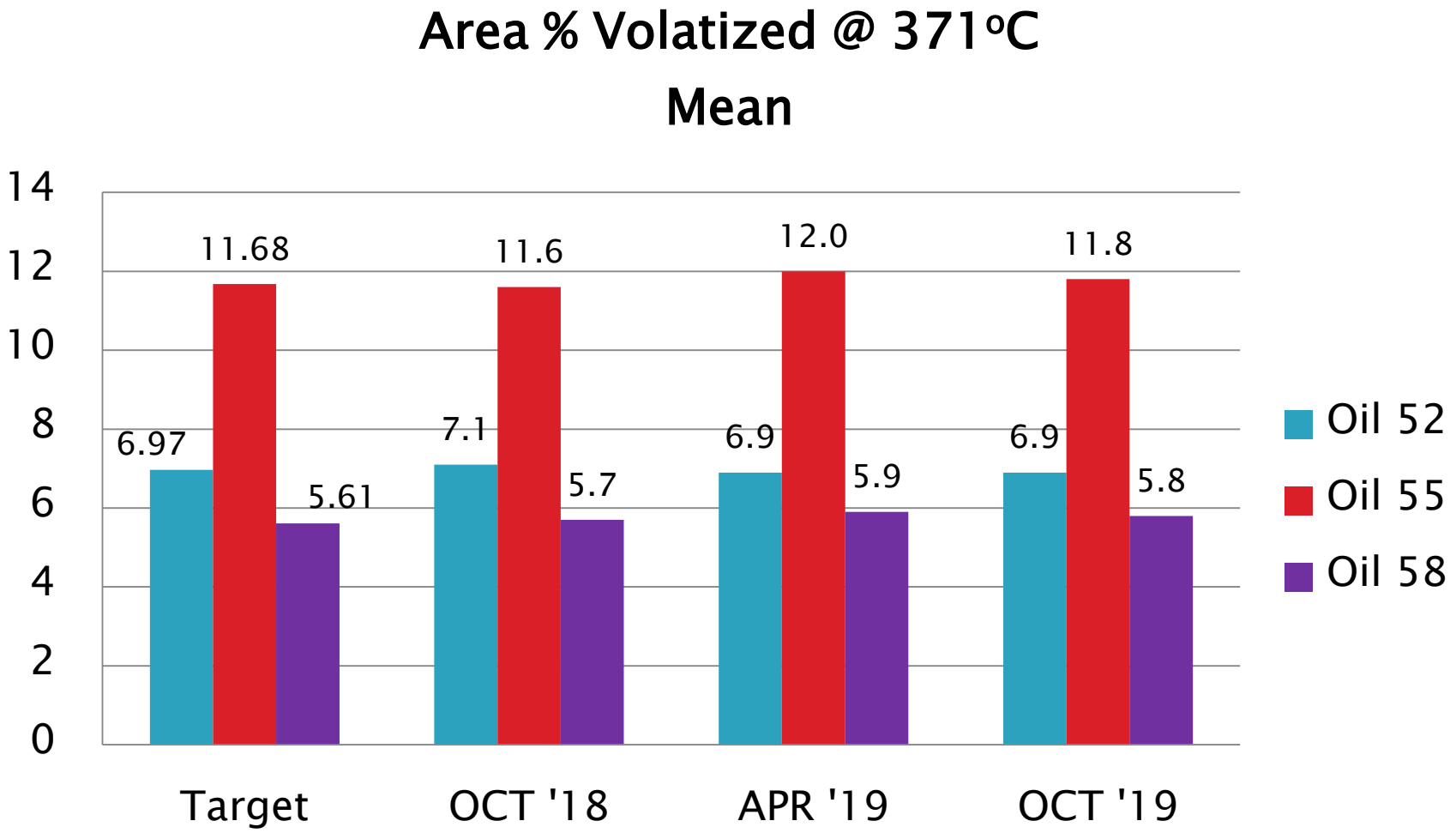
D6417 Performance by Oil



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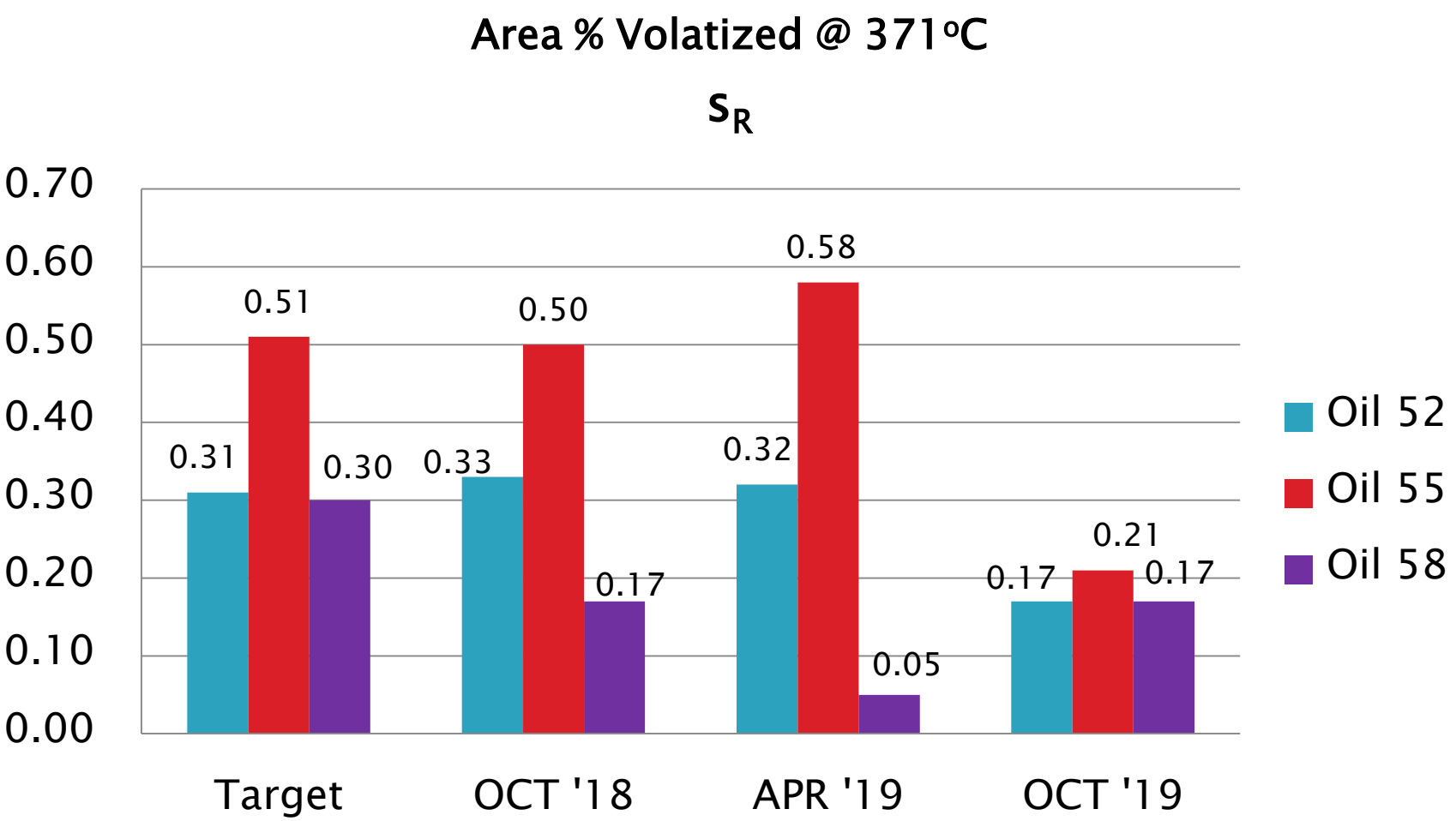
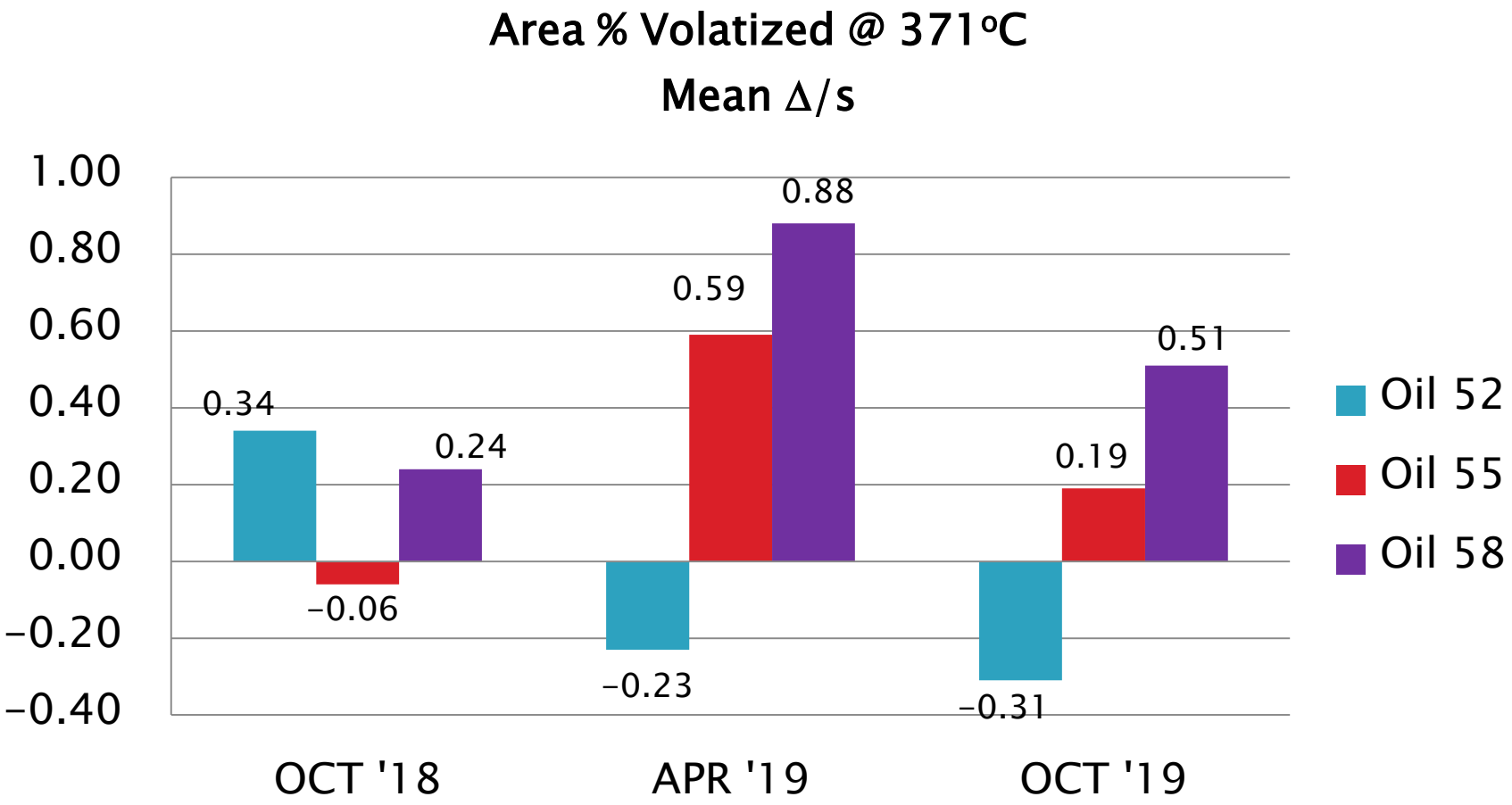
D6417 Performance by Oil



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	147
Failed Calibration Test	OC	17
Operationally Invalidated by Lab	LC, XC	4
Operationally Invalidated After Initially Reported as Valid	RC	2
Non-Blind Instrument Shakedown	NN	20
Held out of statistics (new rig, failed to calibrate)	MC	2
Total		**192**

Number of Labs Reporting Data: 12

Fail Rate of Operationally Valid Tests: 10%

D5800: Evaporation Loss of Lubricating Oil by Noack Method

Statistically Unacceptable Tests (OC)	No. Of Tests
Ei Level 3 Precision Alarm Mild	3
Ei Level 3 Precision Alarm Severe	3
Zi Level 2 Severity Severe	13
Zi Level 2 Severity Mild	0

- The 17 OC tests were on nine different rigs at five labs.
  - Two tests triggered both Ei L3 and Zi L2 alarms
  - Five OC tests from lab/rig J5 (three were consecutive fails; this same rig had four OC fails last period; rig is presently not calibrated)
  - Four OC tests from lab/rig G6 (two consecutive fails followed by a passing run, repeated twice in the period)

- Six operationally invalid calibration runs reported this period:
  - Three tests with the QC sample result off-spec (LC, RC)
  - One test where the lab invalidated the run because the EOT sample was improperly processed (LC)
  - One invalidated because clogged orifice found during post-test discovery after receiving a failing TMC evaluation (RC)
  - One aborted due to pressure failure mid-test.(XC)

D5800: Evaporation Loss of Lubricating Oil by Noack Method

- Non-calibration tests reported for the period:
  - Twenty non-blind shakedown runs to troubleshoot instruments (NN).
  - Two test held out of statistics; new rig that failed to demonstrate a passing initial calibration (MC)

- No TMC technical updates were issued this report period.

- 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 10/19/2016	--	--	0.73	-----
10/1/16 through 3/31/17	136	133	0.70	0.53
4/1/17 through 9/30/17* 4/1/17 through 9/30/17*	147 146	144 143	1.13 0.84	0.56 0.47
10/1/17 through 3/31/18	133	130	0.81	0.15
4/1/18 through 9/30/18* 4/1/18 through 9/30/18*	149 148	146 145	0.82 0.76	0.40 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

*Extreme OC result included and excluded

D5800: Evaporation Loss of Lubricating Oil by Noack Method

Performance Comparison by Procedure & Model

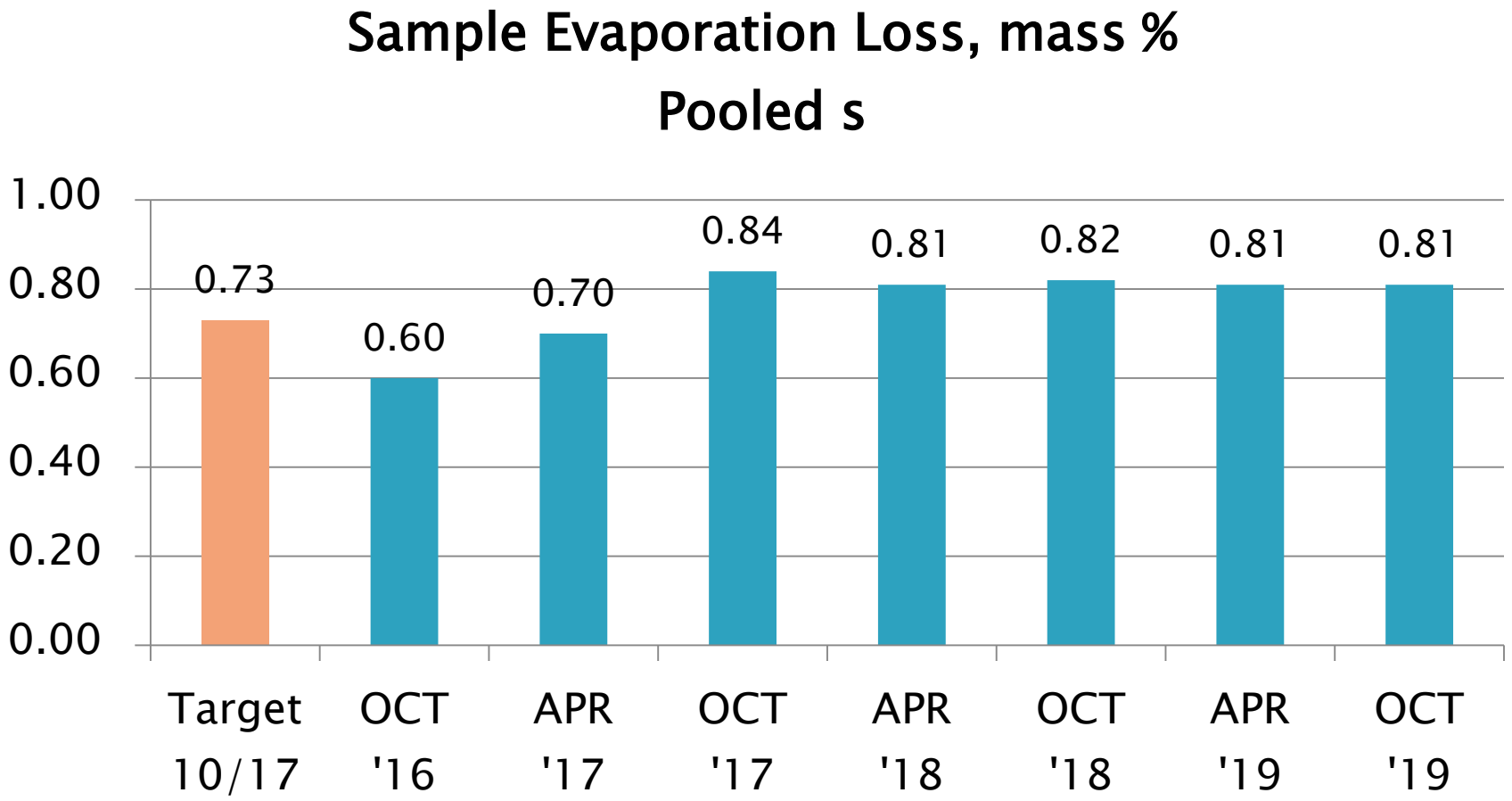
Sample Evaporation Loss, Mass %

Procedure	n	df	Pooled s	Mean Δ/s
Procedure B	128	125	0.69	0.93
Procedure C	No Procedure C tests reported this period.			
Procedure D	36	33	0.64	-0.34

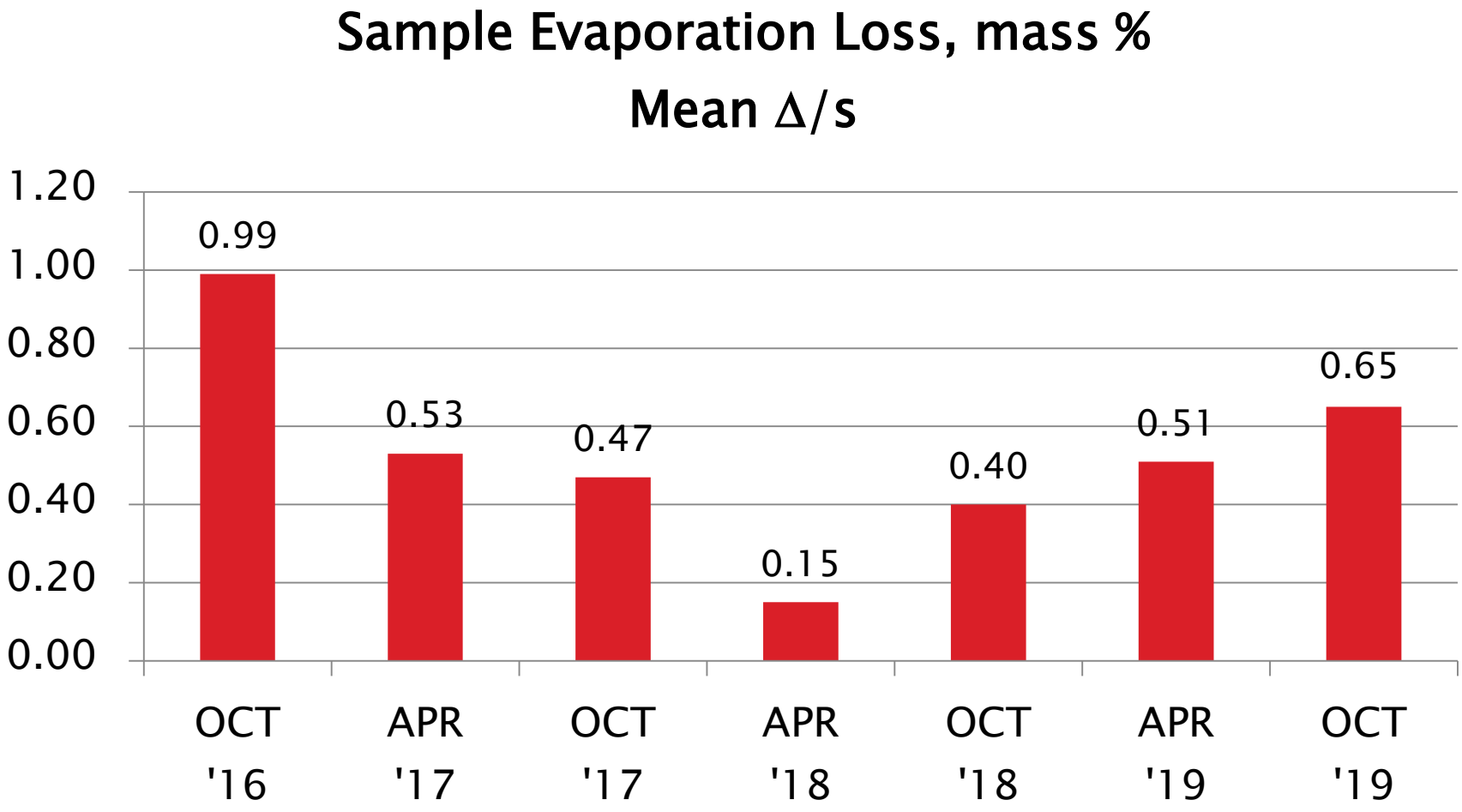
Model	n	df	Pooled s	Mean Δ/s
NCK2	9	6	0.42	0.61
NCK25G	119	116	0.70	0.96
NS2	36	33	0.64	-0.34

2 Procedure B NCK2 Rigs
24 Procedure B NCK25G Rigs
7 Procedure D NS2 Rigs

D5800 Precision Estimates



D5800 Severity Estimates



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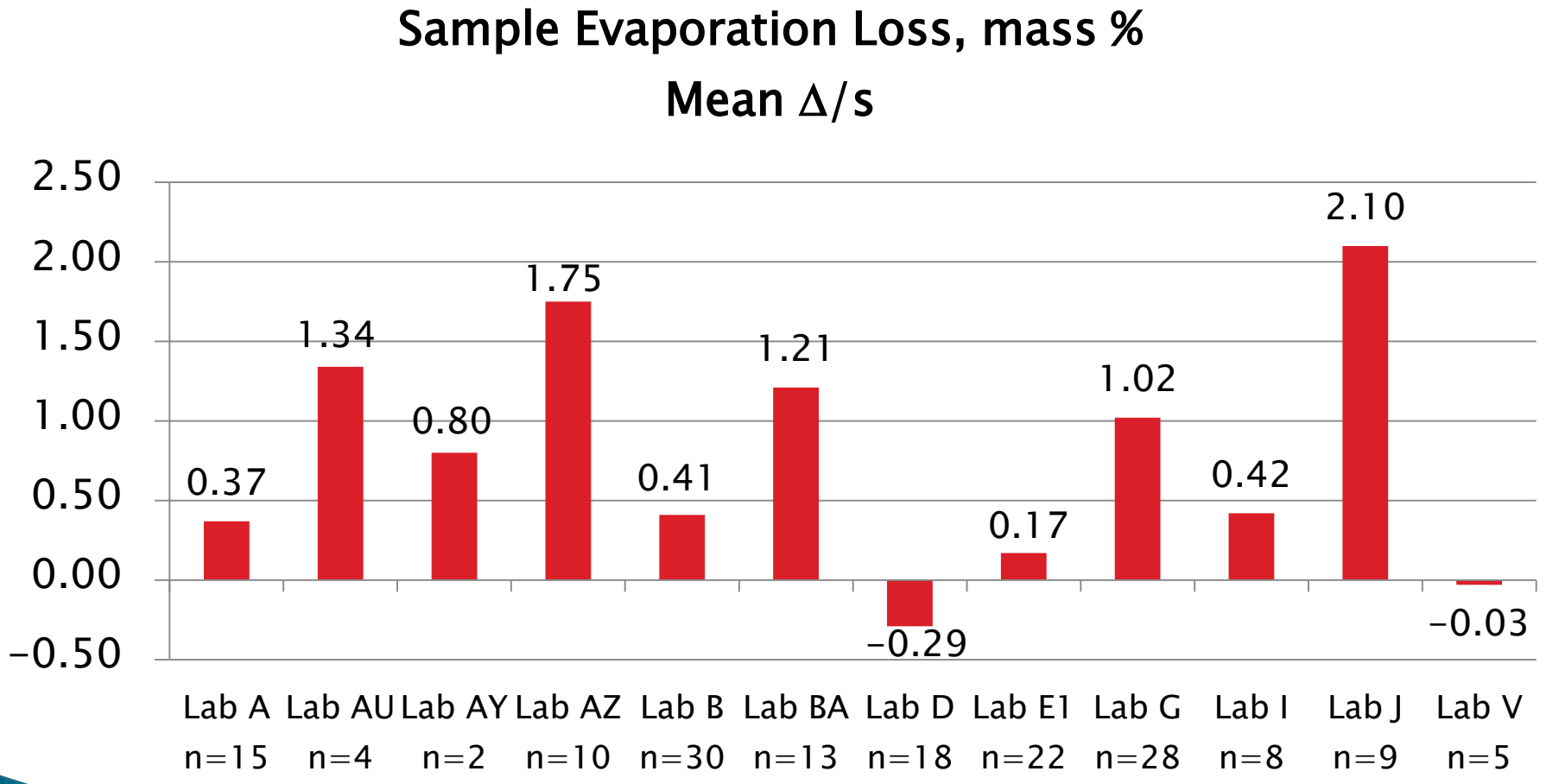
D5800 Lab Severity Estimates



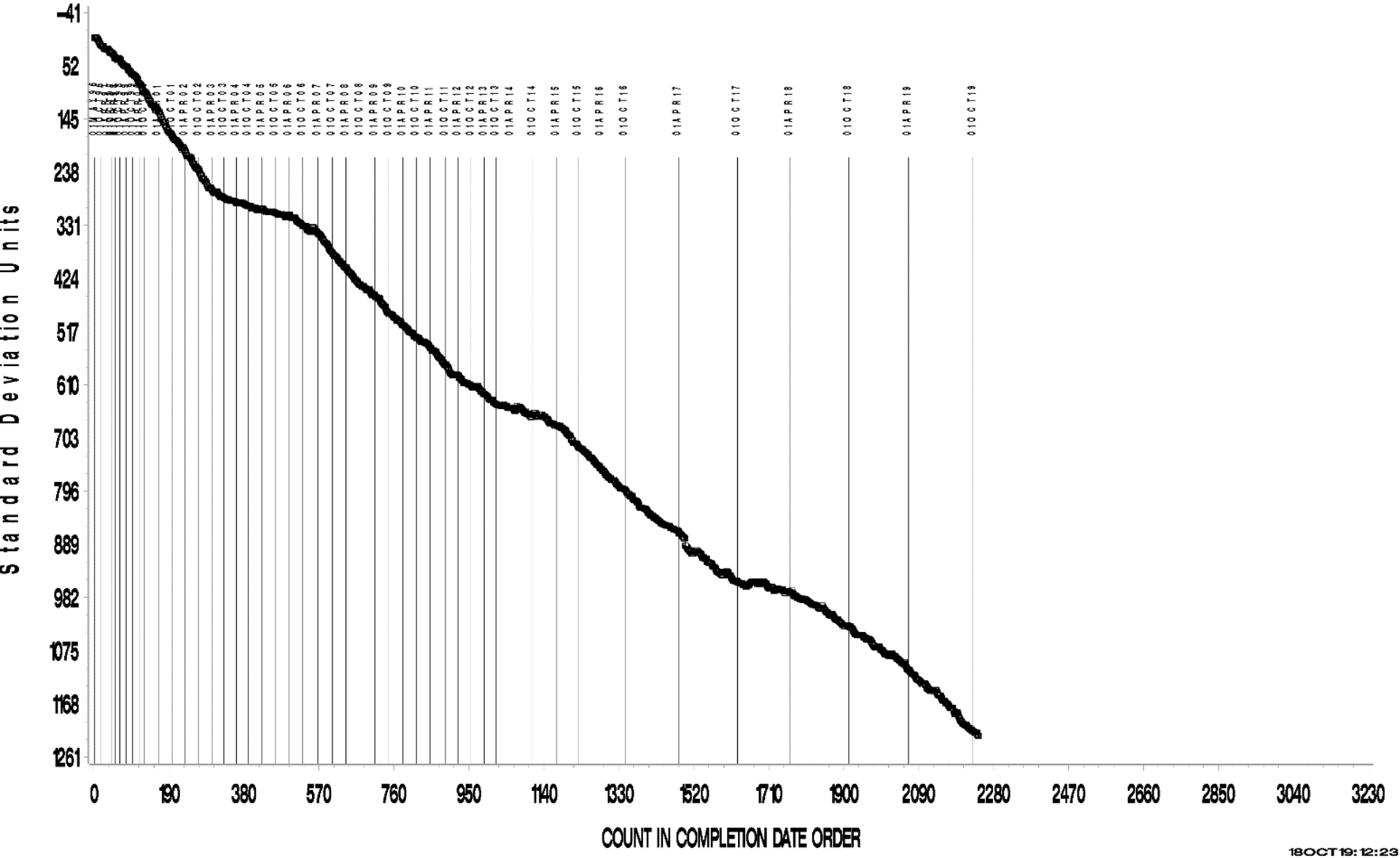
D5800: Evaporation Loss of Lubricating Oil by Noack Method

- Precision (Pooled s) is less precise than the target LTMS pooled precision of 0.73 mass %, but comparable to the prior report period.
- Performance (Mean Δ/s) is 0.65 s severe.
- Two tests exceeded 3 s from targets (rig G6 +3.5 s; rig J5 +4.2 s)
- Fail rate of operationally valid tests (AC & OC) has increased to 10% this period, and was 7% last period (much influenced both periods by Lab J failing test results). The fail rate had dropped to 5% or less for the prior four report periods using EWMA LTMS, compared to approximately 26% under the Shewhart severity only system.
- CUSUM plot shows a continuing (and increasing) overall severe trend with reference testing.

D5800 VOLATILITY BY NOACK INDUSTRY OPERATIONALLY VALID DATA

EVAPORATION LOSS, MASS%

CUSUM Severity Analysis



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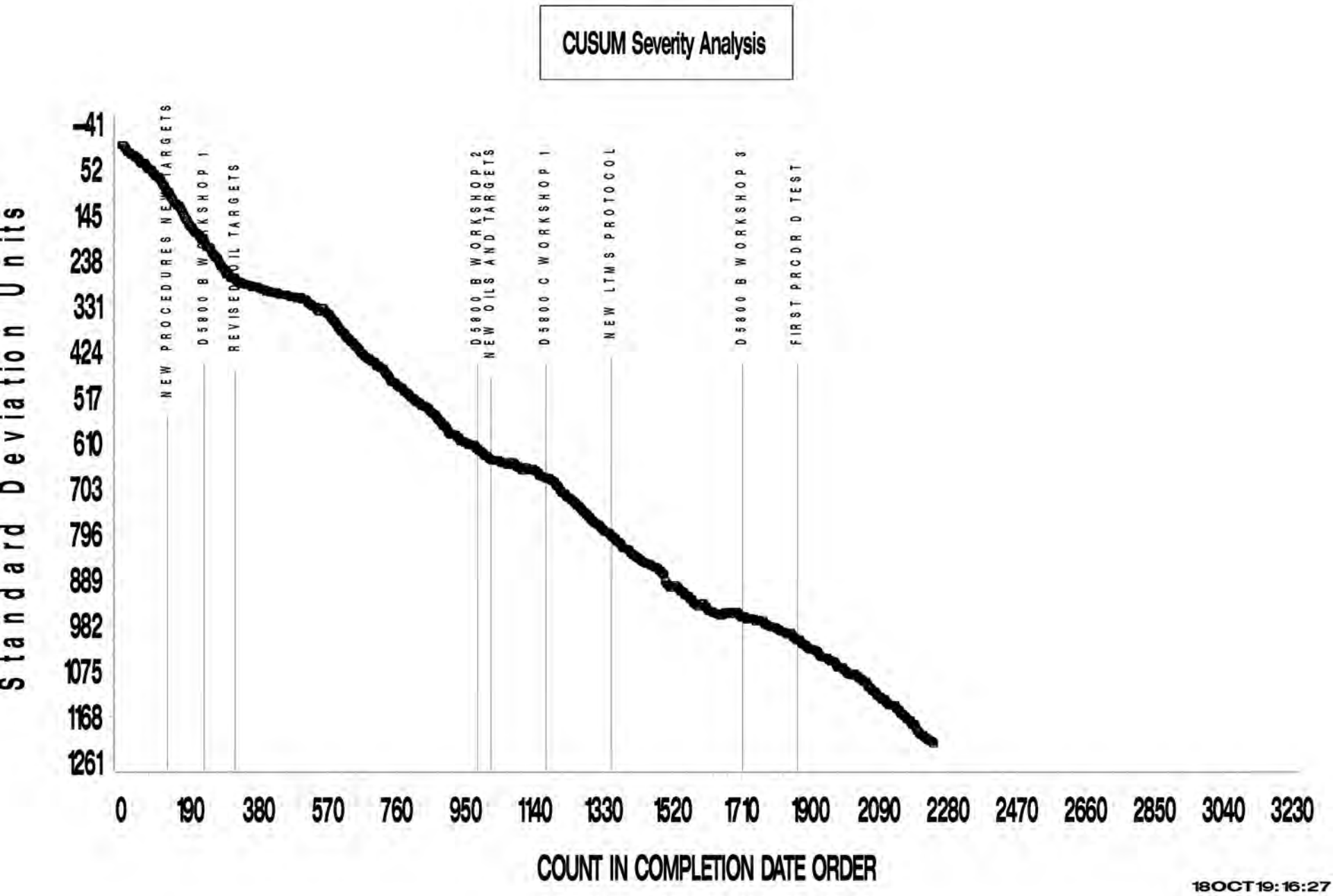
D5800 VOLATILITY BY NOACK INDUSTRY OPERATIONALLY VALID DATA

EVAPORATION LOSS, MASS%



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D5800 VOLATILITY BY NOACK INDUSTRY OPERATIONALLY VALID DATA

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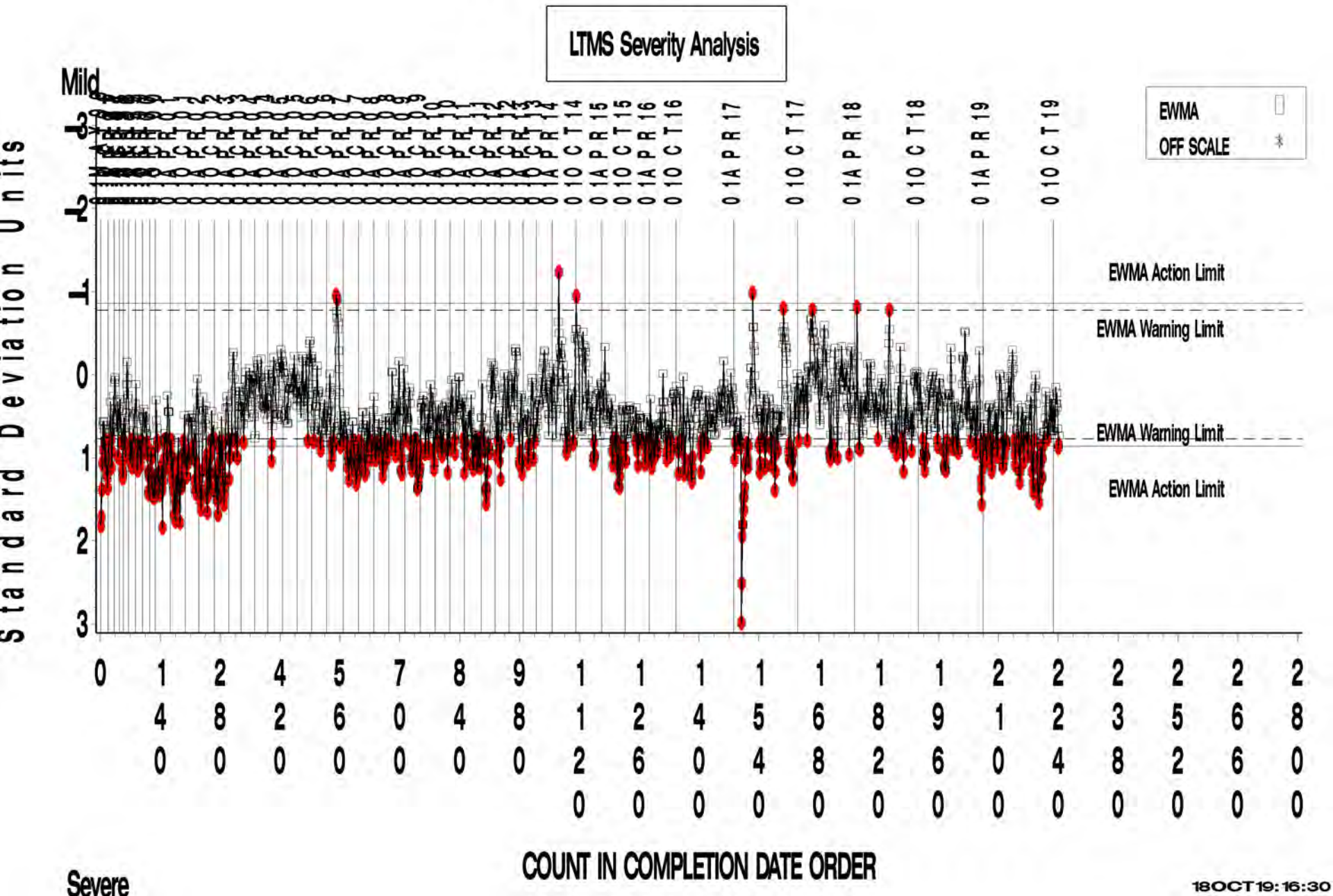
EVAPORATION LOSS, MASS%



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

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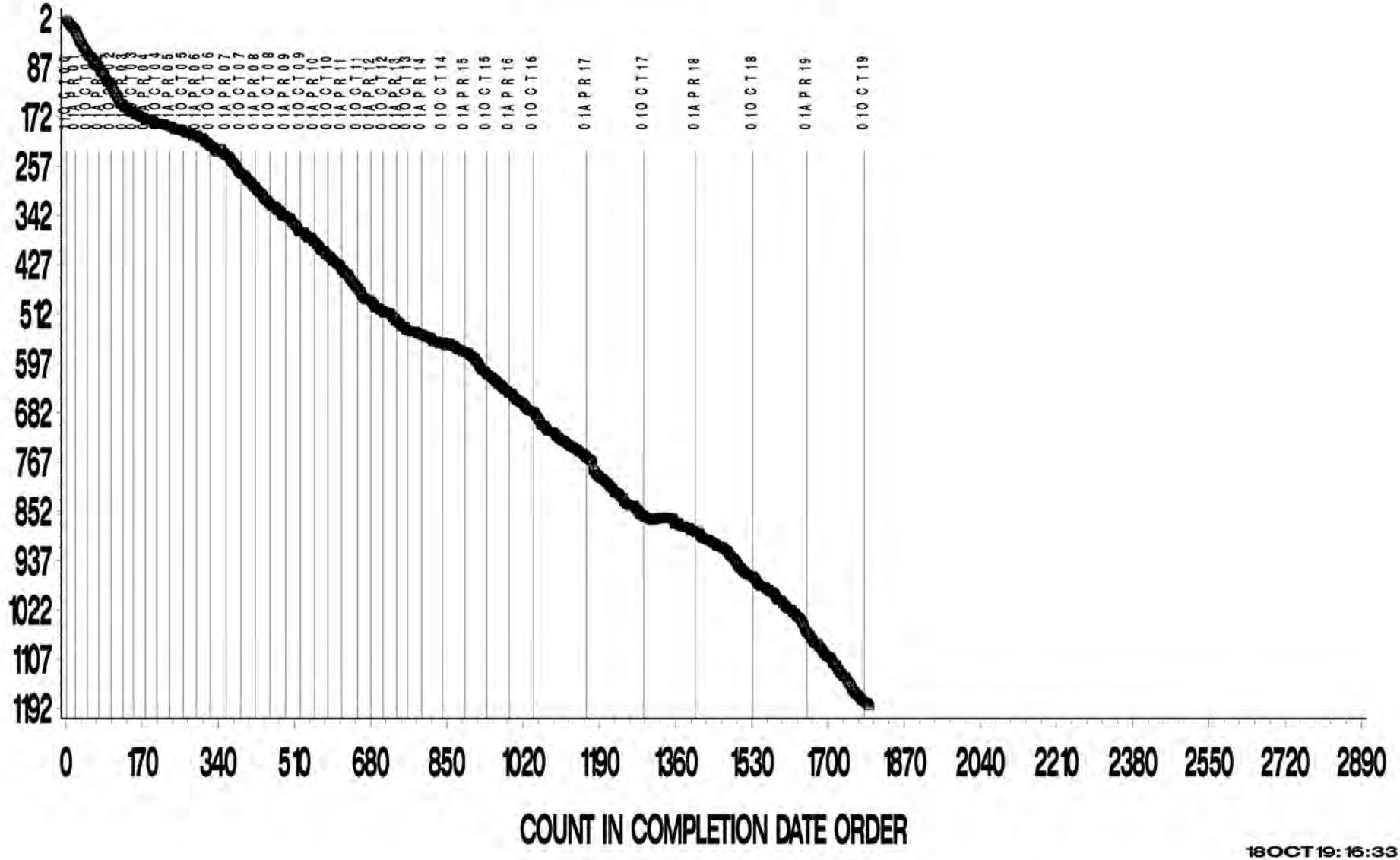
CUSUM Severity Analysis



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

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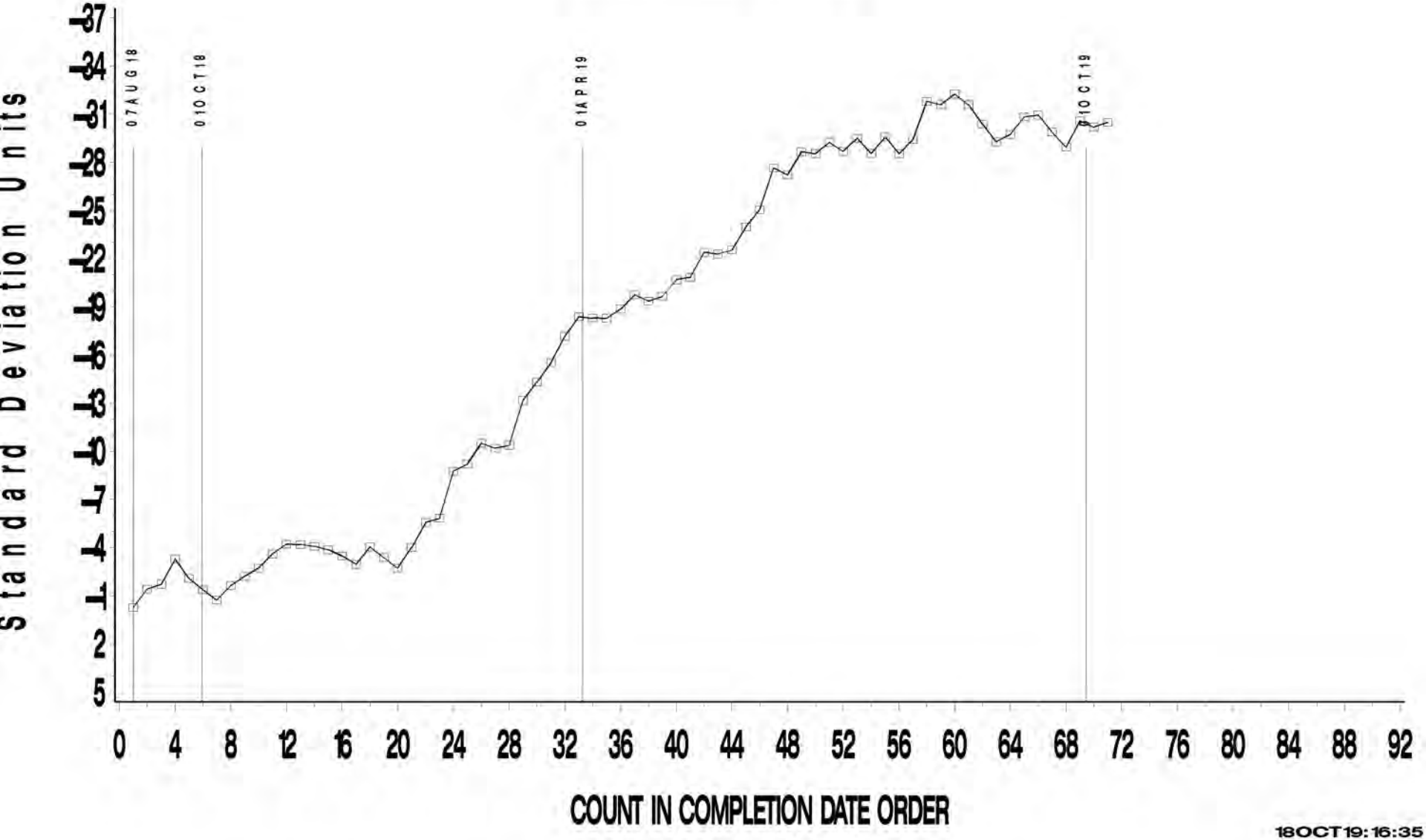
CUSUM Severity Analysis



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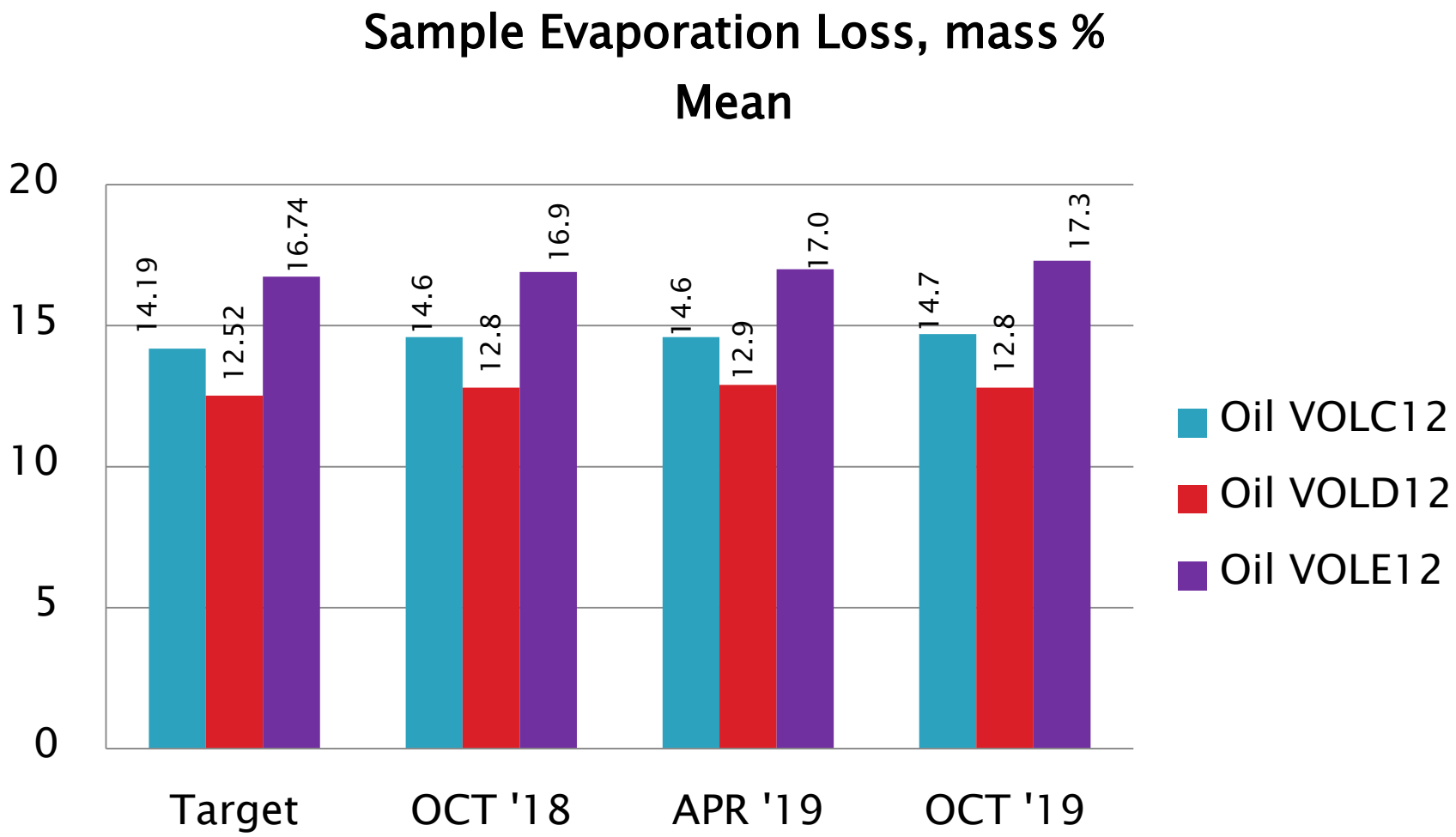
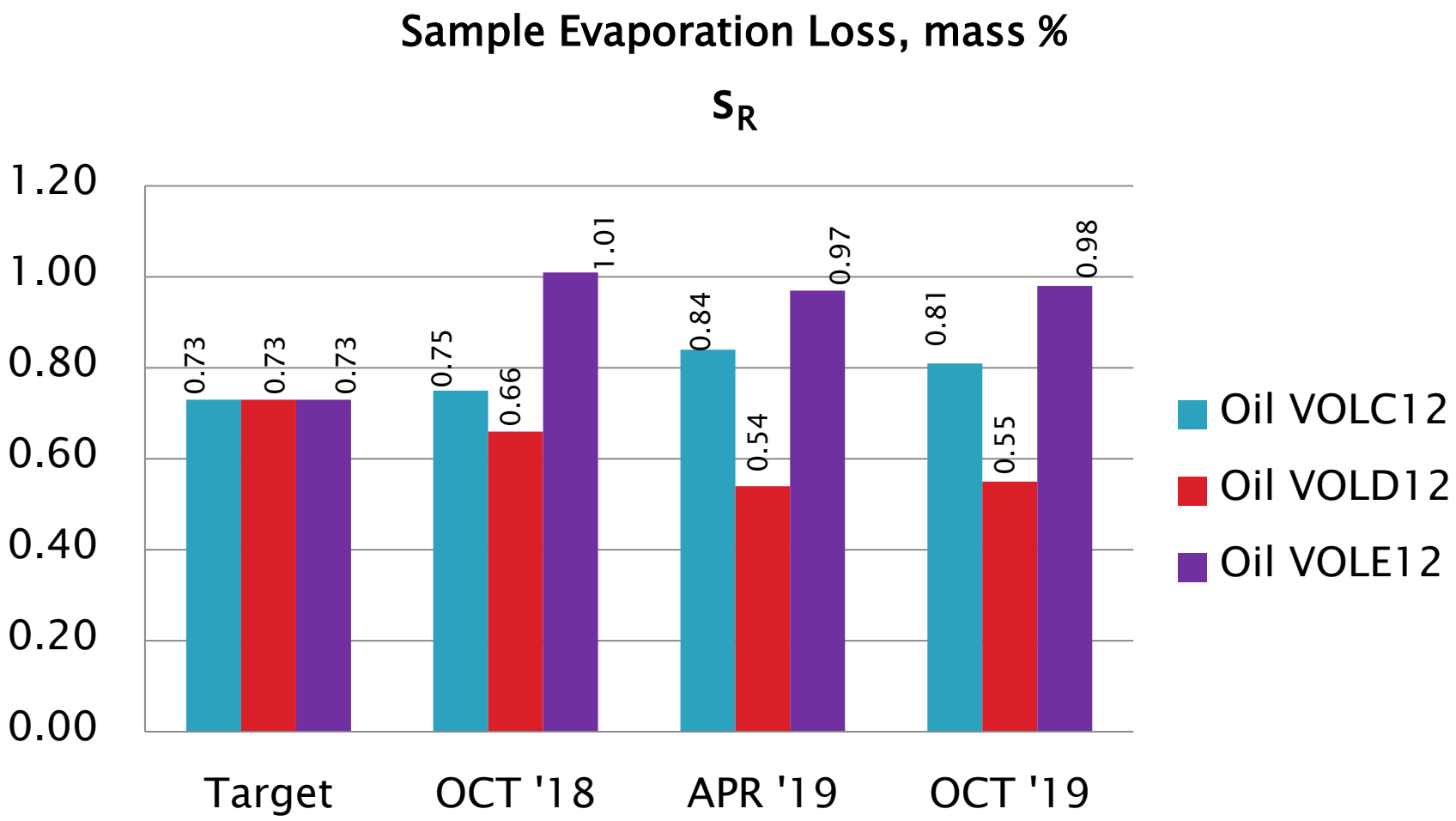
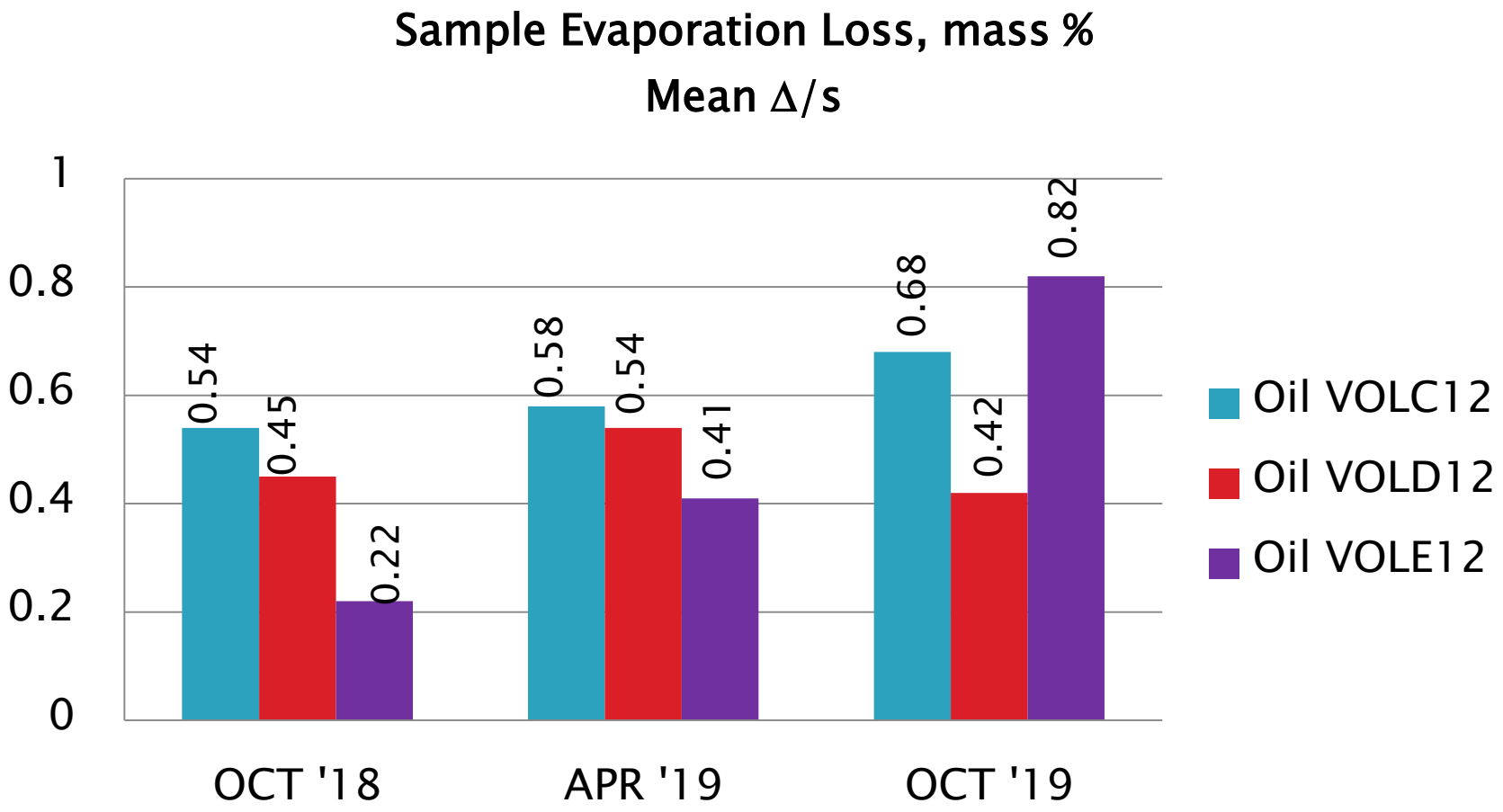
D5800 Performance by Oil



D5800 Performance by Oil



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	4
Operationally Invalidated by Lab	LC, XC	0
Operationally Invalidated After Initially Reported as Valid	RC	5
Non-Blind Instrument Shakedown	NN	3
Total		**55**

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

D5133: Gelation Index

Statistically Unacceptable Tests (OC)	No. Of Tests
Gelation Index Mild	3
Gelation Index Severe	1

- Five operationally invalid calibration runs reported this period:
  - One test invalidated in post-test review after failing TMC calibration due to discovery of a loose electrical contact (RC).
  - Four tests (all different heads) at two labs invalidated in post-test review after failing TMC calibration due to discovery of bad heads requiring service (RC).
- Three non-blind shakedown runs to troubleshoot two instruments at one lab (NN).

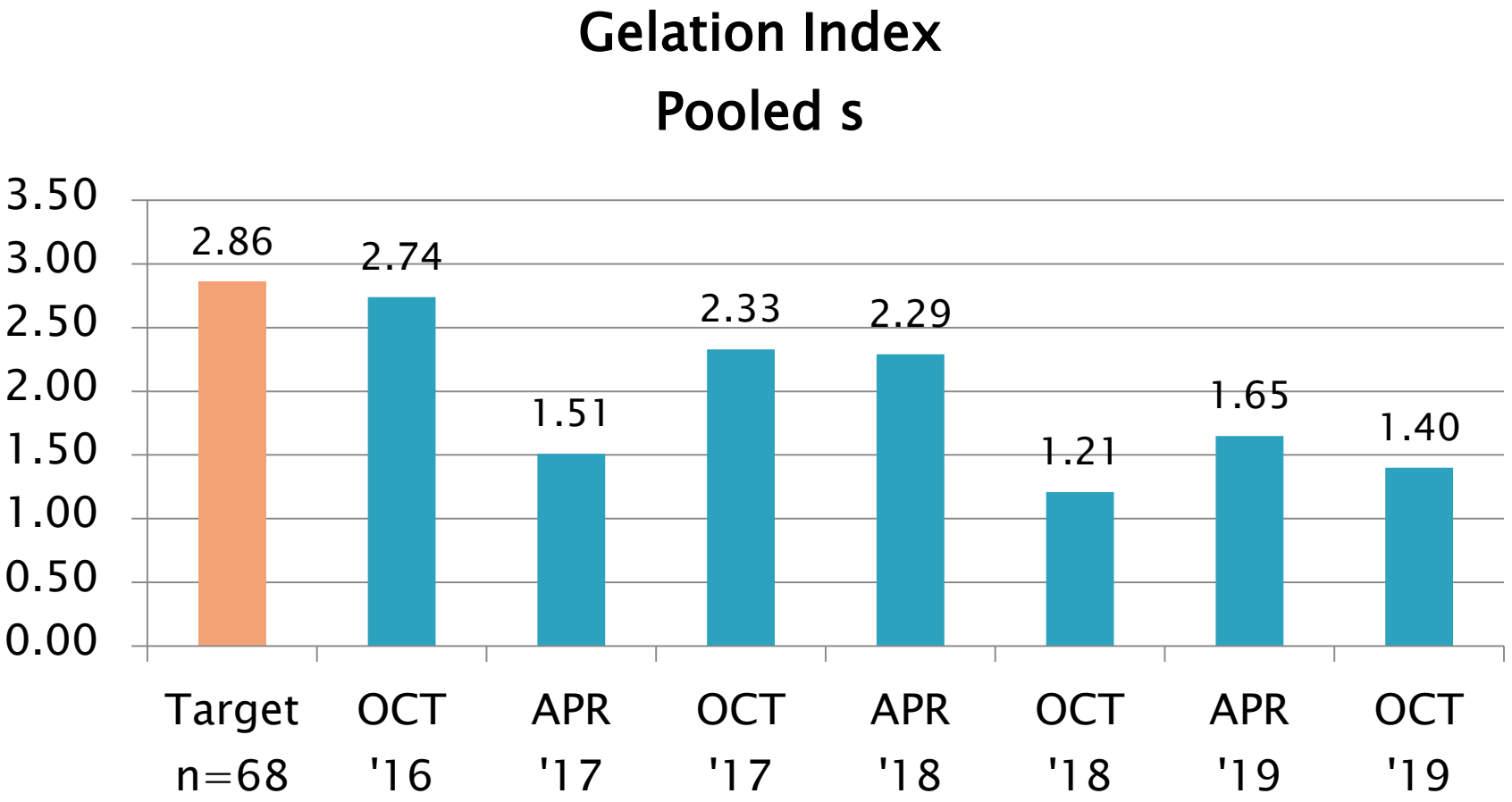
D5133: Gelation Index

Period Precision and Severity Estimates

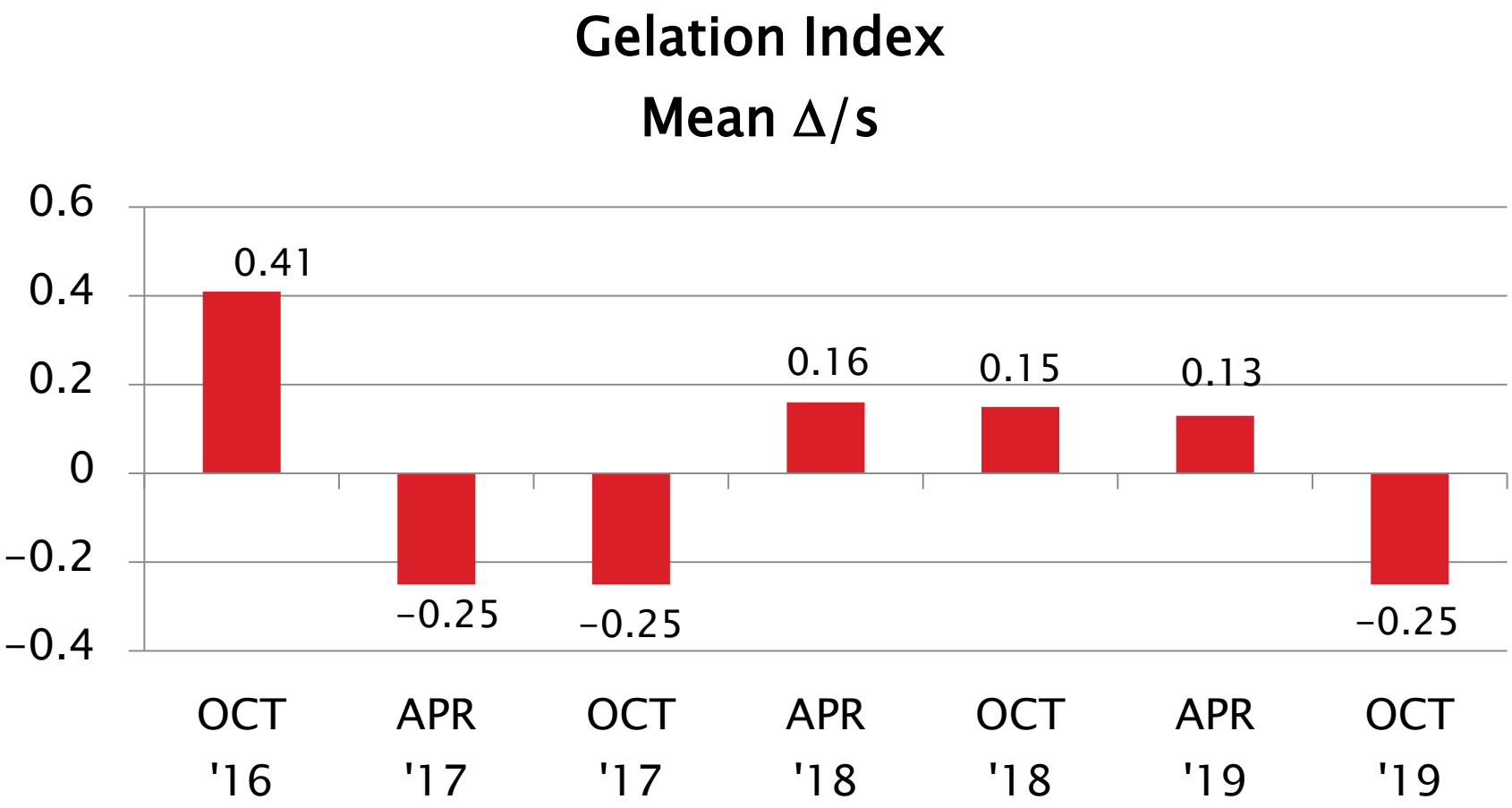
Gelation Index	n	df	Pooled s	Mean Δ/s
Current Targets 7/15/2003	68	65	2.86	-----
10/1/16 through 3/31/17	35	32	1.51	-0.25
4/1/17 through 9/30/17* 4/1/17 through 9/30/17*	30 29	27 26	4.69 2.33	-0.08 -0.25
10/1/17 through 3/31/18	36	33	2.29	0.16
4/1/18 through 9/30/18* 4/1/18 through 9/30/18*	32 31	29 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

*Extreme OC results included and excluded

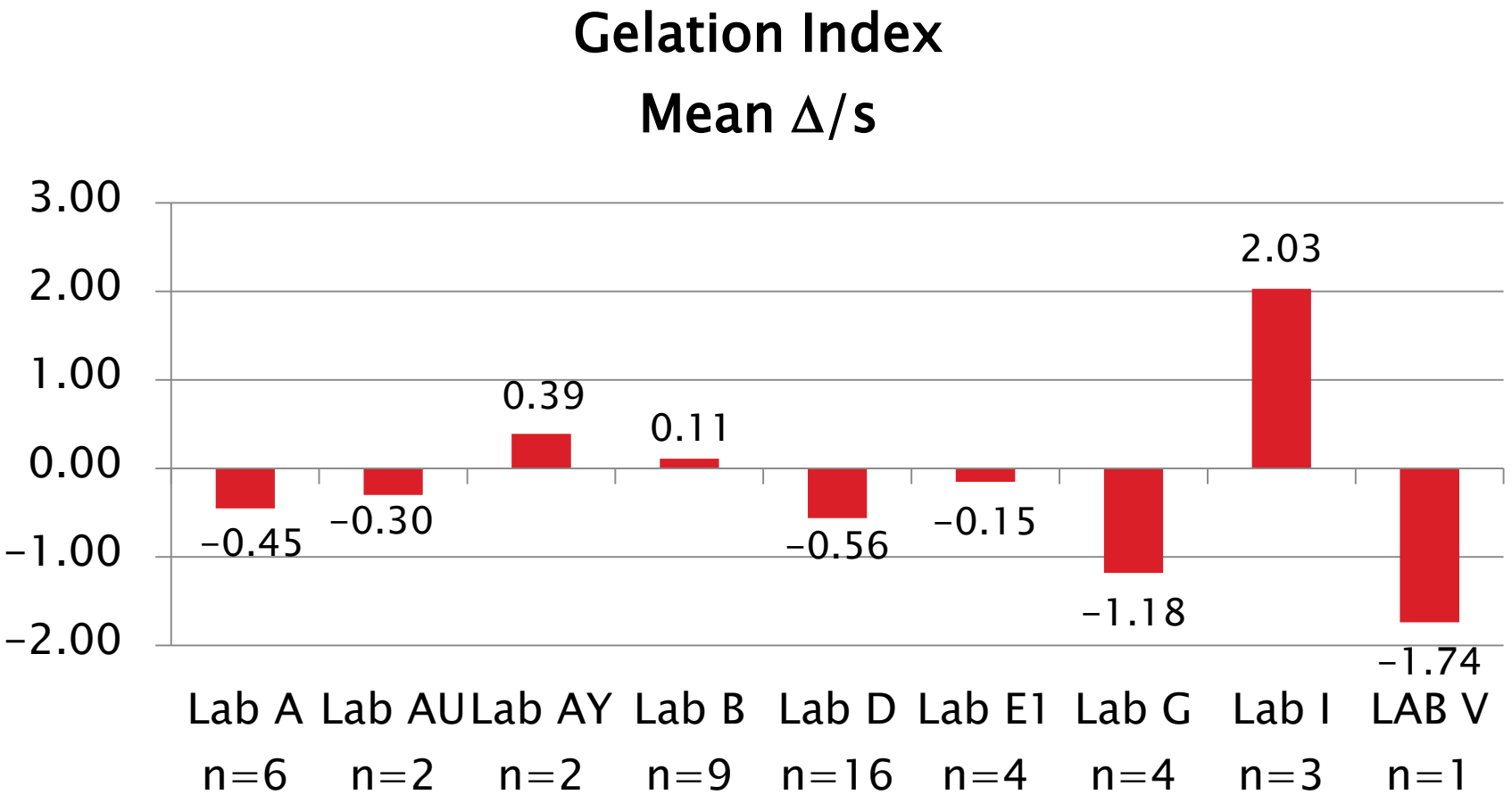
D5133 Precision Estimates



D5133 Severity Estimates



D5133 Lab Severity Estimates



D5133: Gelation Index

- Fail rate of operationally valid tests is 9% this period. Historic period fail rates have ranged between 6% and 26%.
- Precision (Pooled s) is more precise than prior report period, and more precise than target precision.
- Performance (Mean Δ/s) is -0.25 s mild
- Two labs each reported very extreme results as operationally valid, but subsequently found the heads to be bad and in need of service. Another lab reports a result of 6.8 s severe as operationally valid. Also, two of the three mild failing results (OC) were on oil 58, presently with a lower limit set below GI 6.0. These results lend additional support to moving to a head-based calibration system, and reclassifying oil 58 as a discrimination oil with no lower limit.

D5133: Gelation Index

- While overall performance and precision this period is good, ongoing erratic calibration performance of certain heads should raise concerns about the adequacy of the current 'single-test' Shewhart monitoring system to catch severe or mild performing instruments or heads in a timely manner. And, whether those instruments demonstrating multiple failing results should be considered properly calibrated based on just one passing Shewhart test result on just one viscometer head.
  - While the panel has recently been considering proposals for a head-based Shewhart calibration system, industry might be better served if an LTMS EWMA based monitoring system was considered for this test, much like what is currently done in D5800. Capturing data on a head based calibration system, over time, should provide additional data for consideration.
  - **Forward progress on a revised monitoring system, and adding a D5133 GI monitoring protocol to the LTMS document is stalled due to inaction.**

D5133 GELATION INDEX INDUSTRY OPERATIONALLY VALID DATA

GELATION INDEX

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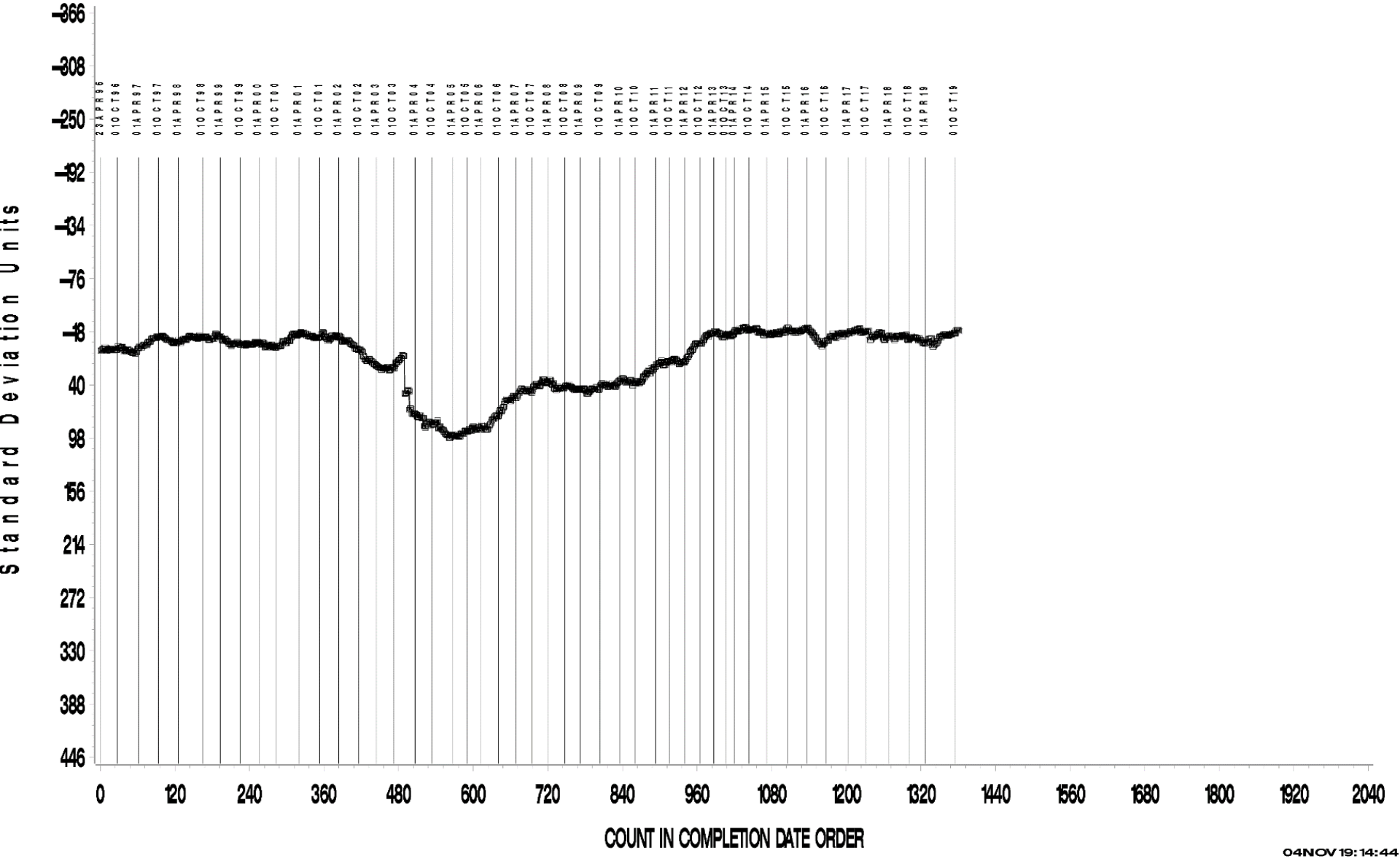
CUSUM Severity Analysis



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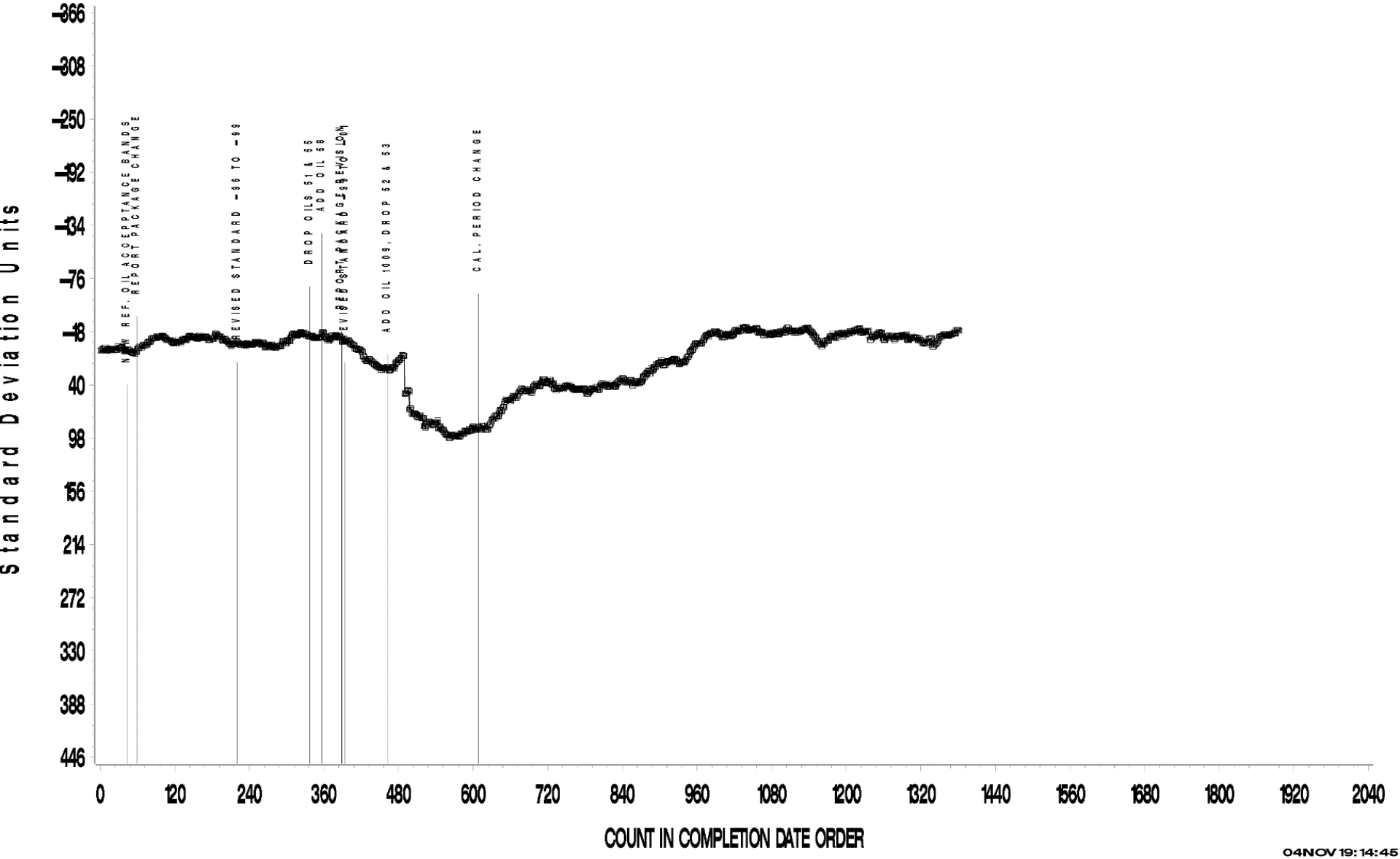
D5133 GELATION INDEX INDUSTRY OPERATIONALLY VALID DATA

GELATION INDEX

CUSUM Severity Analysis



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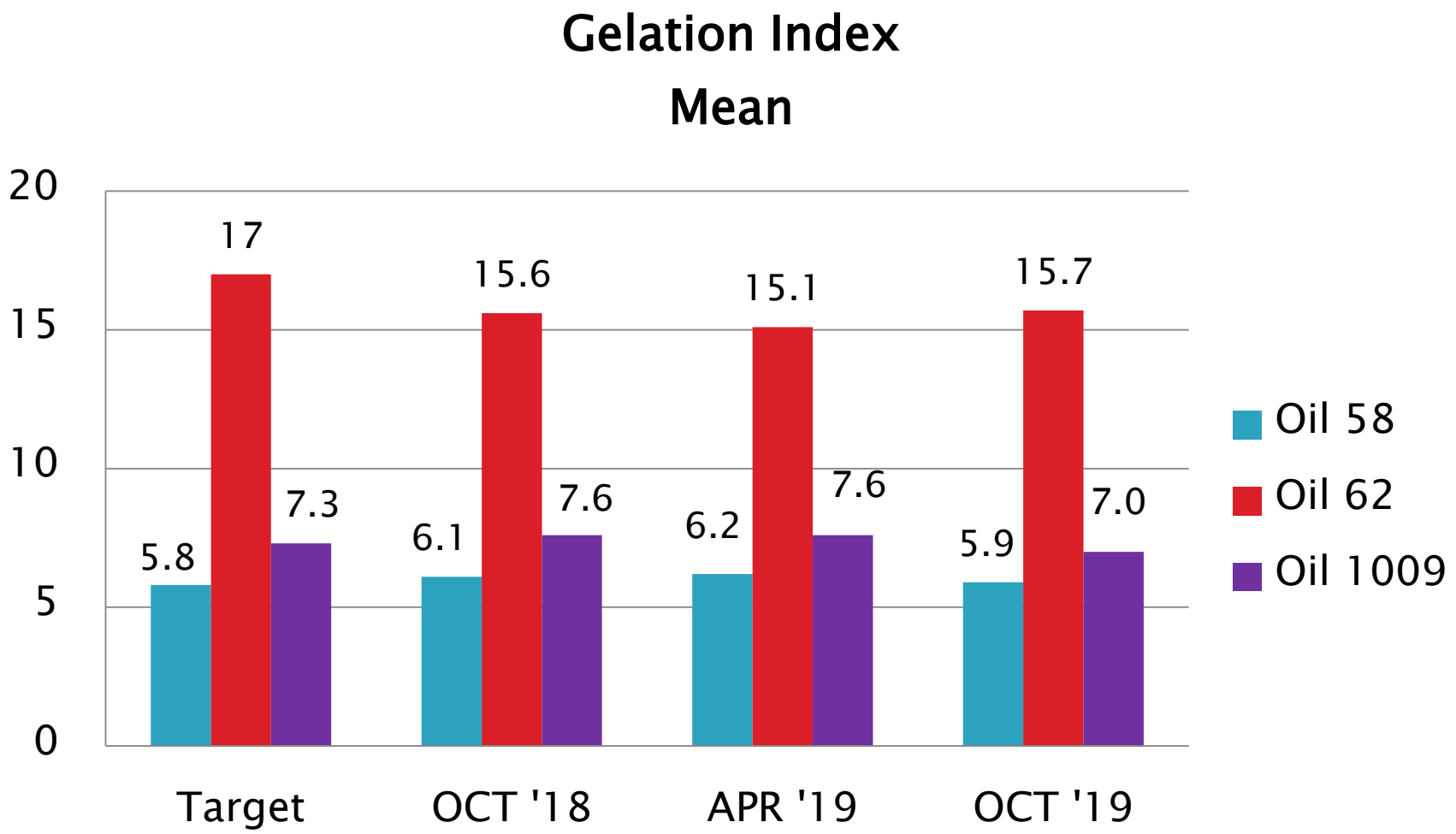
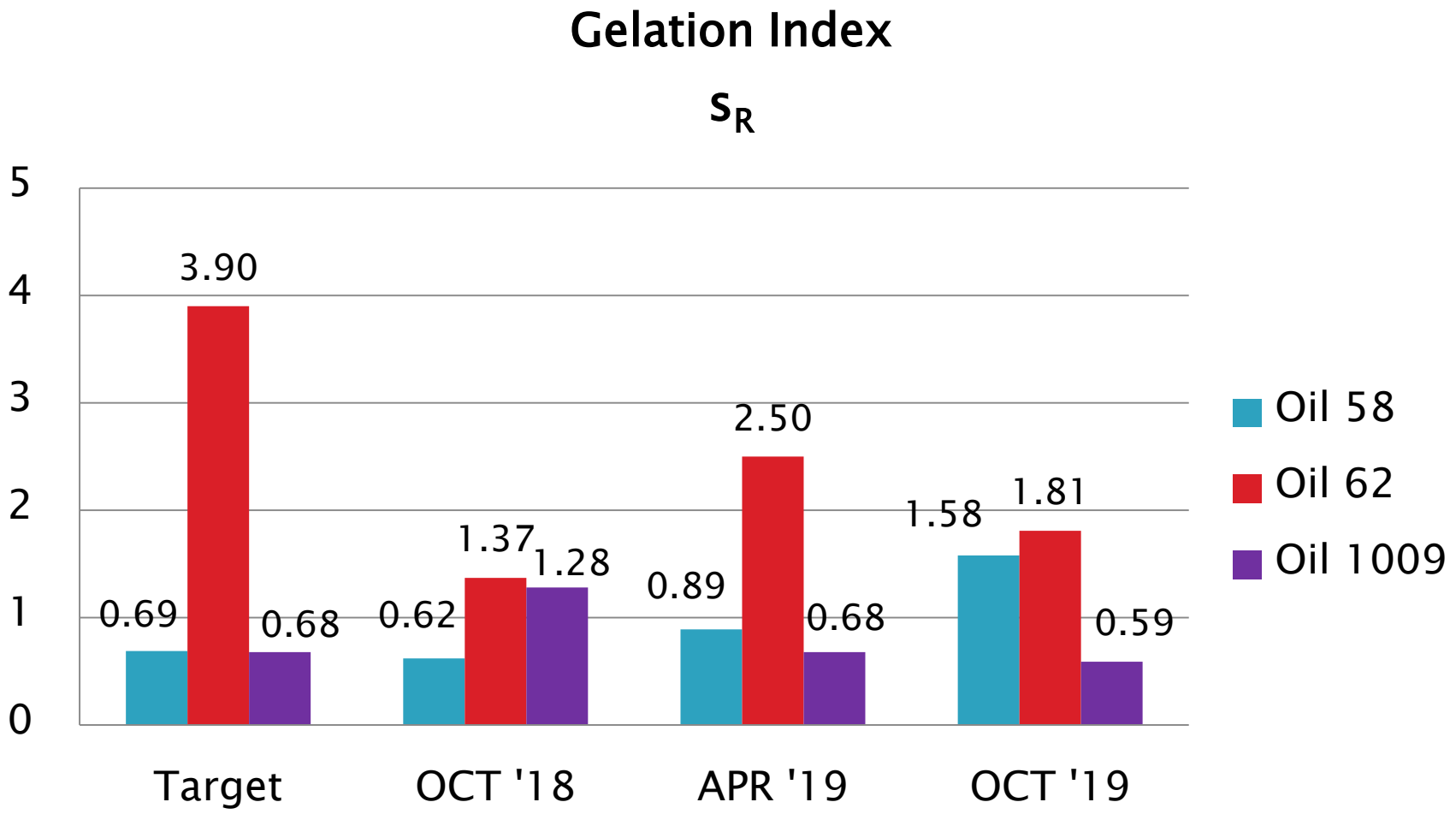
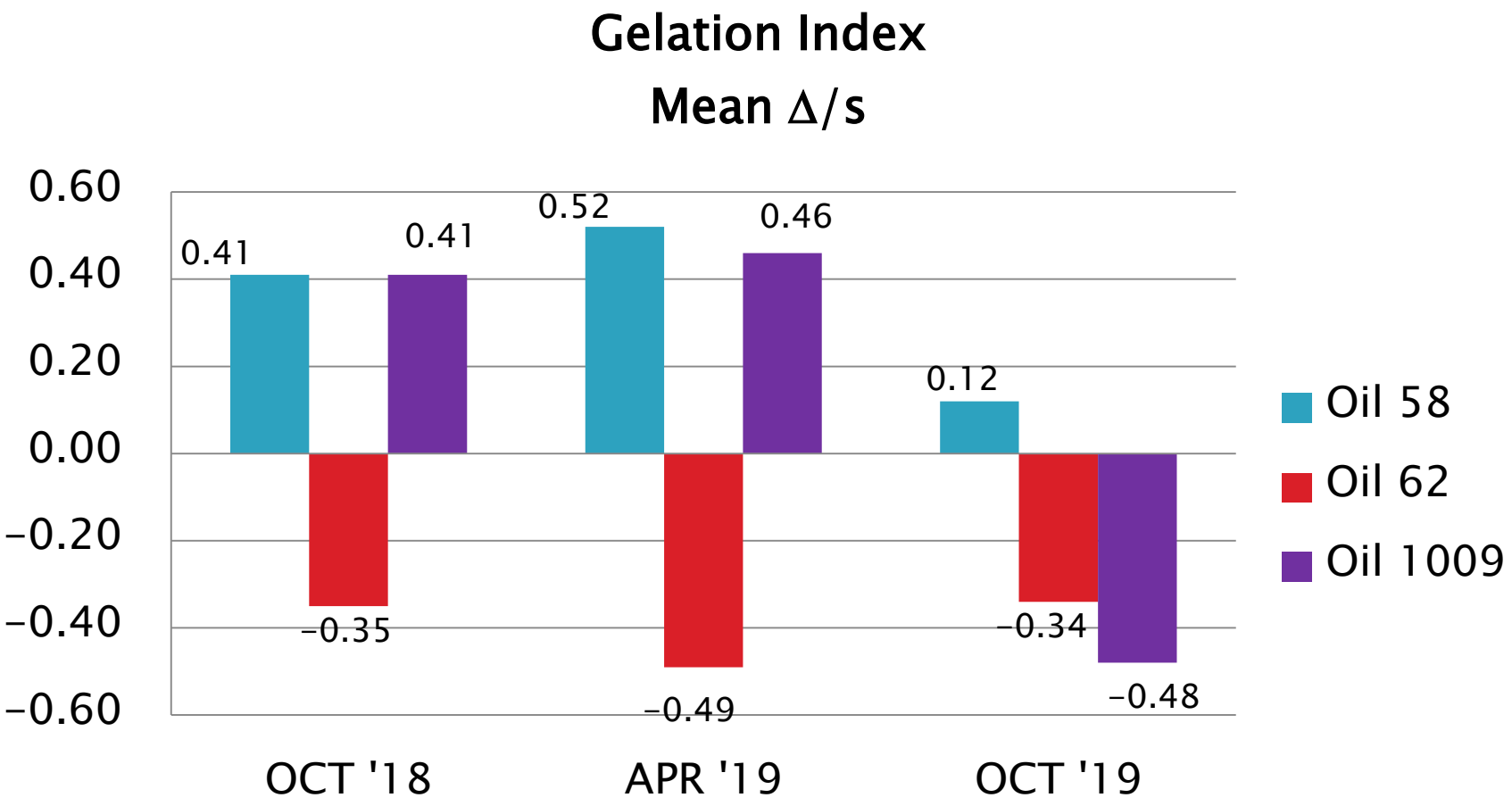
D5133 Performance by Oil



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	23
Failed Calibration Test	OC	7
Operationally Invalidated by Lab	LC, XC	1
Operationally Invalidated After Initially Reported as Valid	RC	1
Excluded from statistics (two-test fail on new rig)	MC	2
Non-Blind Instrument Shakedown	NN	2
Total		**36**

Number of Labs Reporting Data: 9

Fail Rate of Operationally Valid Tests: 23%

D6335: Deposits by TEOST-33C

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

- Four consecutive failing runs, ranging from 3 to 7 s severe, were reported on the same instrument (G1) following instrument conversion (two-test calibration sequences).
  - Followed by two shakedown runs (the only two reported this period).
  - Rig subsequently passed a two-test calibration sequence but the lab did not invalidate the prior failing runs.
  - Period statistics are shown with and without these four results.

- One test invalidated after failing TMC calibration, airflow problem discovered post-test (RC).

- One aborted run (XC) reported due to off-spec catalyst weight.

- Initial two-test sequence on new lab/rig (P1) excluded from statistics (validity MC) because 1st test failed mild, instrument failed to demonstrate an initial passing calibration. To date, this rig has not calibrated.

- Calibration requirement updates are issued as LTMS document updates.

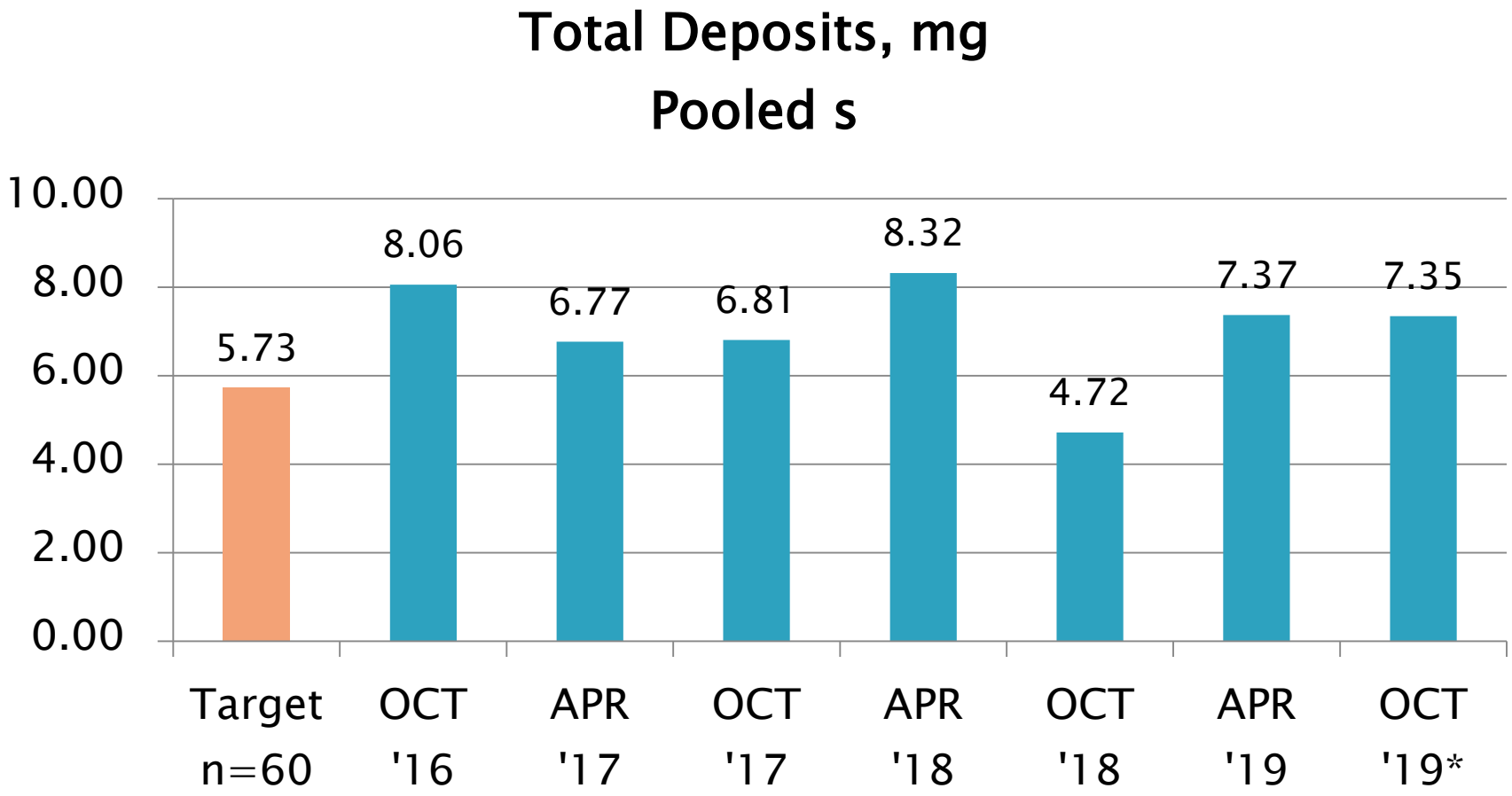
D6335: Deposits by TEOST-33C

Period Precision and Severity Estimates

Total Deposits, mg	n	df	Pooled s	Mean Δ/s
Updated Targets 20130415	60	58	5.73	-----
10/1/16 through 3/31/17	21	19	6.77	-0.14
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

*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.

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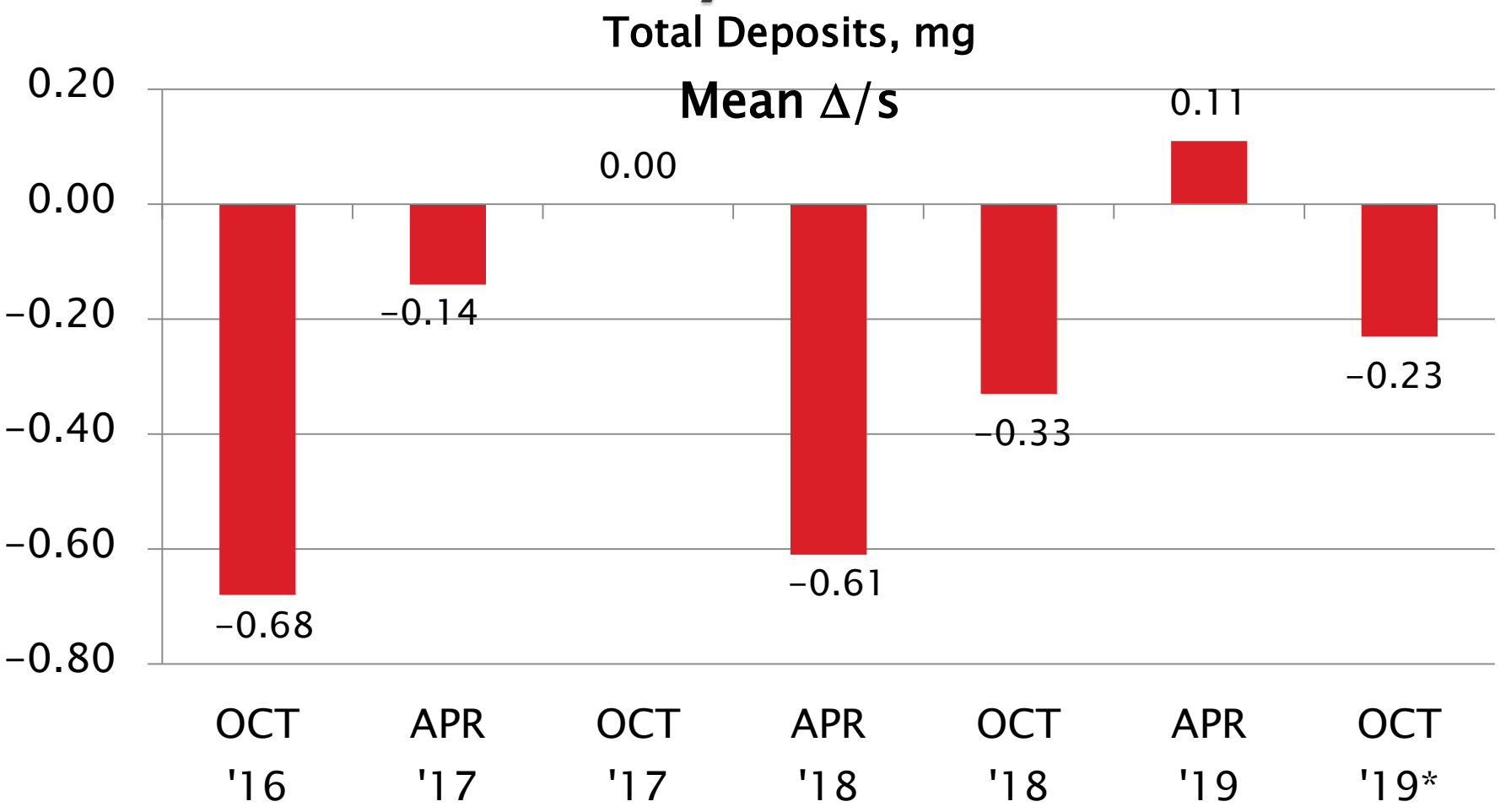
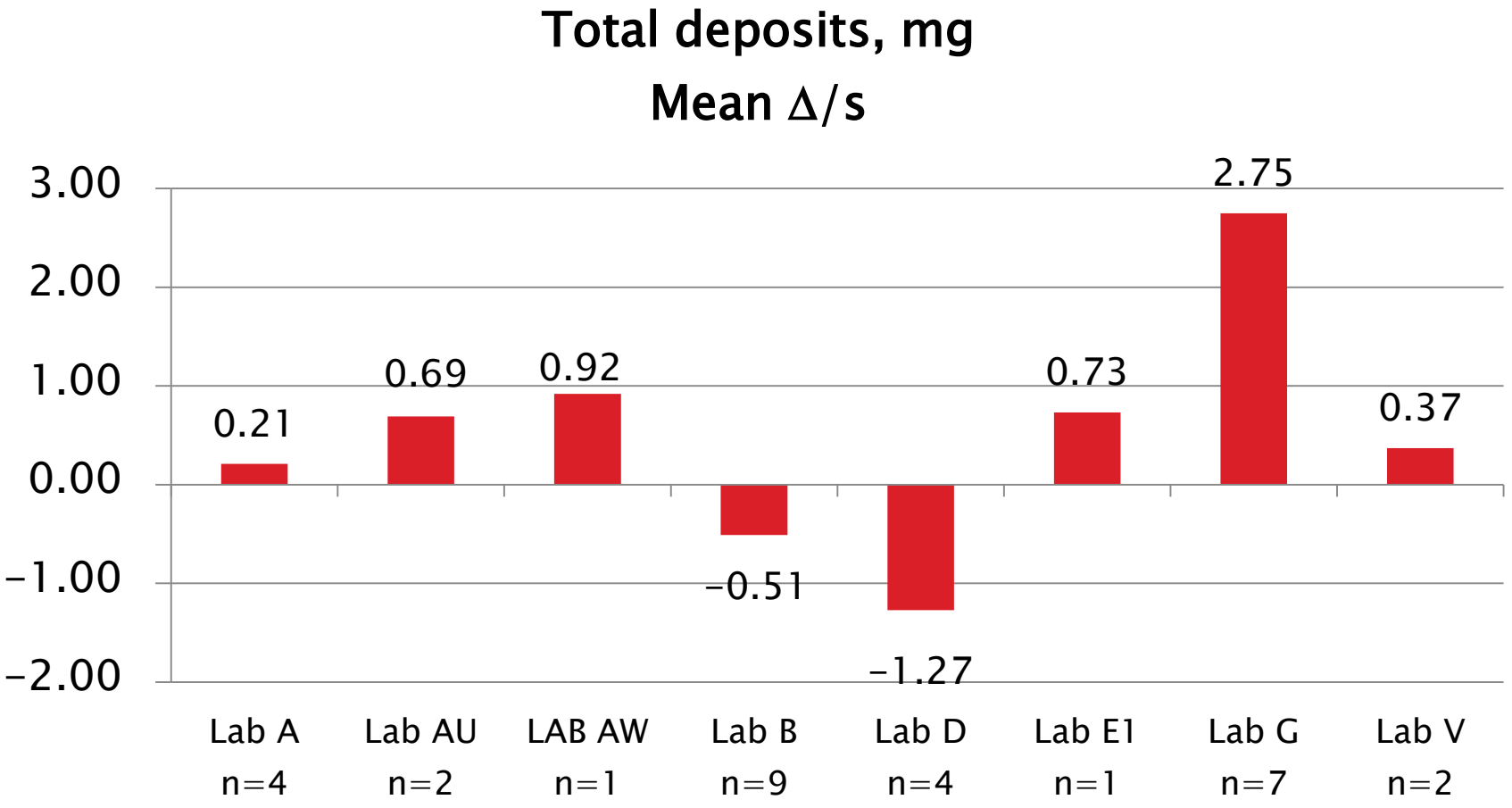
D6335 Severity Estimates



* Four consecutive OC results on same rig excluded.

D6335 Lab Severity Estimates



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D6335: Deposits by TEOST-33C

- Precision (Pooled s) is less precise than prior period, and less precise than target precision.
  - Comparable to prior period with four results from rig G1 excluded, but still less precise than target precision.
- Performance (Mean Δ/s) is 0.47 s severe.
  - -0.27 s mild excluding four results from rig G1.
- Fail rate of 23% is high again for the period.
  - Comparable to last period (20%).
- 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.

TEOST—33C INDUSTRY OPERATIONALLY VALID DATA

TOTAL DEPOSITS MG

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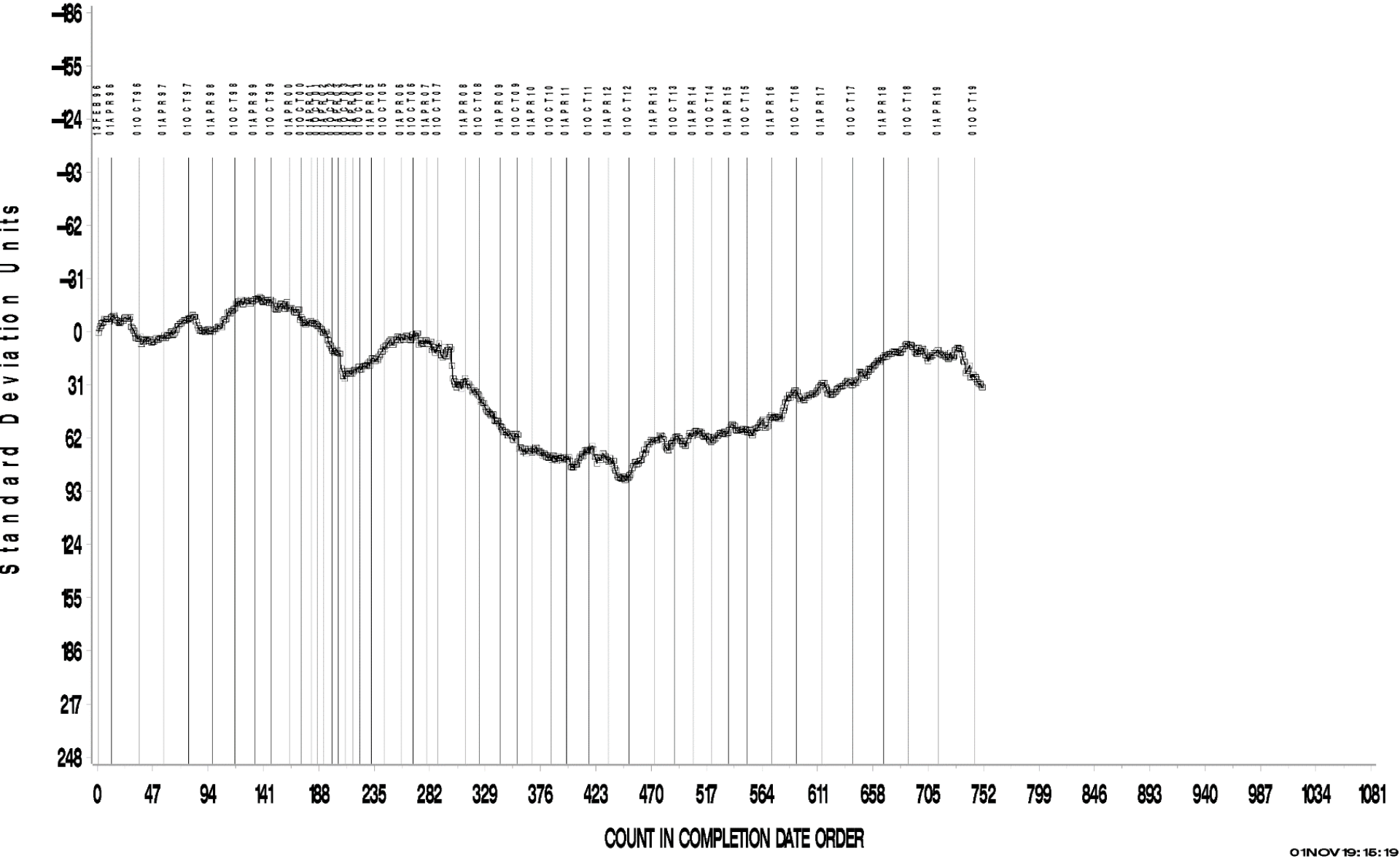
CUSUM Severity Analysis



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TEOST —33C INDUSTRY OPERATIONALLY VALID DATA

TOTAL DEPOSITS MG

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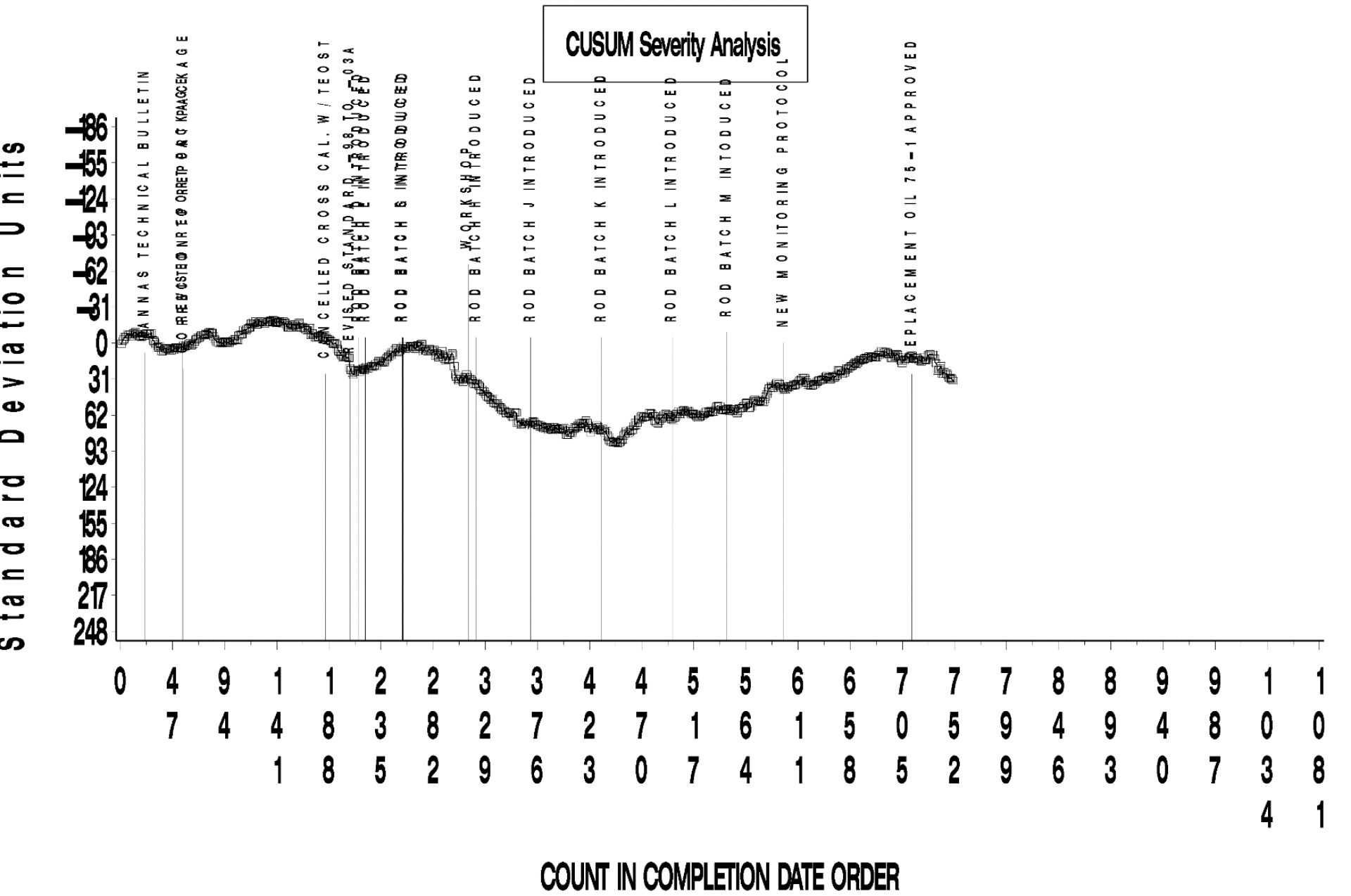

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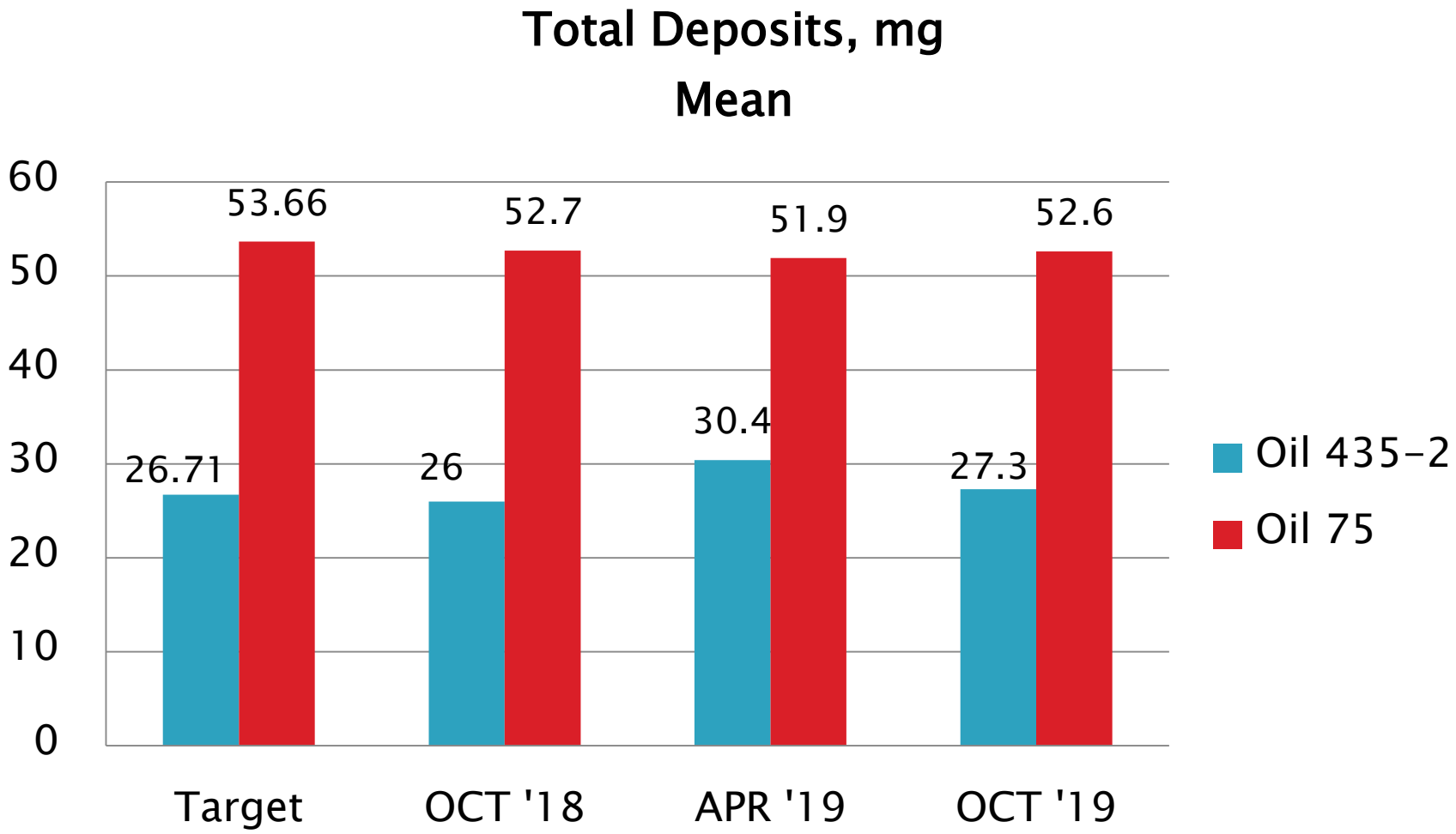
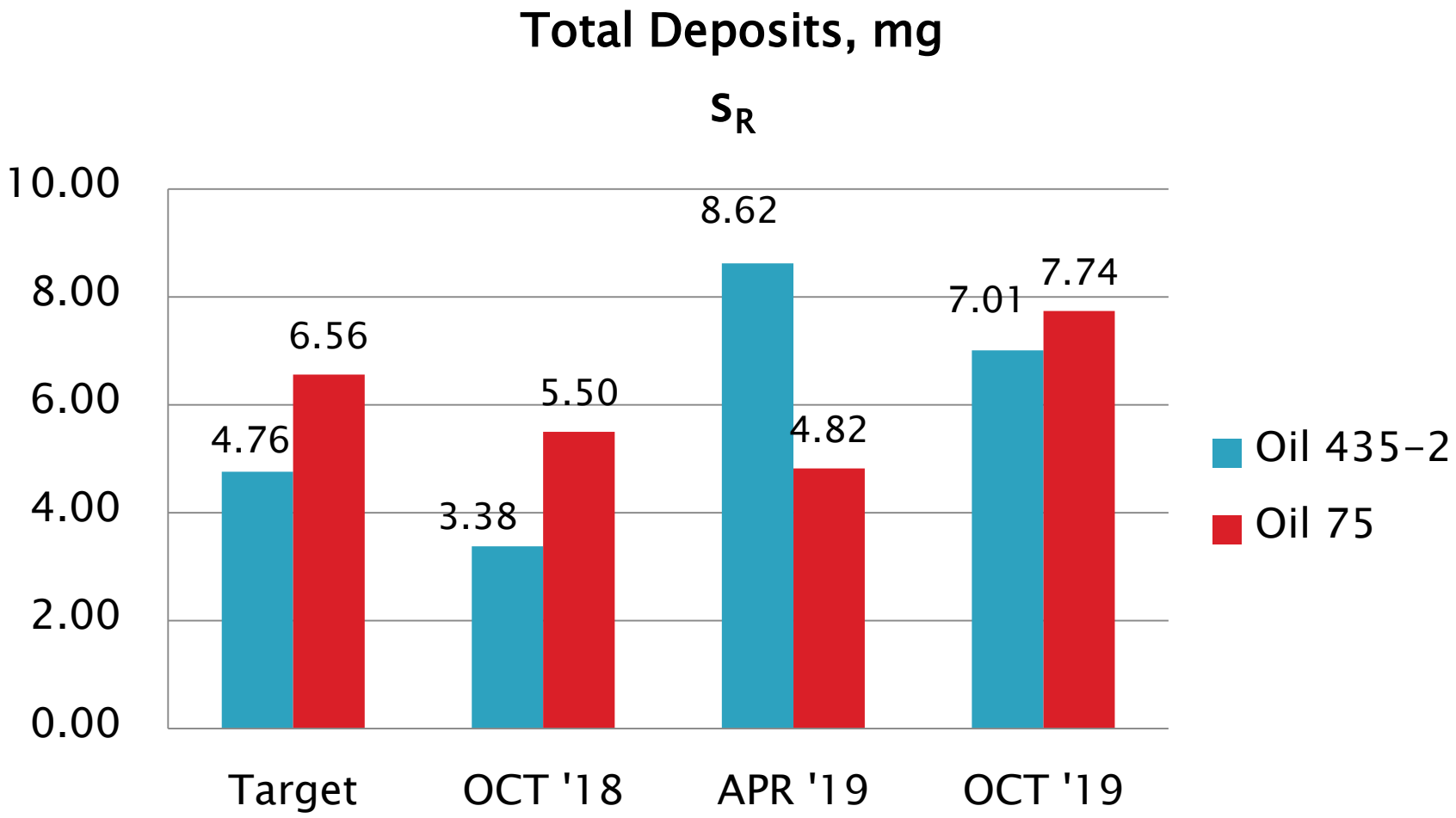
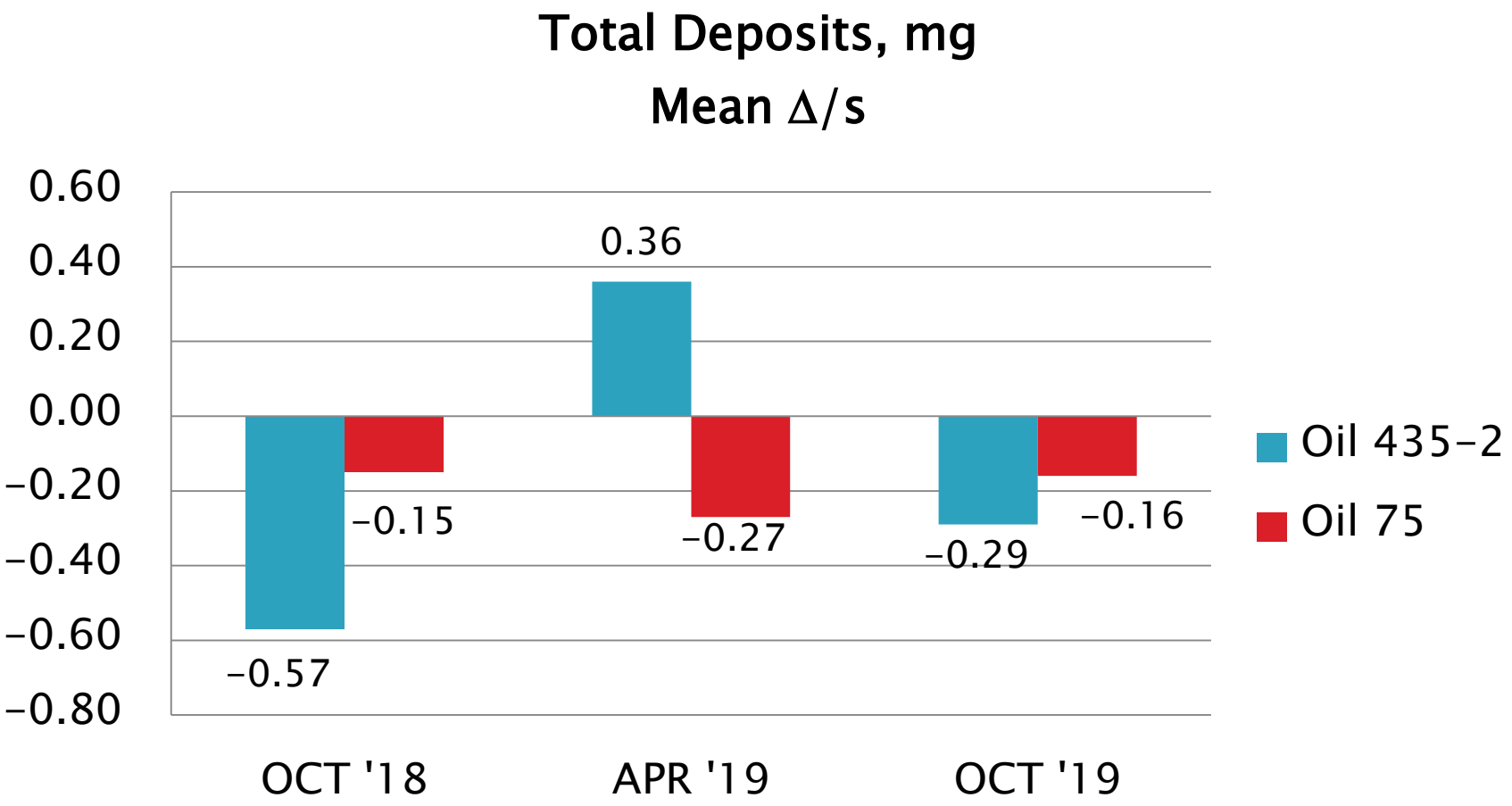
D6335 Performance by Oil



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	102
Failed Calibration Test	OC	7
Operationally Invalidated by Lab	LC, XC	5
Operationally Invalidated After Initially Reported as Valid	RC	0
Industry Information Runs	AG, OG	22
Total		**136**

Number of Labs Reporting Data: 11
Fail Rate of Operationally Valid Tests: 6%

D7097: Deposits by MHT TEOST

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

- Five operationally invalid calibration test reported this period:
  - 3 test sample leak (XC)
  - 2 air flow interruption during test (LC)

- 8 industry information runs to evaluate proposed replacement oil 434-3 (AG)

- 14 industry information runs to screen new catalyst batch 19BA (AG, OG)

- Calibration requirement updates are issued as LTMS document updates.

D7097: Deposits by MHT TEOST

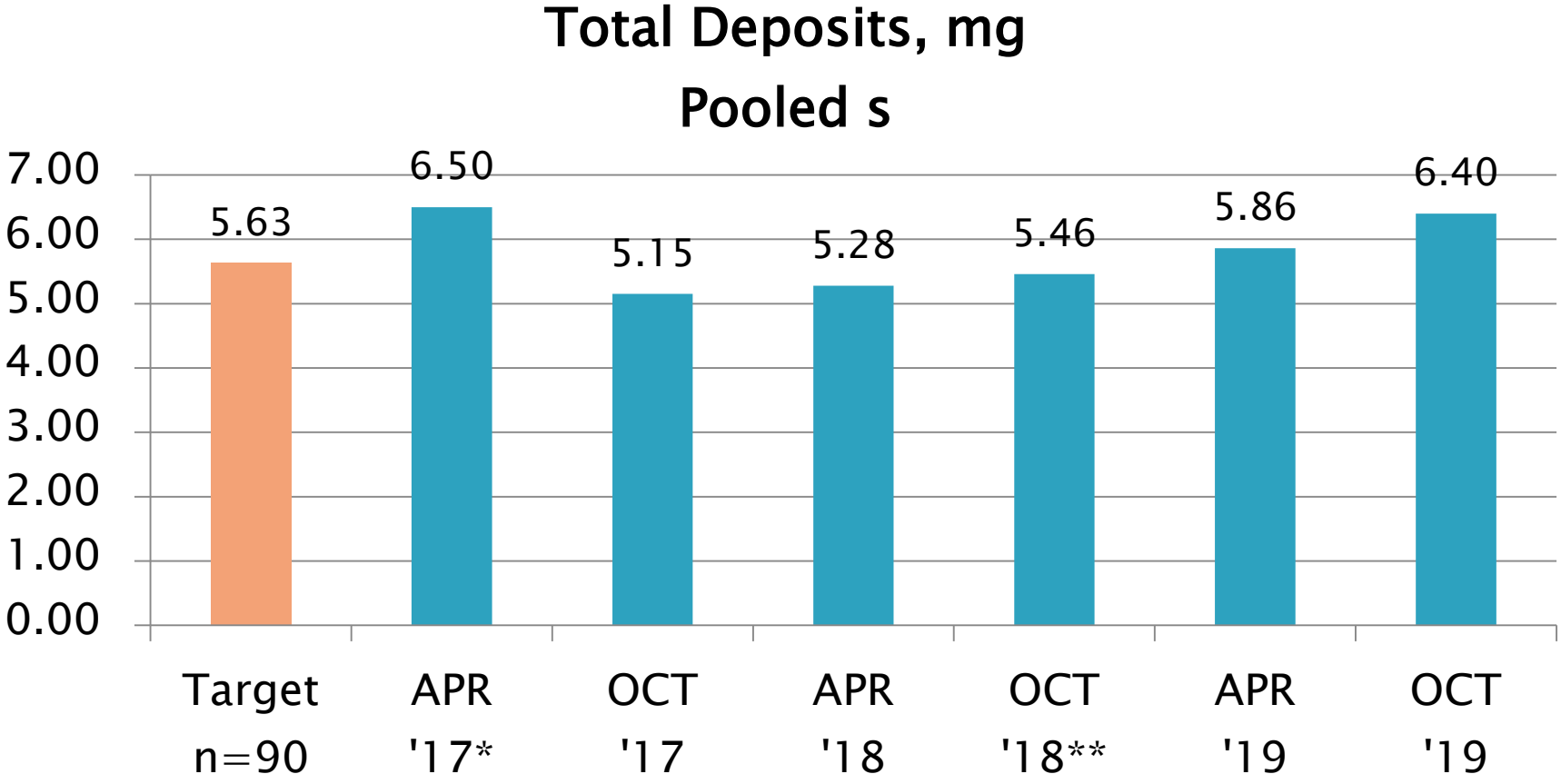
Period Precision and Severity Estimates

Total Deposits, mg	n	df	Pooled s	Mean Δ/s
Current Targets 7/31/2006	90	87	5.63	-----
10/1/16 through 3/31/17*	105	103	7.11	0.17
10/1/16 through 3/31/17*	97	95	6.50	0.03
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

*Eight 2TESTCAL tests from instrument J2 included and excluded

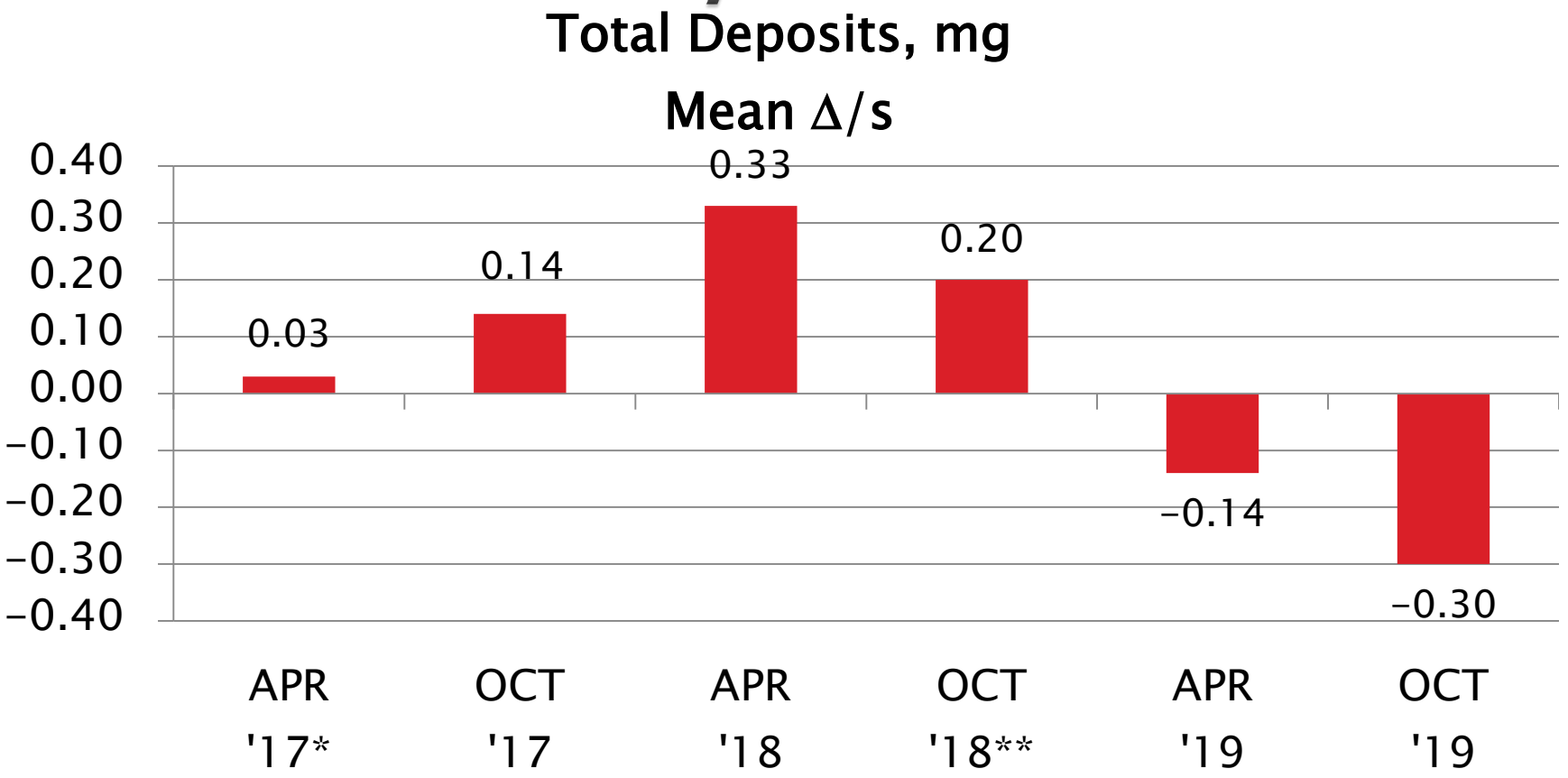
**One severe OC test from instrument G5 included and excluded (8.9 s)

D7097 Precision Estimates



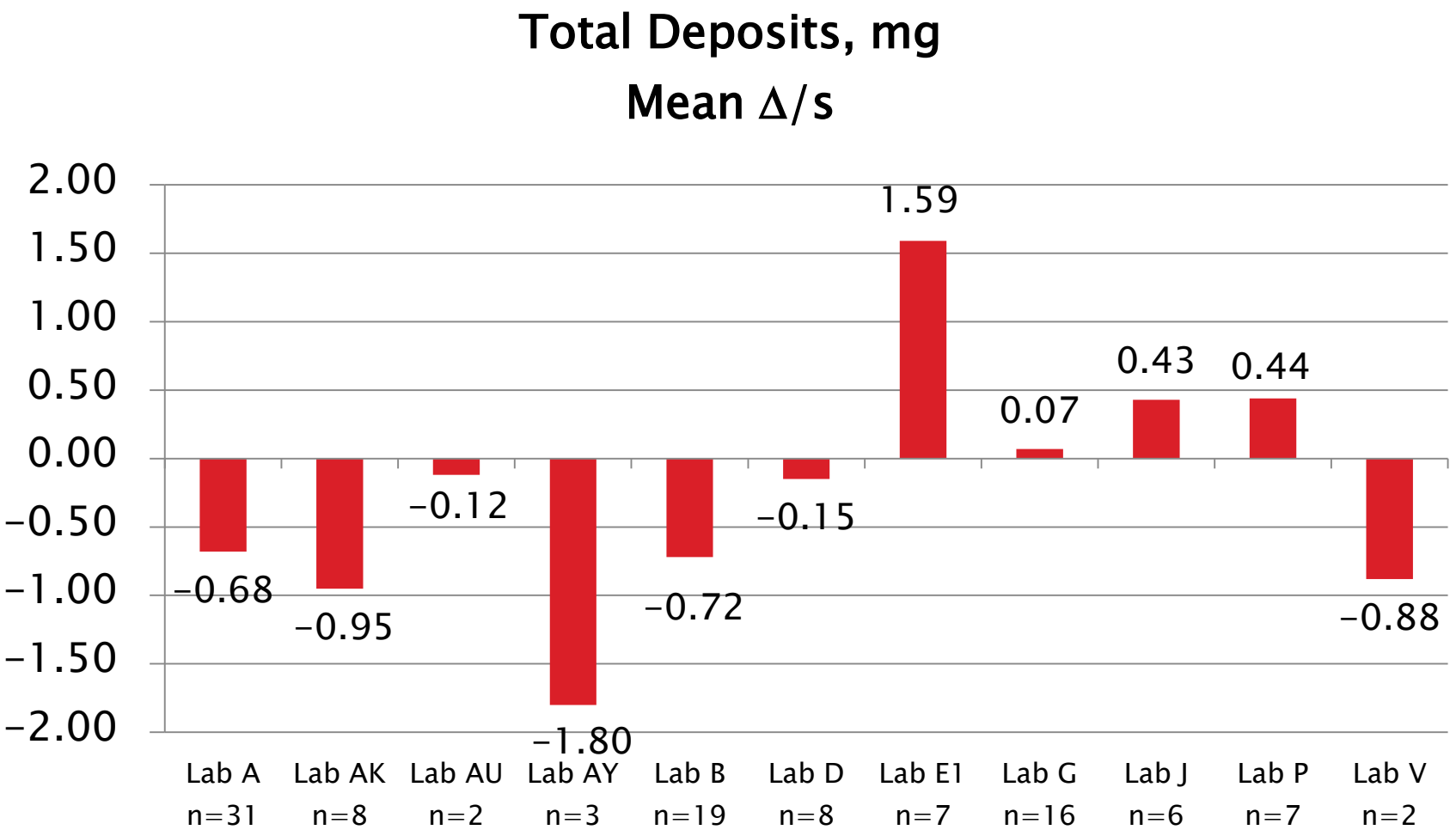
*Eight tests instrument J2 excluded (failed to calibrate)
**One severe OC test from instrument G5 excluded (8.9 s)

D7097 Severity Estimates



*Eight tests instrument J2 excluded (failed to calibrate)
**One severe OC test from instrument G5 excluded (8.9 s)

D7097 Lab Severity Estimates



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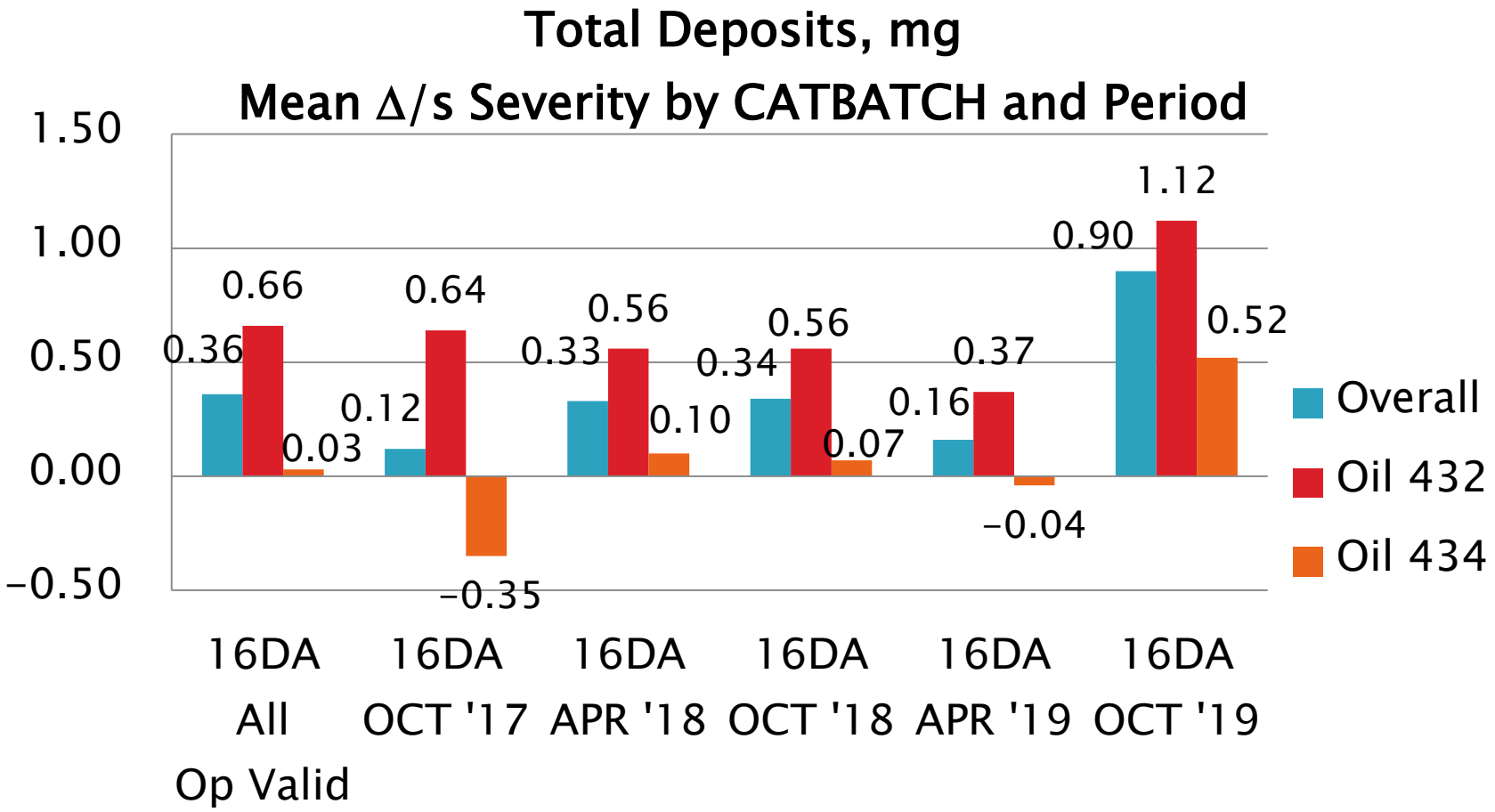
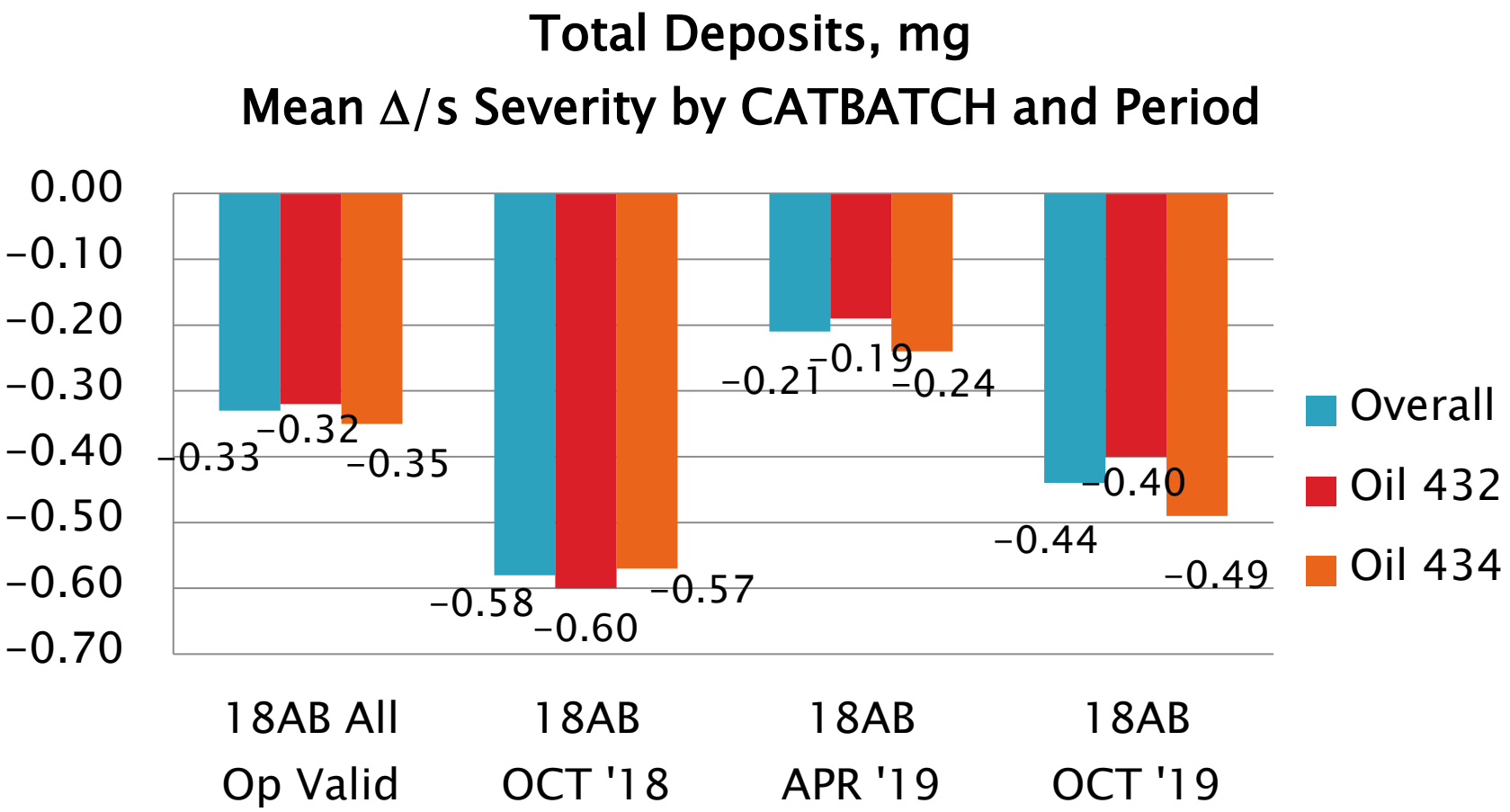
D7097: Deposits by MHT TEOST



D7097: Deposits by MHT TEOST



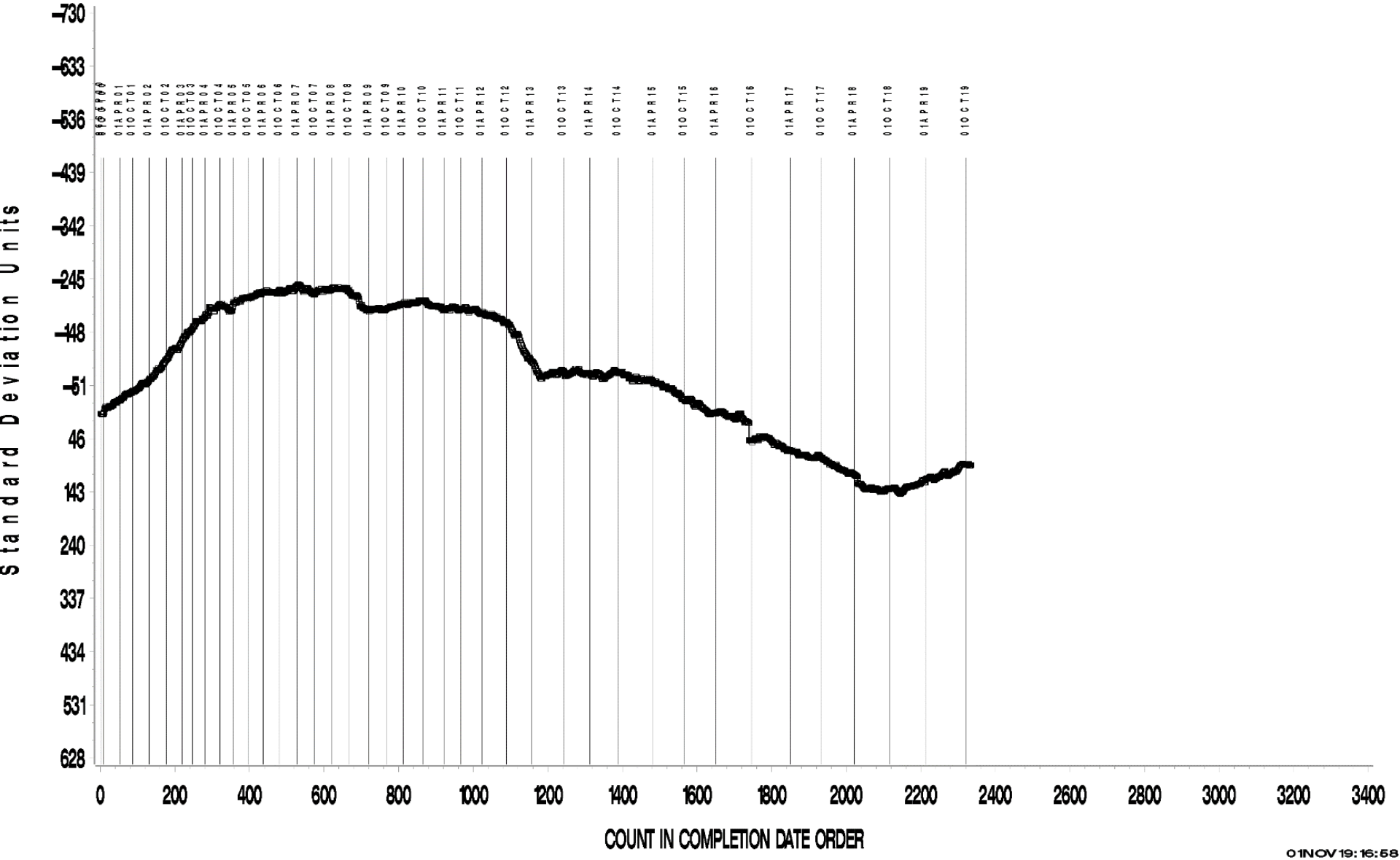
D7097: Deposits by MHT TEOST

- Precision (Pooled s) is less precise than the prior report period and less precise than target precision
- Performance (Mean Δ/s) is -0.30 s mild.
- All operationally valid tests this period report using Rod Batch M
- All operationally valid calibration tests this period report using Catalyst Batch 16DA (n=11) or 18AB (n=98).
- Overall severity of catalyst batch 18AB (n=199) appears to be about -0.3 s mild, and comparably mild on both reference oils.

MHT—4 TEOST INDUSTRY OPERATIONALLY VALID DATA

TOTAL DEPOSITS MG

CUSUM Severity Analysis



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MHT—4 TEOST INDUSTRY OPERATIONALLY VALID DATA

TOTAL DEPOSITS MG

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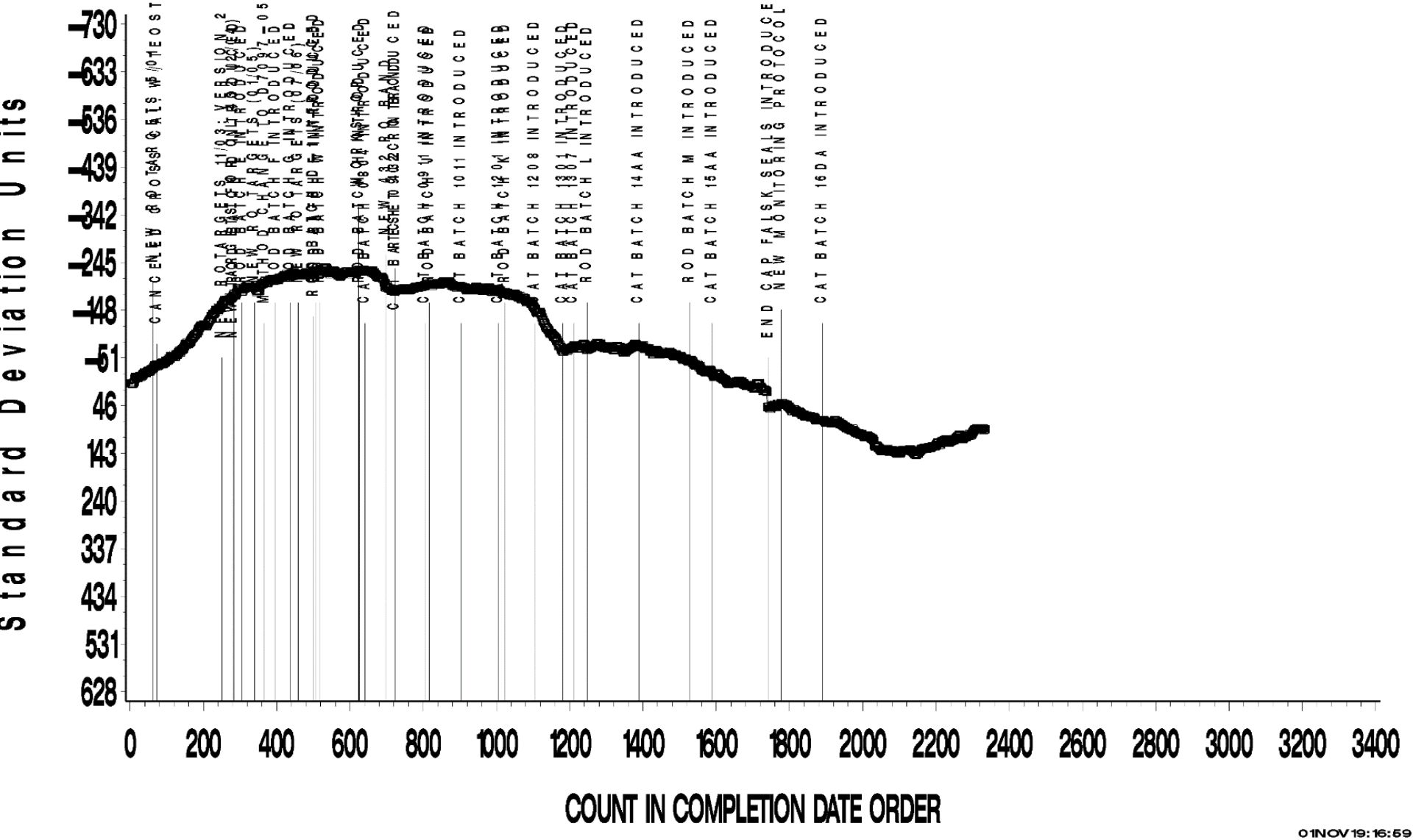
CUSUM Severity Analysis



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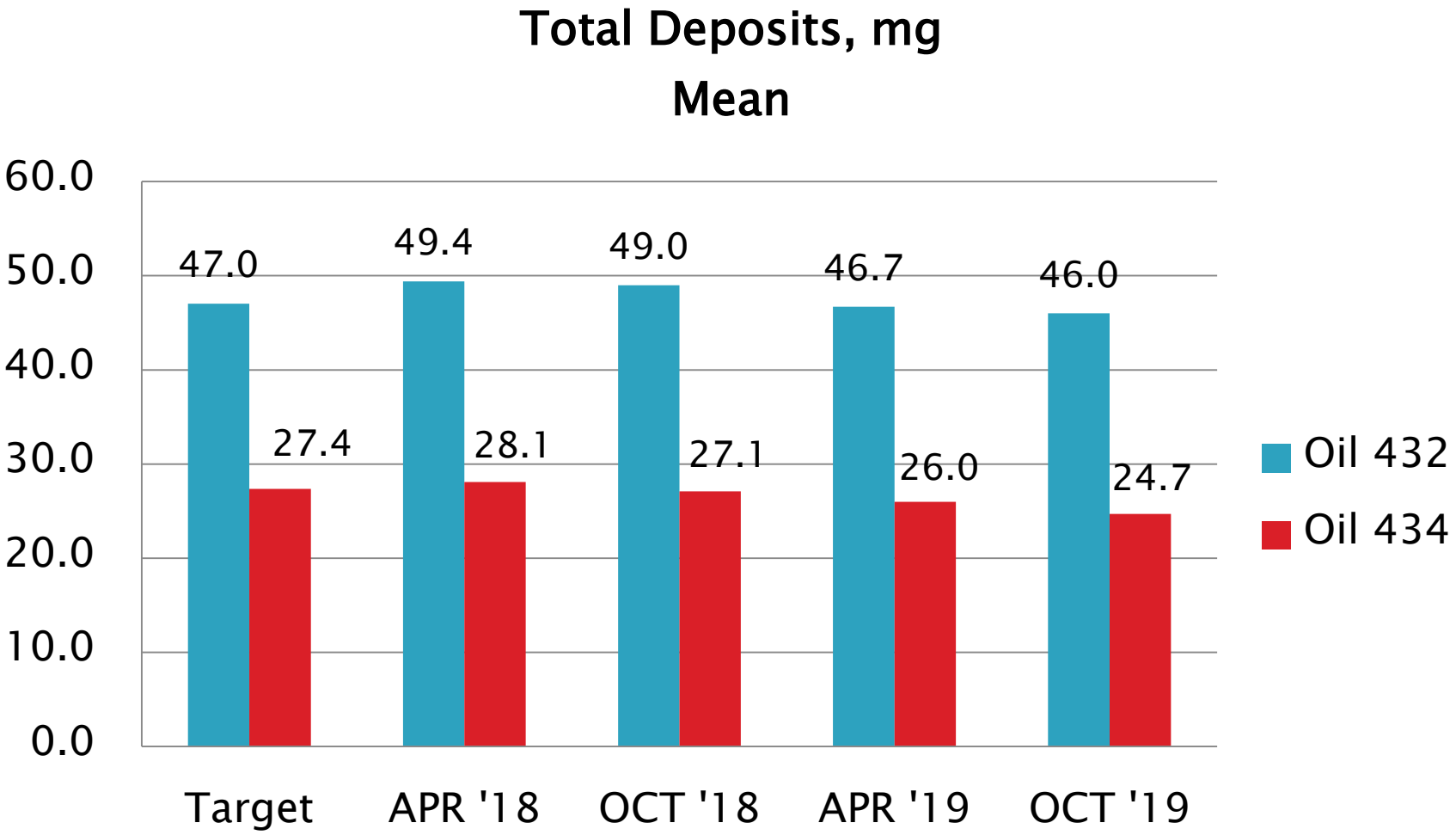
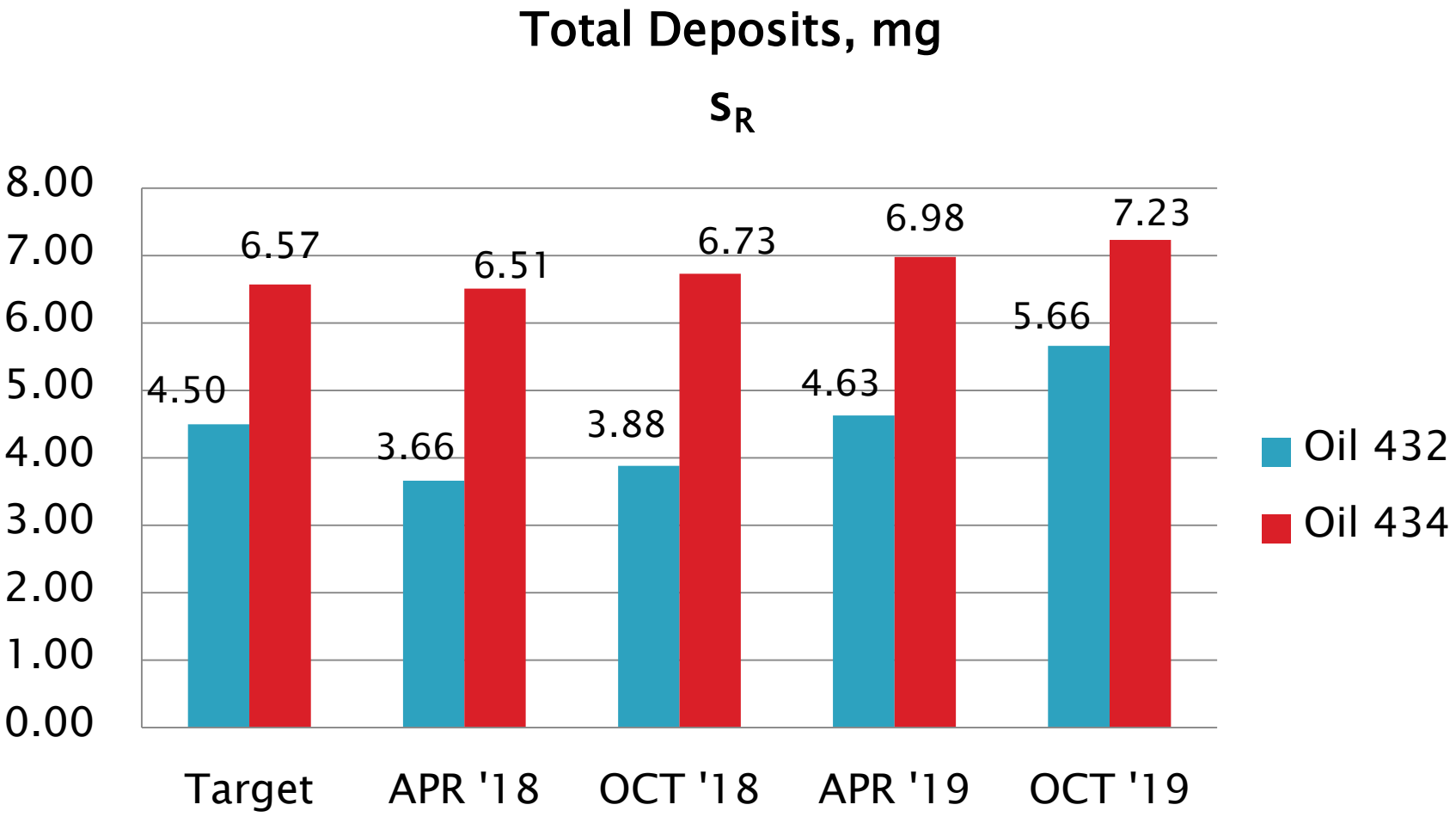
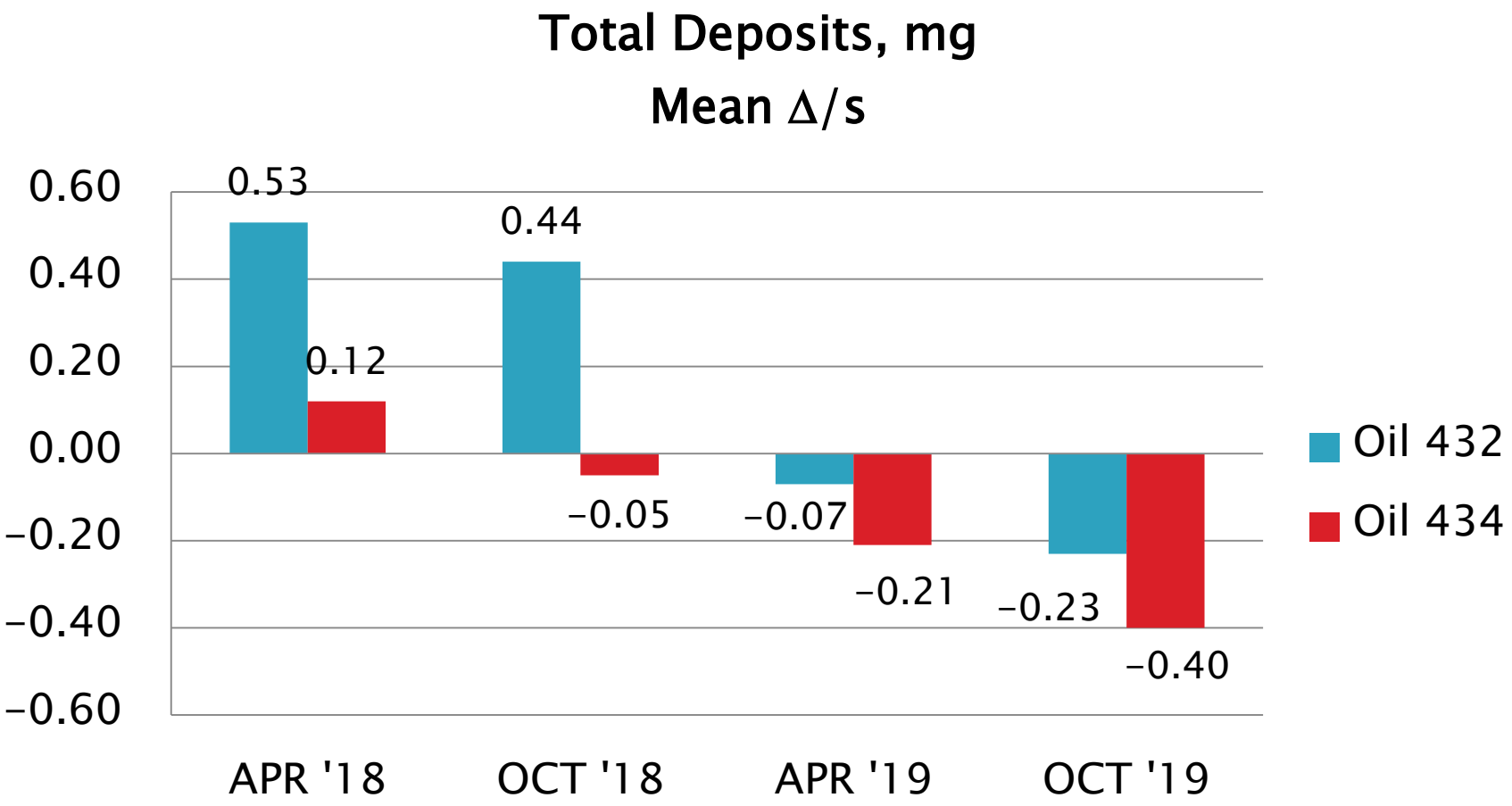
D7097 Performance by Oil



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	14
Acceptable Discrimination Test	AS	6
Failed Statistically	OC	0
Operationally Invalidated by Lab	LC, XC	0
Operationally Invalidated After Initially Reported as Valid	RC	0
Instrument Shakedown Run	NN	1
Total		**21**

Number of Labs Reporting Data: 6

Fail Rate of Operationally Valid Calibration Tests: 0%

D6082: High Temperature Foam

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

- All severe oil discrimination runs (on TMC oil 66) reported this period demonstrated acceptable discrimination.
  - Discrimination runs are not evaluated for overall period precision or severity due to poor test precision above 100 ml foam tendency.
- No invalid runs this period.
- One instrument shakedown run reported (new instrument).
- 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	-----
10/1/15 through 3/31/16	8	7	10	-0.45
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

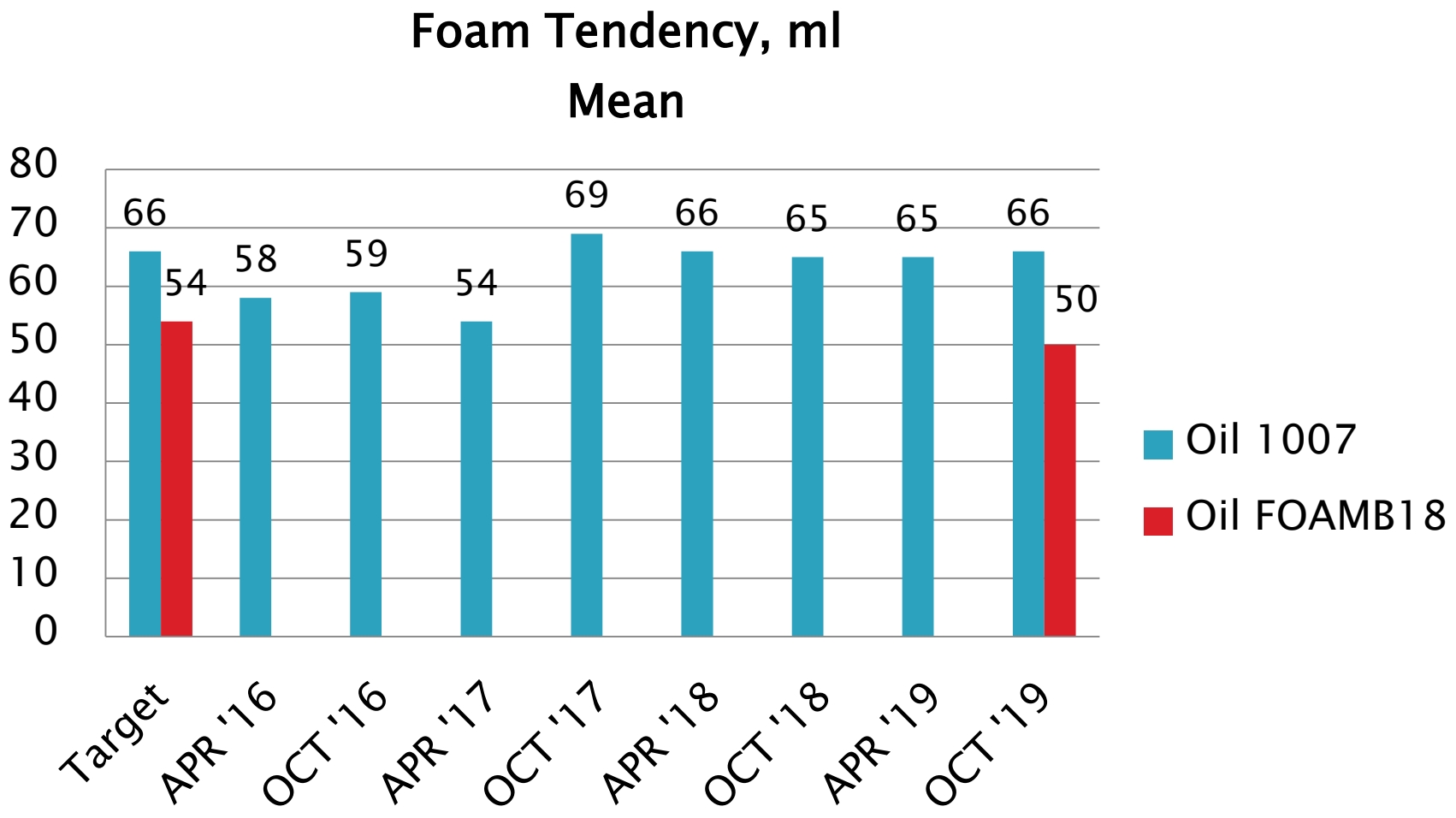
*Single OC result Yi=2.3 s severe included and excluded

D6082: High Temperature Foam

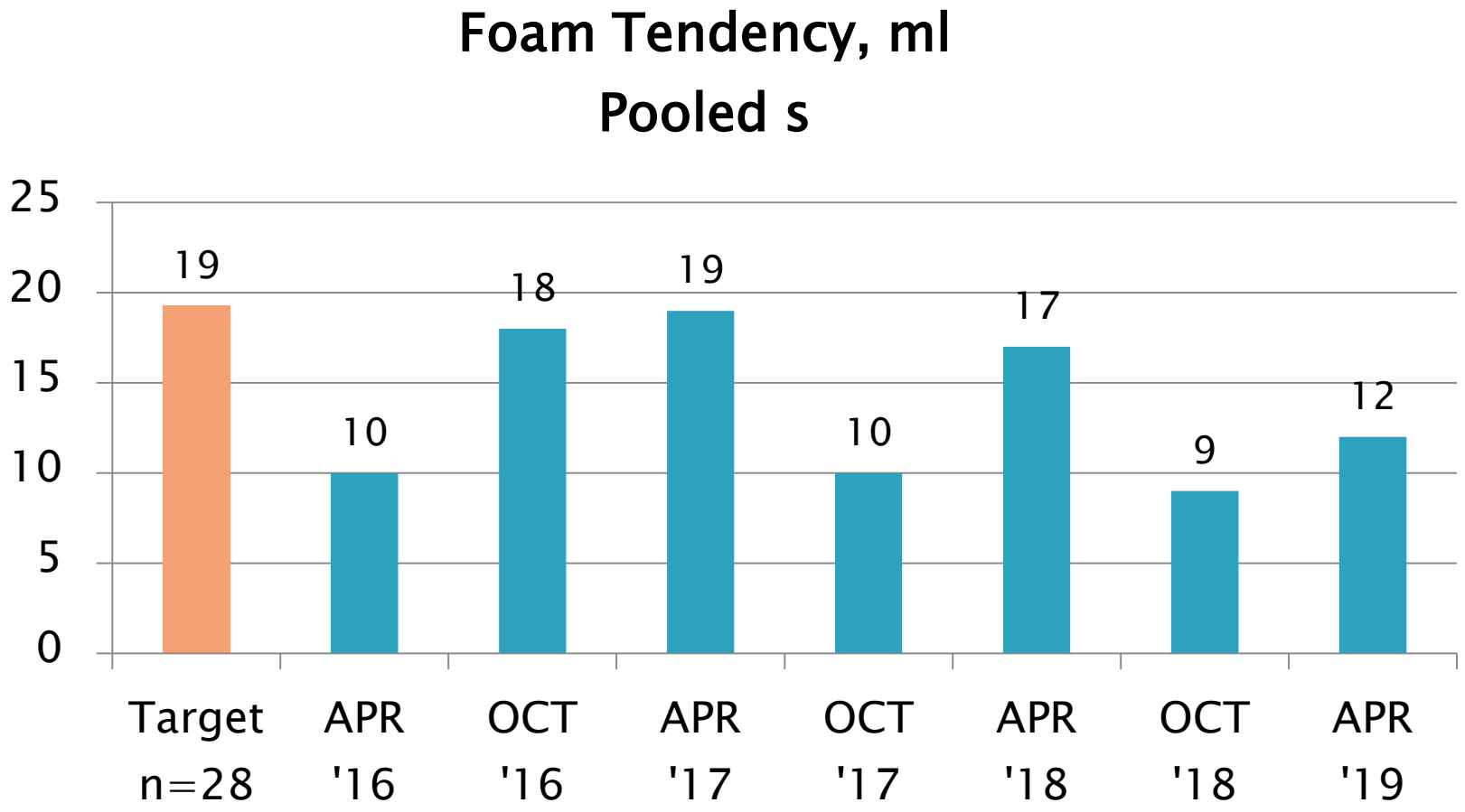
Period Precision and Severity Estimates

Foam Stability @ 1 min, ml	n	Mean	s
Current Targets	28	0.00	0.00
10/1/15 through 3/31/16	8	No non-zero occurrences	
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	

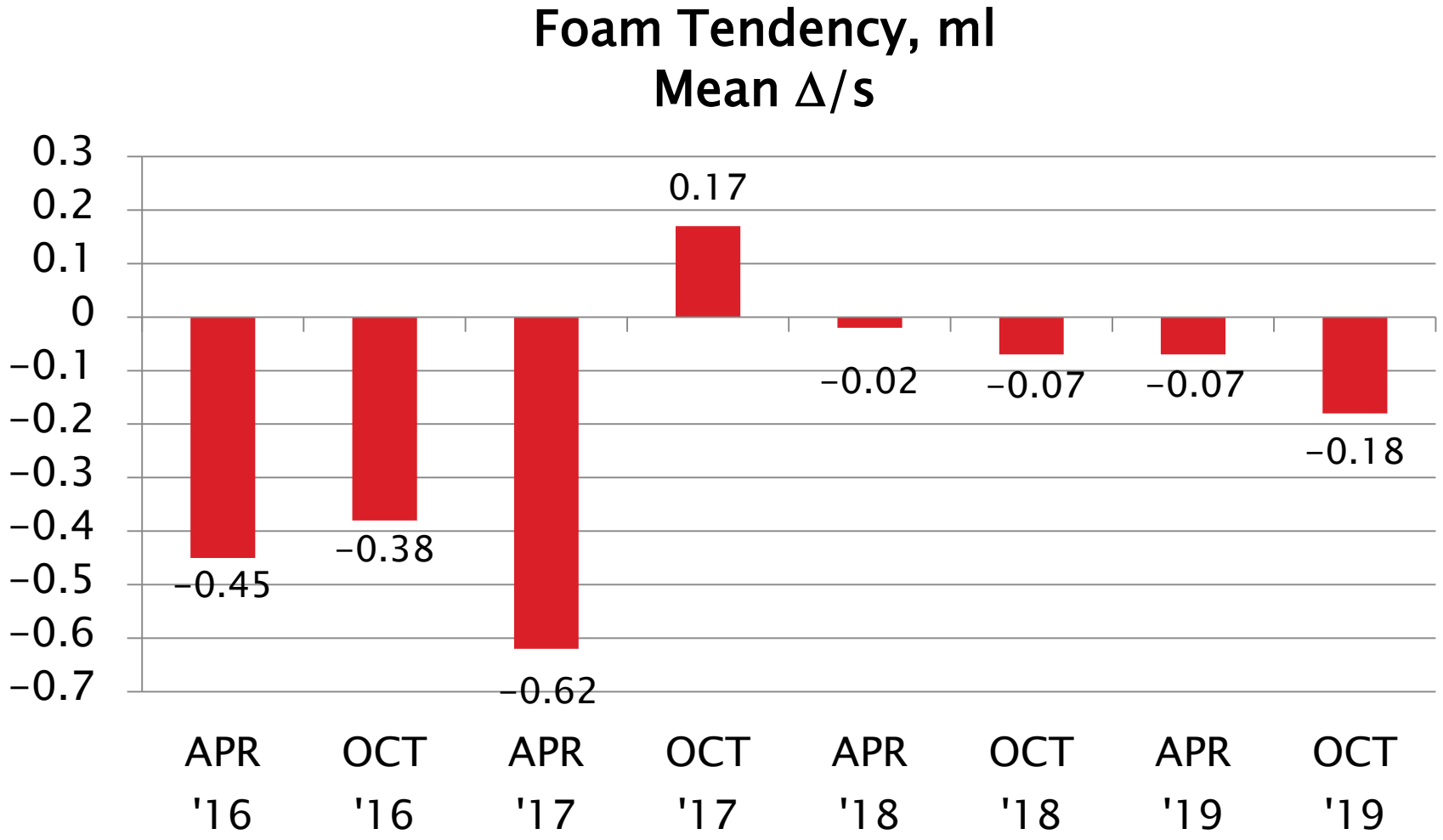
D6082 Performance by Oil



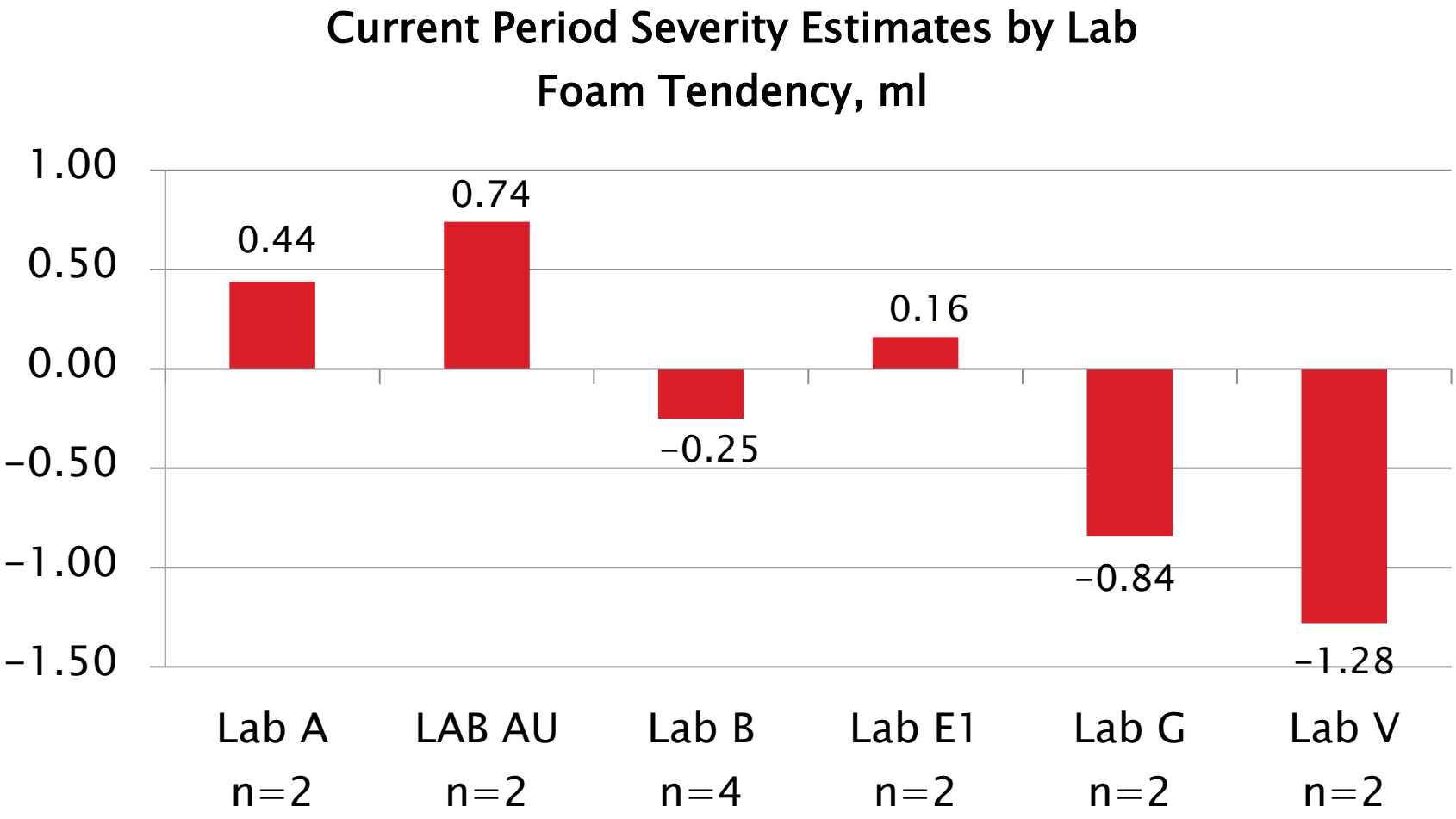
D6082: High Temperature Foam



D6082: High Temperature Foam



D6082: High Temperature Foam



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D6082: High Temperature Foam

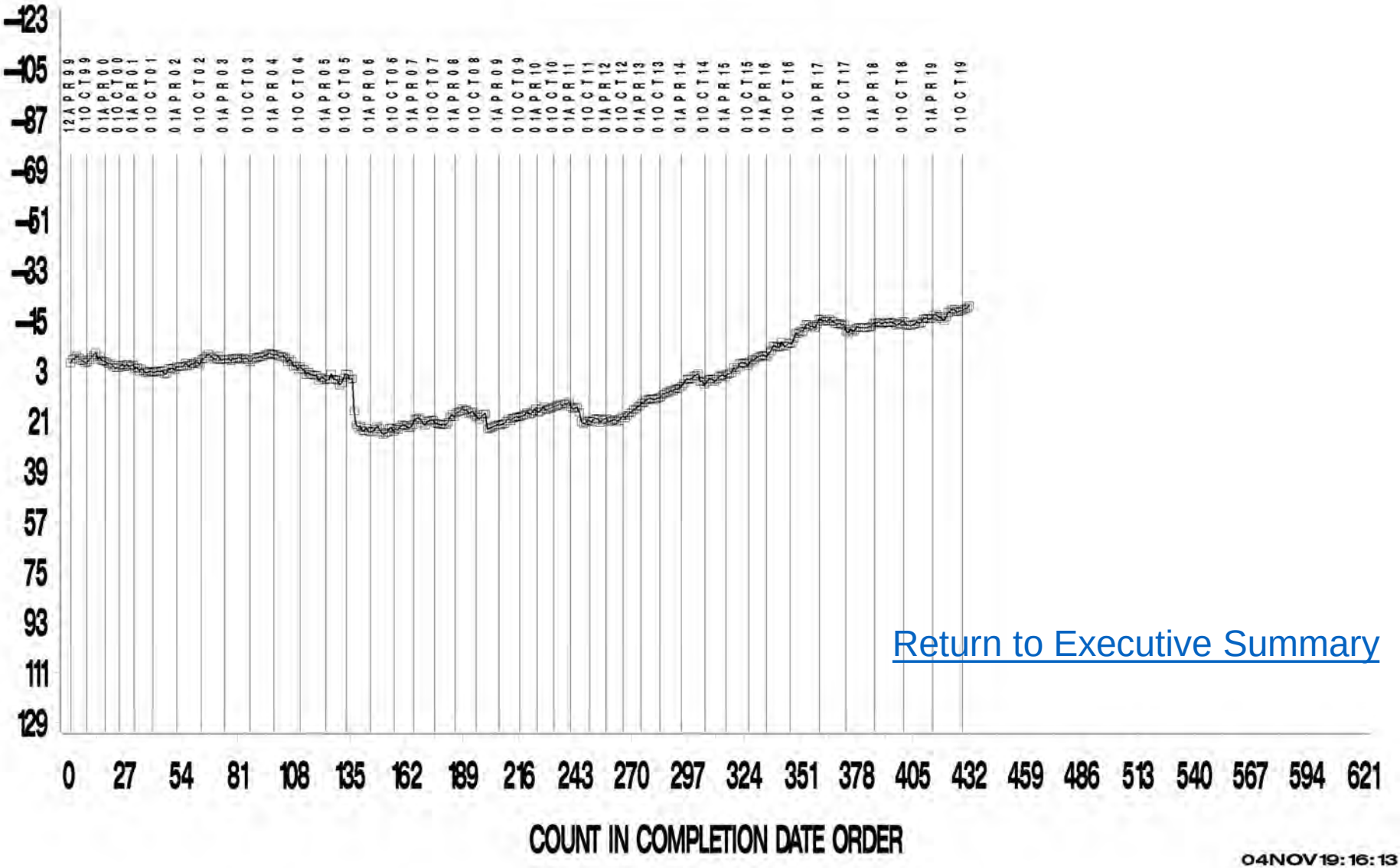
- Foam Tendency Precision (Pooled s) is comparable to the prior report period
  - More precise than target precision
- Performance (Mean Δ/s) is on target (slight mild bias)
- No non-zero occurrences of Foam Stability
- All six severe oil discrimination runs (on TMC oil 66) demonstrated acceptable discrimination.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

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

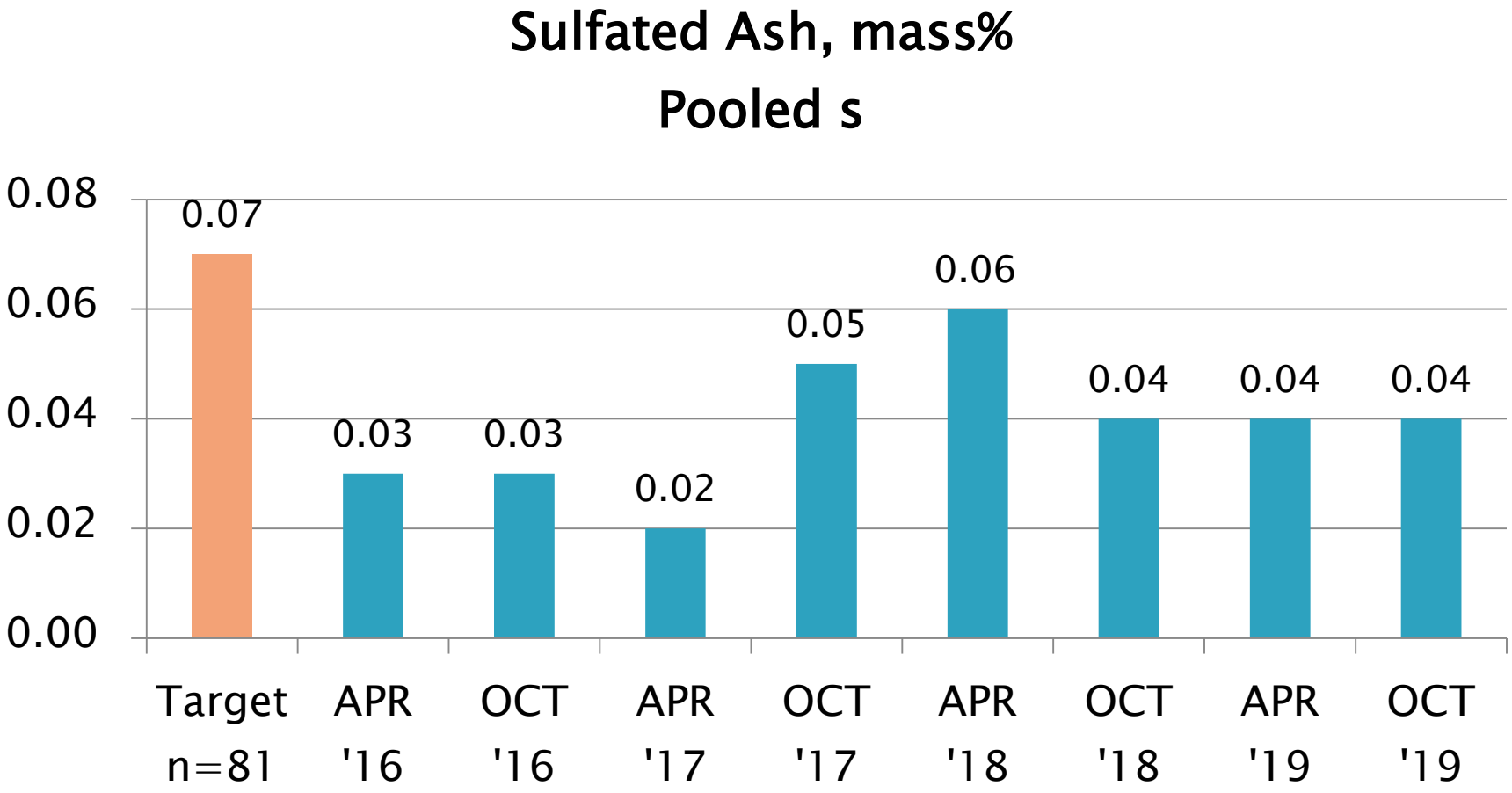
- No statistically or operationally invalid tests reported this period
- No TMC technical updates issued this period

D874: Sulfated Ash

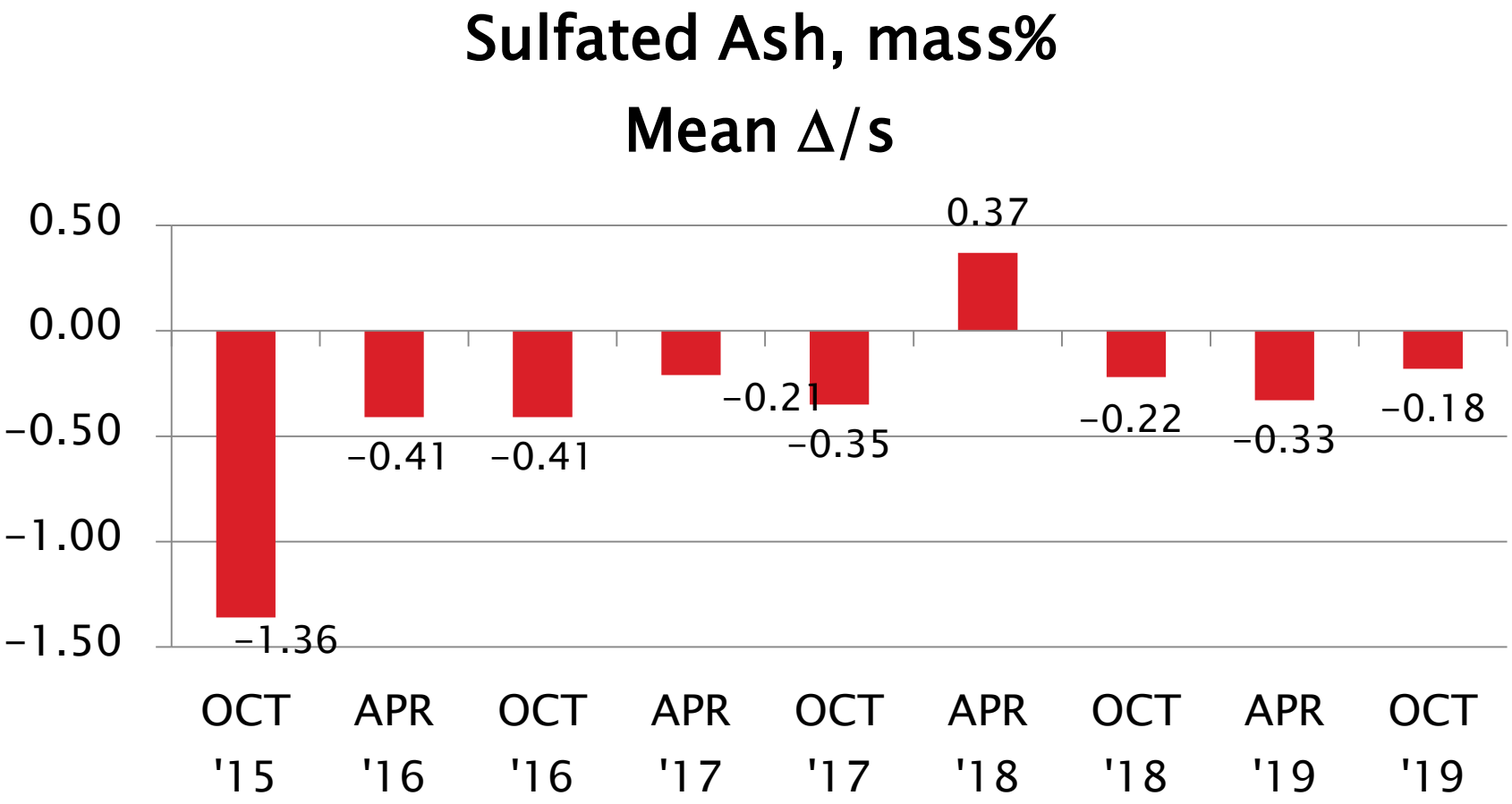
Period Precision and Severity Estimates

Total Deposits, mg	n	df	Pooled s	Mean Δ/s
Current Targets	81	78	0.07	-----
10/1/15 through 3/31/16	7	4	0.03	-0.41
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

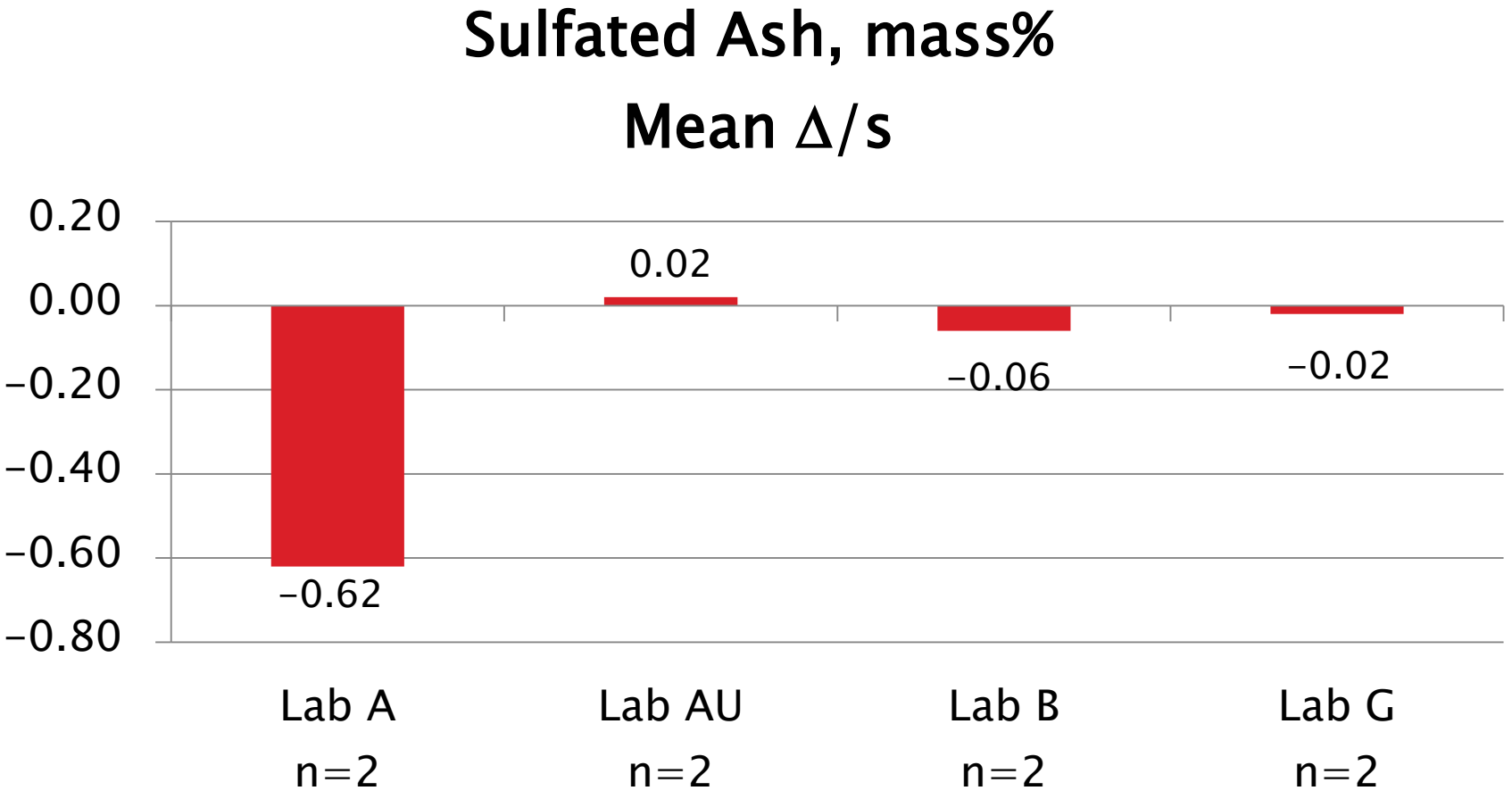
D874: Sulfated Ash



D874: Sulfated Ash



D874: Sulfated Ash

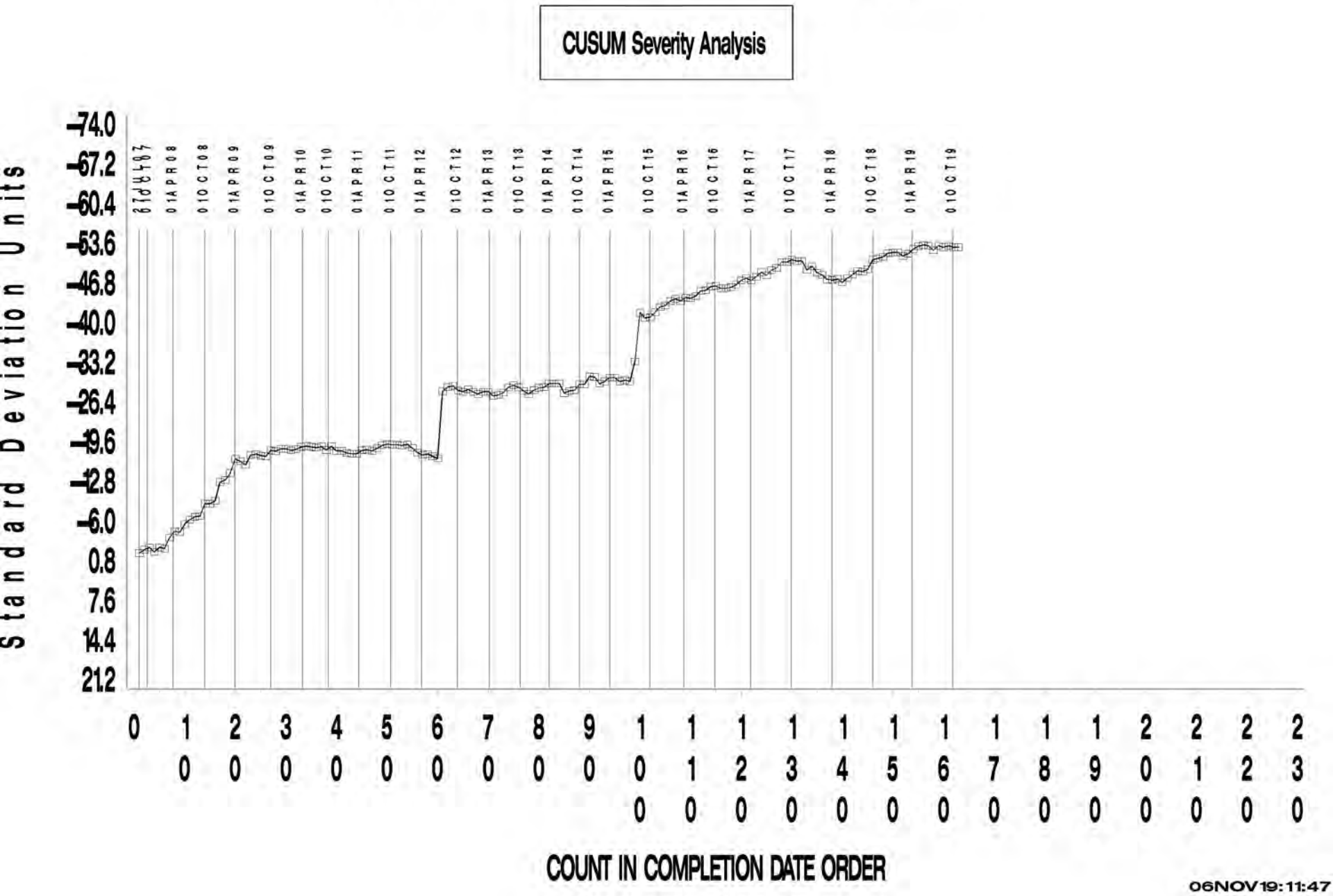


D874: Sulfated Ash

- Precision (Pooled s) is comparable to prior periods
  - More precise than target precision
- Performance (Mean Δ/s) is -0.18 s mild

D874 INDUSTRY OPERATIONALLY VALID DATA

TEST SAMPLE PERCENT SULFATED ASH



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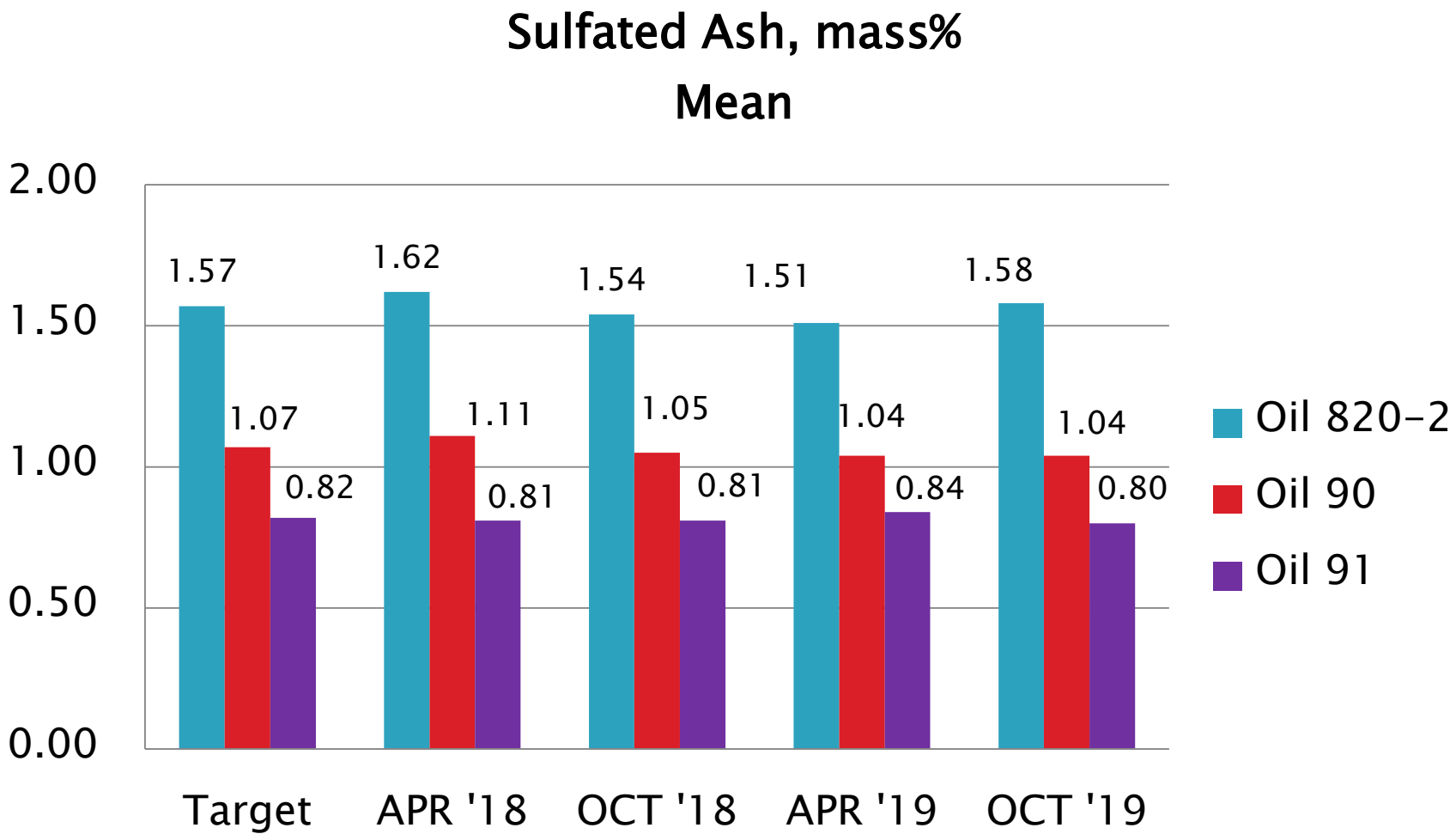
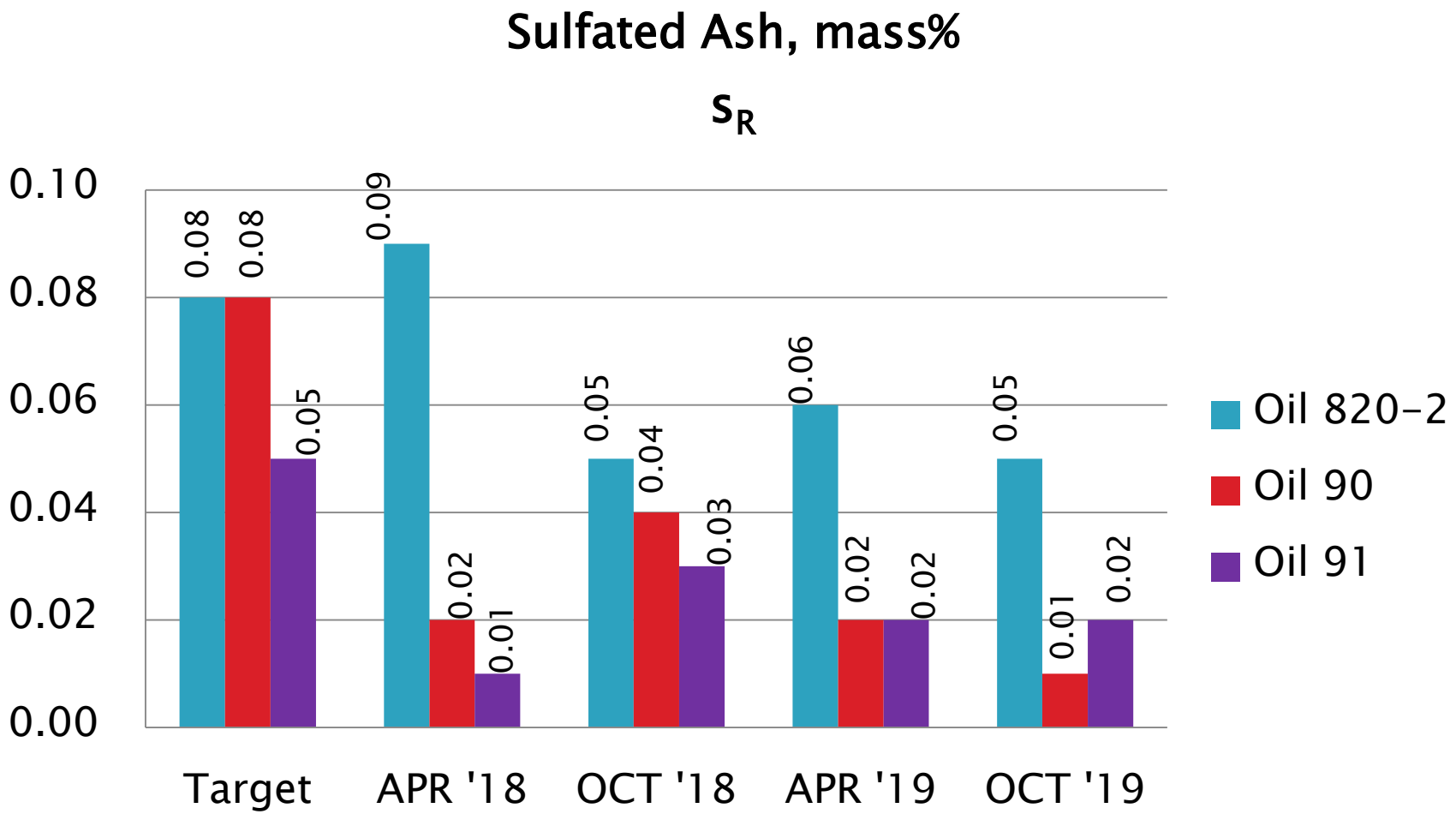
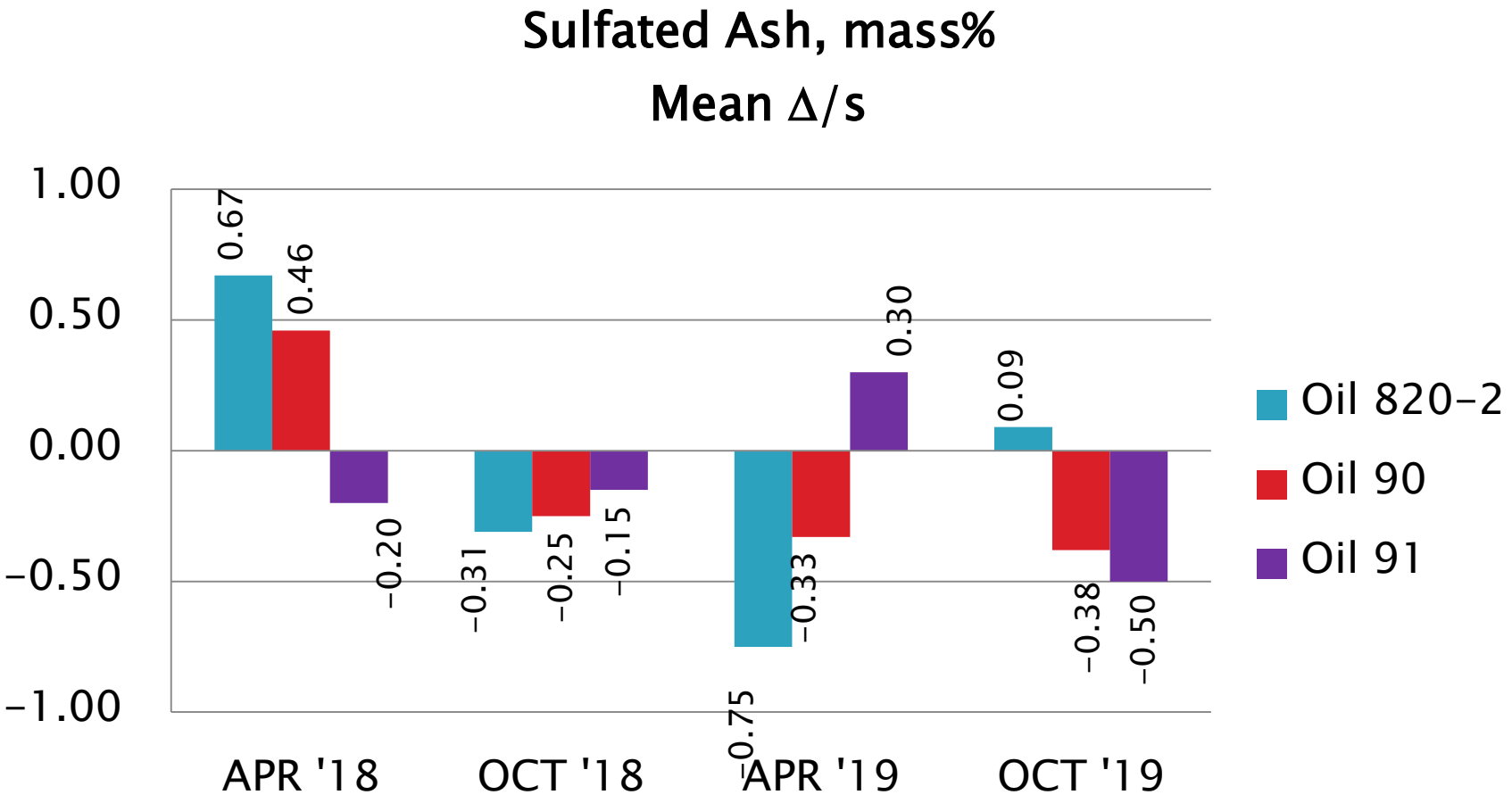
D874: Sulfated Ash



D874: Sulfated Ash



D874: Sulfated Ash



Return to Executive Summary

D7528: Oxidation by ROBO

Test Status	Validity Code	No. Tests
Acceptable Calibration Test	AC	80
Failed Calibration Test	OC	15
Operationally Invalidated by Lab	LC, XC	7
Operationally Invalidated After Initially Reported as Valid	RC	0
434-3 Replacement Oil RR	AG, RG	13
Dilute NO_2 Study	AG, OG	3
Total		**118**

Number of Labs Reporting Data: 5
Fail Rate of Operationally Valid Tests: 16%

D7528: Oxidation by ROBO

Operationally Invalid Calibration Tests

- 3 tests NO_2 flow off-spec (LC)
- 2 tests stirrer failure (LC)
- 1 test exceeded 40 hour run time (XC)
- 1 test improper sample preparation (LC)

Other Tests

- 13 industry information runs to establish initial performance targets on replacement oil 434-3 (AG, RG)
- 3 runs reported to further study performance of modified rig setup using dilute NO2 (AG, OG)

D7528: Oxidation by ROBO

Statistically Unacceptable Tests (OC)	No. Of Tests
Natural Log (MRV Viscosity) Mild	11
Natural Log (MRV Viscosity) Severe	4

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

- There was one technical update issued after the report period end date:
  - Updated Reference Oil Targets, TMC Memo 19-051, October 31, 2019

- Calibration requirement updates are issued as LTMS document updates

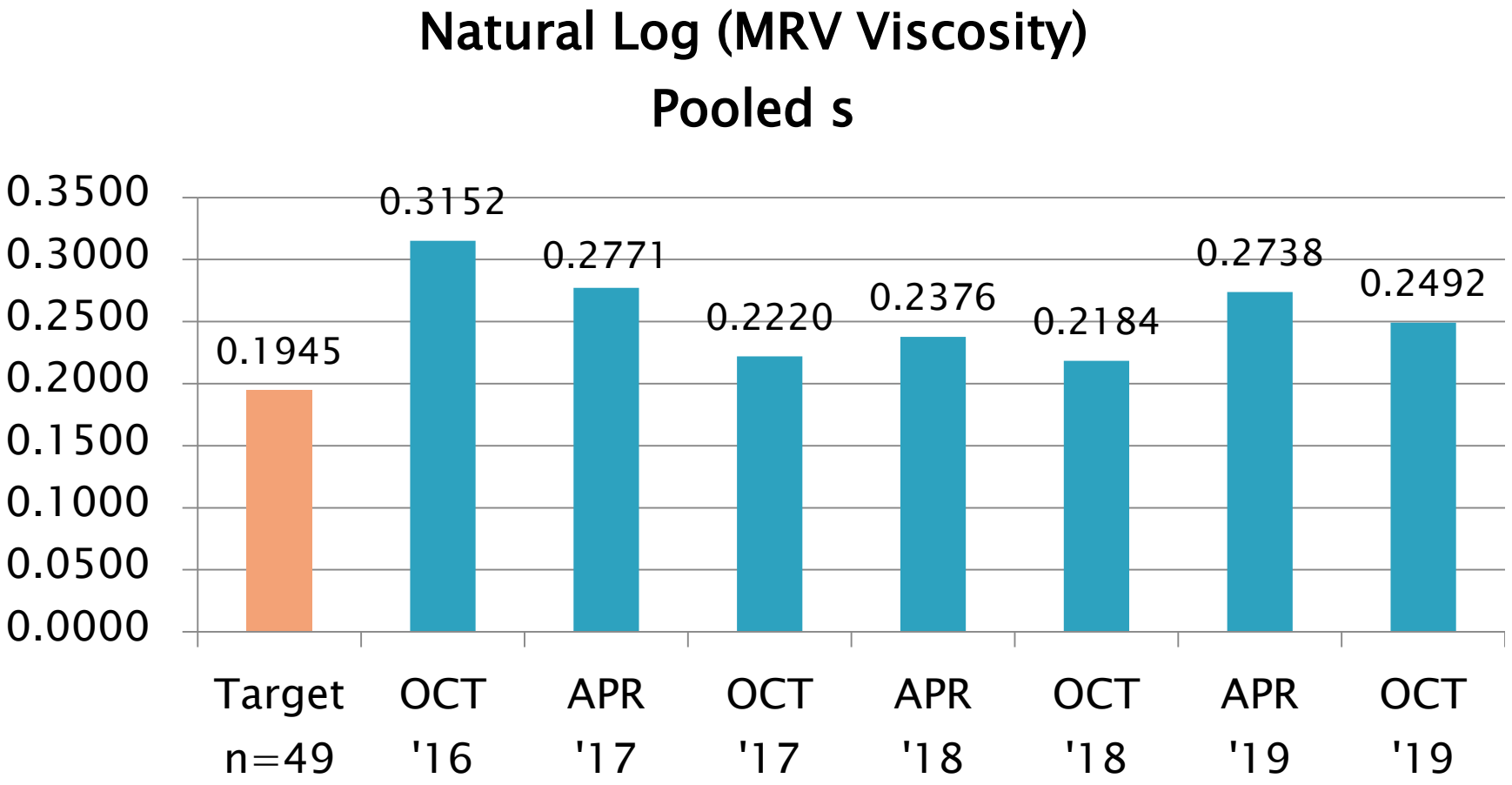
D7528: Oxidation by ROBO

Period Precision and Severity Estimates

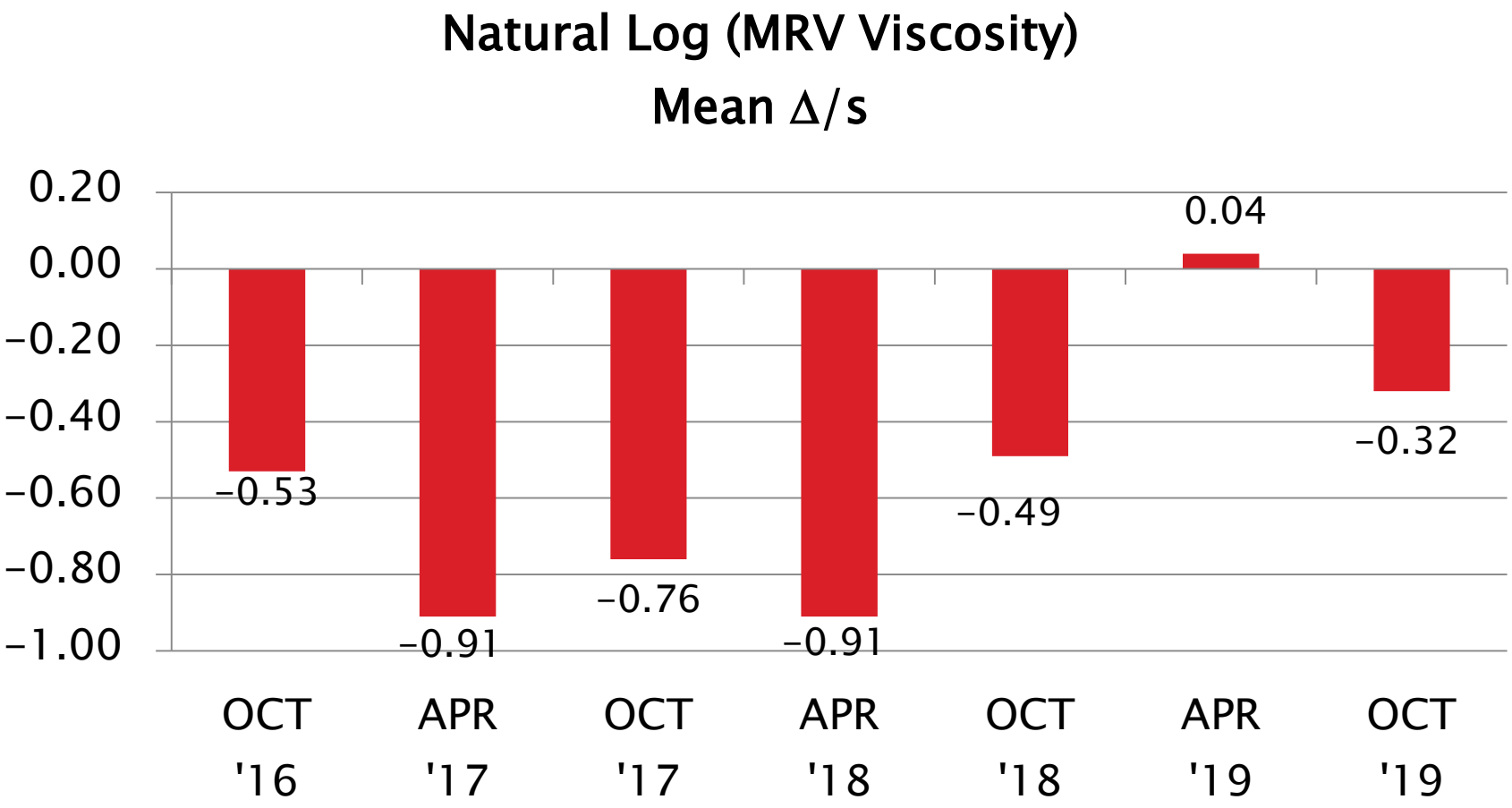
Natural Log (MRV Viscosity)	n	df	Pooled s	Mean Δ/s
Current Targets	49	46	0.1945	-----
4/1/16 through 9/30/16	74	71	0.3152	-0.53
10/1/16 through 3/31/17	78	75	0.2771	-0.91
4/1/17 through 9/30/17	99	95	0.2220	-0.76
10/1/17 through 3/31/18*	90	86	0.2376	-0.91
10/1/17 through 3/31/18*	83	79	0.2076	-0.74
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

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

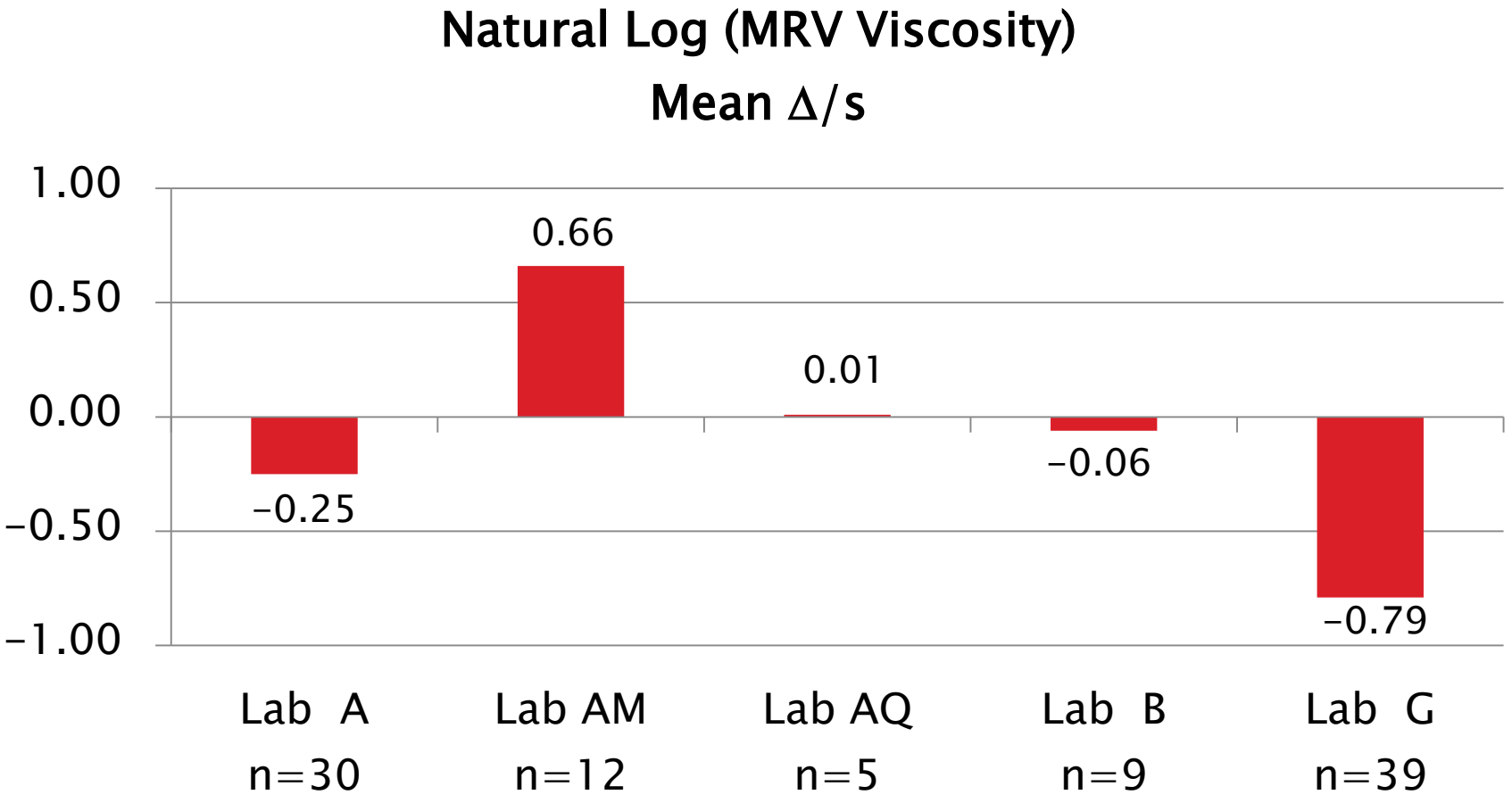
D7528: Oxidation by ROBO



D7528: Oxidation by ROBO



D7528: Oxidation by ROBO



D7528: Oxidation by ROBO

- One test reported this period as operationally valid failed 5.3 s severe (Rig A 10). 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 more precise than last period
  - Continues to be less precise than target
- Performance (Mean Δ/s) is -0.32 s mild for this report period

D7528: Oxidation by ROBO

- CUSUM Severity Plot shows an overall mild trend with a brief leveling to on-target performance last period. A similar brief leveling is also noted in the CUSUM plot coincident with the October 2015 ROBO workshop held in San Antonio, TX, but the mild trend returned on subsequent periods, denoted by date timelines in the plot.

ROBO TEST INDUSTRY OPERATIONALLY VALID DATA

AGED OIL MRV APPARENT VISCOSITY

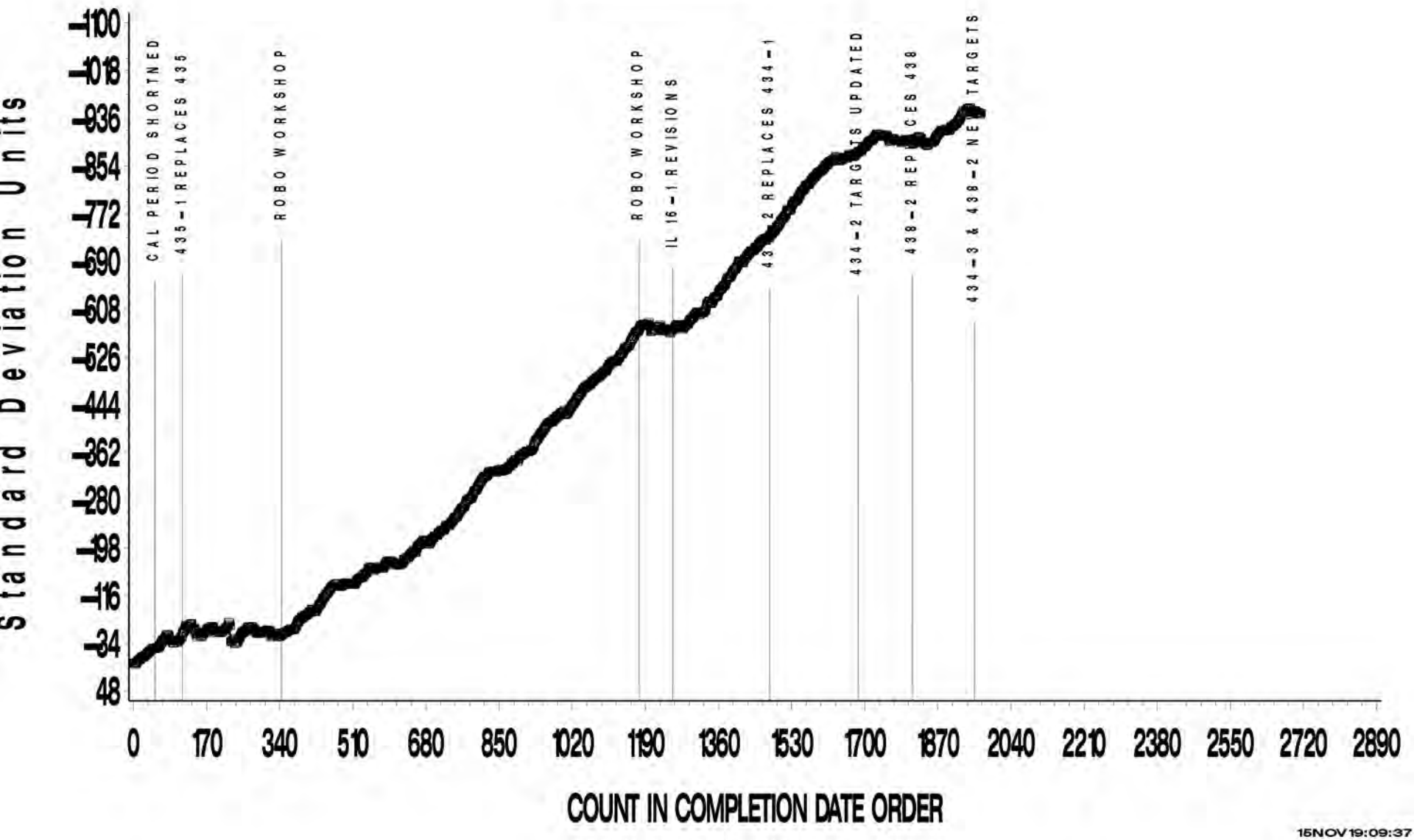
CUSUM Severity Analysis

15NOV19:09:25

ROBO TEST INDUSTRY OPERATIONALLY VALID DATA

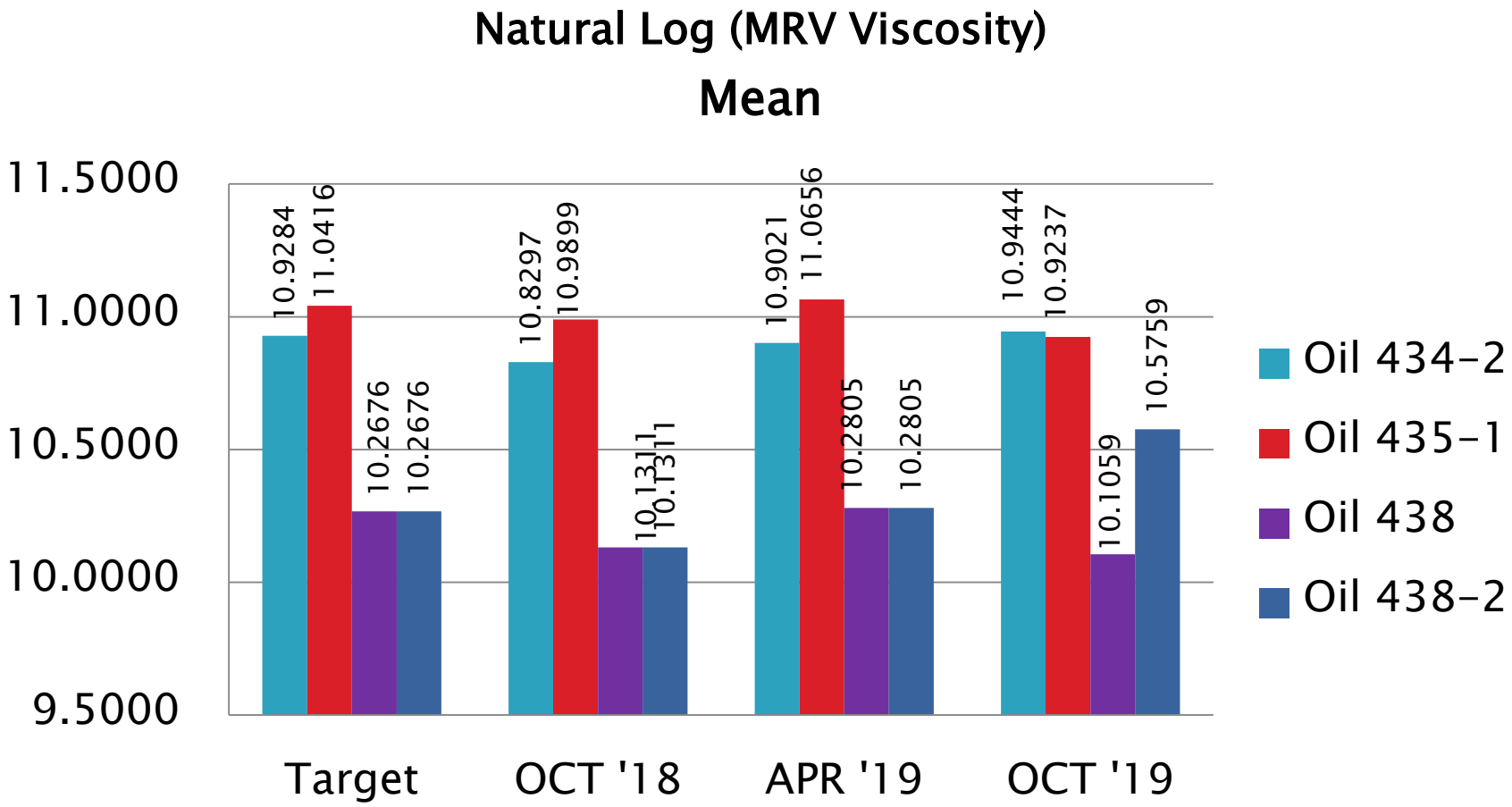
AGED OIL MRV APPARENT VISCOSITY

CUSUM Severity Analysis

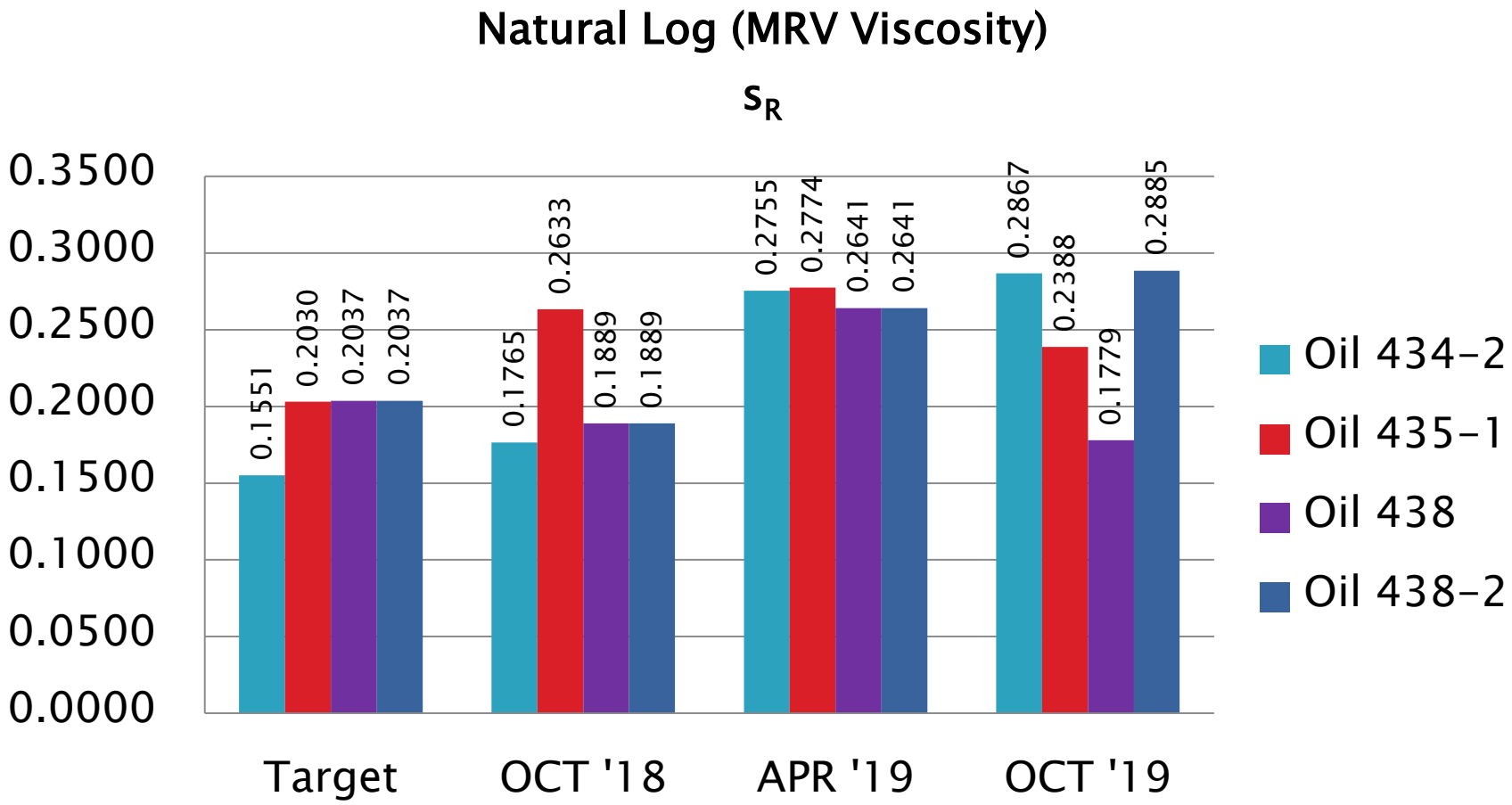


15NOV19:09:37

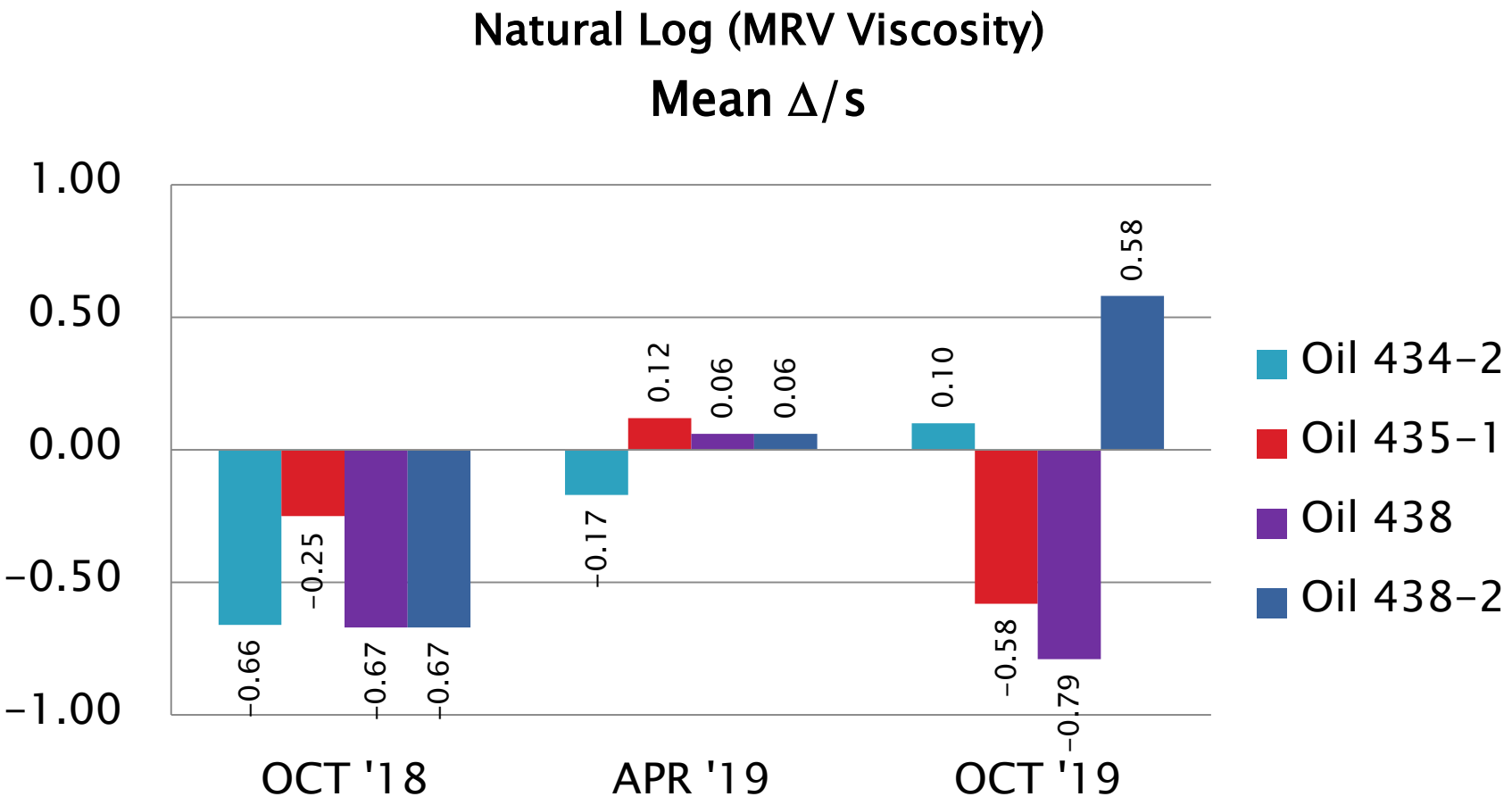
D7528: Oxidation by ROBO



D7528: Oxidation by ROBO



D7528: Oxidation by ROBO



Return to Executive Summary

Reference Oil Inventory

- As of 9/30/2019

Reference Oil Inventory

D5800

Oil	Year Rec'd By TMC[A]	Tests	TMC Inventory, gallons	Gallons Shipped last 12 months
VOLC12	2013	D5800	32.5	2.7
VOLD12	2013	D5800	30.7	2.8
VOLE12	2013	D5800	28.8	3.1
VOLD14[B]	2014	D5800QC	2.4	26.6
VOLD18[B]	2018	D5800QC	1031	57.6

[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	115.3	0.2
62[C]	1996	GI	0.3	0.1
GIA17[C]	2017	GI	9.8	0.1
1009	2002	GI	37.8	0.2

[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

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	103.7	0.5
434[B]	2003	MTEOS	0.7	0.6
75-1	2016	TEOST	8.0	0.0
435-2[C]	2010	TEOST	41.5	0.8
434-2[B]	2014	ROBO	4.4	6.4
434-3[B,C]	2017	ROBO/MTEOS	49.0	0.0
435-1	2008	ROBO	405	17.9
438-2[C]	2017	ROBO	46.8	1.5

[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 for ROBO and proposed to replace 434 in MTEOS

[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	92.3	6.0
66	2002	D6082	76.8	3.1
820-2	2001	D874	8.9	0.0
90[B]	2005	D874/D874QC	17.7	1.9
91	2006	D874	3.6	0.0

[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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