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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)

October 2018

B0.07 Bench Testing Executive Summary

- D6417 (Volatility by GC)
- Precision (Pooled s) is less precise than prior period
  - Comparable to target precision
- Performance (Mean Δ/s) is 0.15 s severe
- CUSUM plot shows overall near on-target performance this period (slightly severe).

B0.07 Bench Testing
Executive Summary

- D5800 (Volatility by Noack)
- Precision (Pooled s), at 0.82 mass %, 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 0.40 s severe.
- Lab G, Rig 5, reported one result more than -5 s mild (oil VOLE12), followed by a number of passing calibrations during the period. Precision and severity are shown with this result included and excluded, though it has little overall impact due to the high number of D5800 results reported for the period.
- Fail rate of operationally valid tests (AC & OC) has dropped to 5% or less for the most recent four report periods using LTMS, compared to 26% under the Shewhart severity only system.
- CUSUM plot showed some leveling (mean 0.15 s severe) last period for the first time since a brief period in 2014, but a modest increase in severity returns this period (mean 0.40 s severe). With LTMS monitoring, since 20161019, D5800 non-reference results are severity adjusted by instrument, with SA's updated by LTMS calibration evaluation.

B0.07 Bench Testing Executive Summary

- D5133 (Gelation Index)
- Fail rate of operationally valid tests is 6% this period. Fail rates had been high over the prior three periods, with fail rates between 10% and 26%. Five periods back the fail rate was also 6%.
- Overall severity is 0.15 s severe (on target at -0.02 s mild with one extreme result from Instrument E1 2 excluded).
- Precision (Pooled s), is more precise than target precision, and more precise than all report periods since at least April 2016, even with one extreme result included.
- Lab E1, Rig 2, reported one result more than 5 s severe (oil 1009), both preceded and followed by passing calibrations. However, the same instrument had two failing results last period that were 4 s severe, and the same lab (E1) last period reported three consecutive failing runs on their Rig 1 (non-gelling oil 58), and later, two consecutive fails on oil 1009.

B0.07 Bench Testing
Executive Summary

- D5133 (Gelation Index, continued)
- The calibration performance of instrument E1 2 this period and last, instrument E1 1 last period, as well as past similar experiences with other instruments, 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 these instruments, after demonstrating multiple failing results, should subsequently be considered properly calibrated based on just one passing test result on just one viscometer head.
- The precision on oil 62 is much better than target precision for that oil this period, while oil 1009 precision this period is notably less precise than target.
- Oil 62 is in low supply, a round robin has been completed to evaluate two oils as possible replacements. The surveillance panel has not yet convened to discuss the results.

B0.07 Bench Testing Executive Summary

- D6335 (TEOST-33C)

- Precision (Pooled s) is substantially more precise than prior periods, and more precise than target precision for the first time since at least 2015.
- Performance (Mean Δ/s) is -0.33 s mild.
- One test reported as using Rod Batch L, all other tests this period report using Rod Batch M.
- Round robin on replacement oil 75-1 is completed, waiting on surveillance panel action.

B0.07 Bench Testing Executive Summary

- D7097 (MHT-4 TEOST)
- Excluding one extreme result 8.9 s severe:
  - Precision (Pooled s) is less precise than last report period
    - More precise than target precision for three consecutive report periods
    - Improved precision last three report periods, compared to prior report periods, is coincident with use of new end cap flask seals
  - Performance (Mean Δ/s) is 0.20 s severe.
- All operationally valid tests this period report using Rod Batch M
- All operationally valid calibration tests this period report using Catalyst Batch 15AA (n=2), 16DA (n=77) or 18AB (n=15).

B0.07 Bench Testing Executive Summary

- D7097 (MHT-4 TEOST) continued

- Severity of the newest catalyst batch 18AB (n=15) appears to be about 0.6 s mild on both reference oils.

B0.07 Bench Testing Executive Summary

- D6082 (High Temperature Foam)

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

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

- No non-zero occurrences of Foam Stability

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

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 -0.22 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 precision (but comparable to target with one extreme severe result excluded)
- Performance (Mean Δ/s) is -0.49 s mild
  - Overall performance is -0.59 s mild with one extreme severe result excluded

B0.07 Bench Testing Executive Summary

- D7528 (ROBO) continued
- Oil 434-1 is depleted at the TMC, reblend 434-2 had been introduced last period with preliminary targets set by round robin. 434-2 targets were updated 20180728 with additional calibration test results and by surveillance panel consensus.
  - Any 434-1 in current lab inventories is still being assigned.
  - 434-2 targets were set with consideration of preserving (or not canceling out) the mild trend observed on oil 434-1, and the 434-2 performance reflects that ongoing mild trend.
- CUSUM Severity Plot shows an overall mild trend since the 01APR11 timeline (following a 2011 ROBO workshop) with a brief leveling coincident with the October 2015 ROBO workshop held in San Antonio, TX, but the mild trend returns following the April 2016 timeline.

Calibrated Labs and Stands*

Test	Labs	Stands
D6417	6	8
D5800	9	18
D5133 (GI)	6	9
D6335 (TEOST)	7	10
D7097 (MTEOS)	11	46
D6082	6	7
D874	4	--
D7528 (ROBO)	6	23

*As of 9/30/2018

D02.B0.07
TMC Monitored Tests

- April 1, 2018 –
  September 30, 2018

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D6417: Estimation of Engine Oil Volatility by Capillary GC

Test Status	Validity Code	No. Tests
Acceptable Calibration Test	AC	16
Failed Calibration Test	OC	0
Operationally Invalidated by Lab	LC, XC	0
Operationally Invalidated After Initially Reported as Valid	RC	0
Total		**16**

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

D6417: Estimation of Engine Oil Volatility by Capillary GC

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

- There were no operationally or statistically unacceptable D6417 tests reported this period.

- There was one technical memo issued this period for D6417:
  - Memo 18-029, September 30, 2018, New TMC Calibration Requirements Effective October 1, 2018
- Future calibration requirement updates will now be issued as LTMS document updates

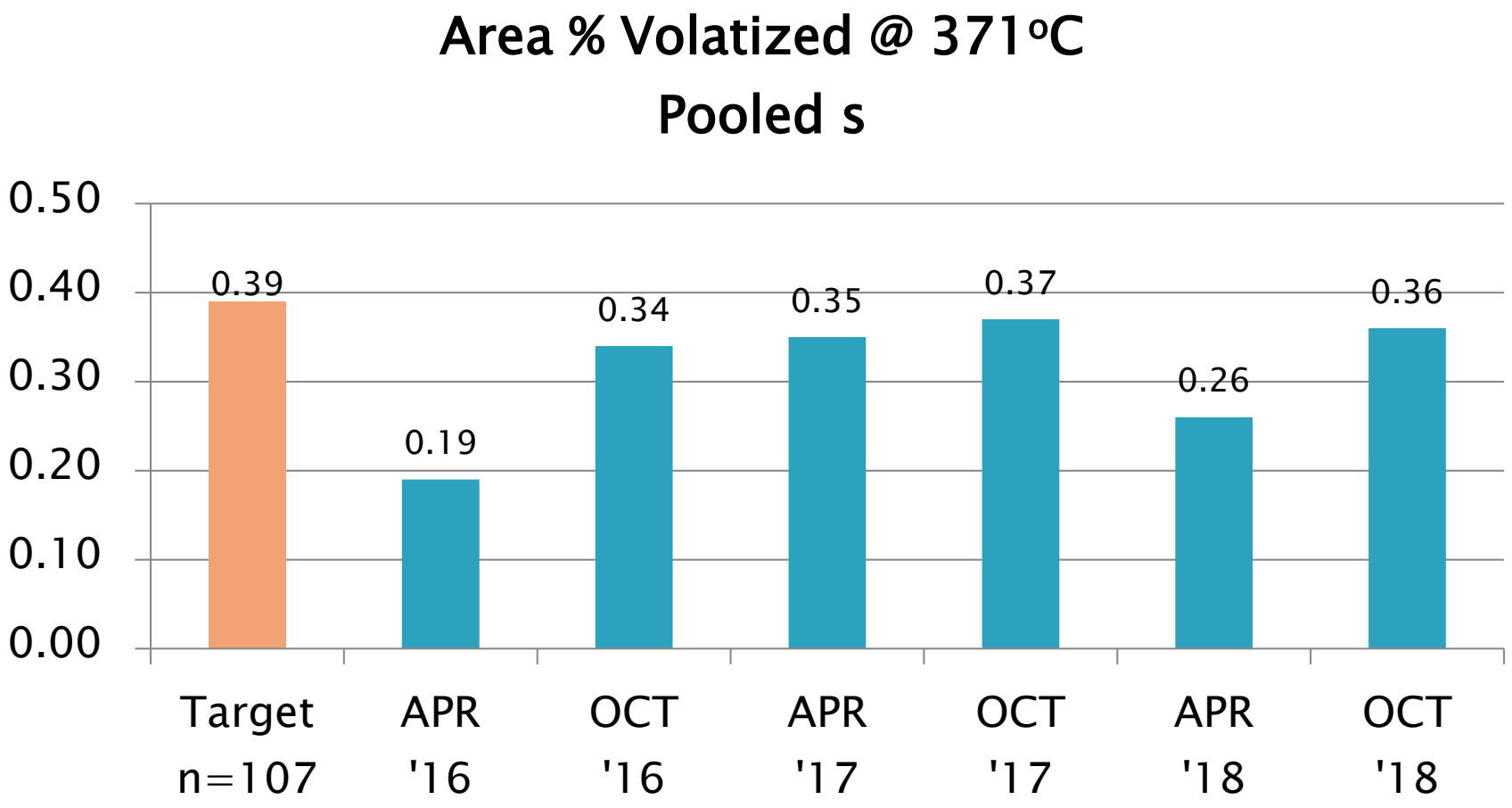
D6417: Estimation of Engine Oil Volatility by Capillary GC

Period Precision and Severity Estimates

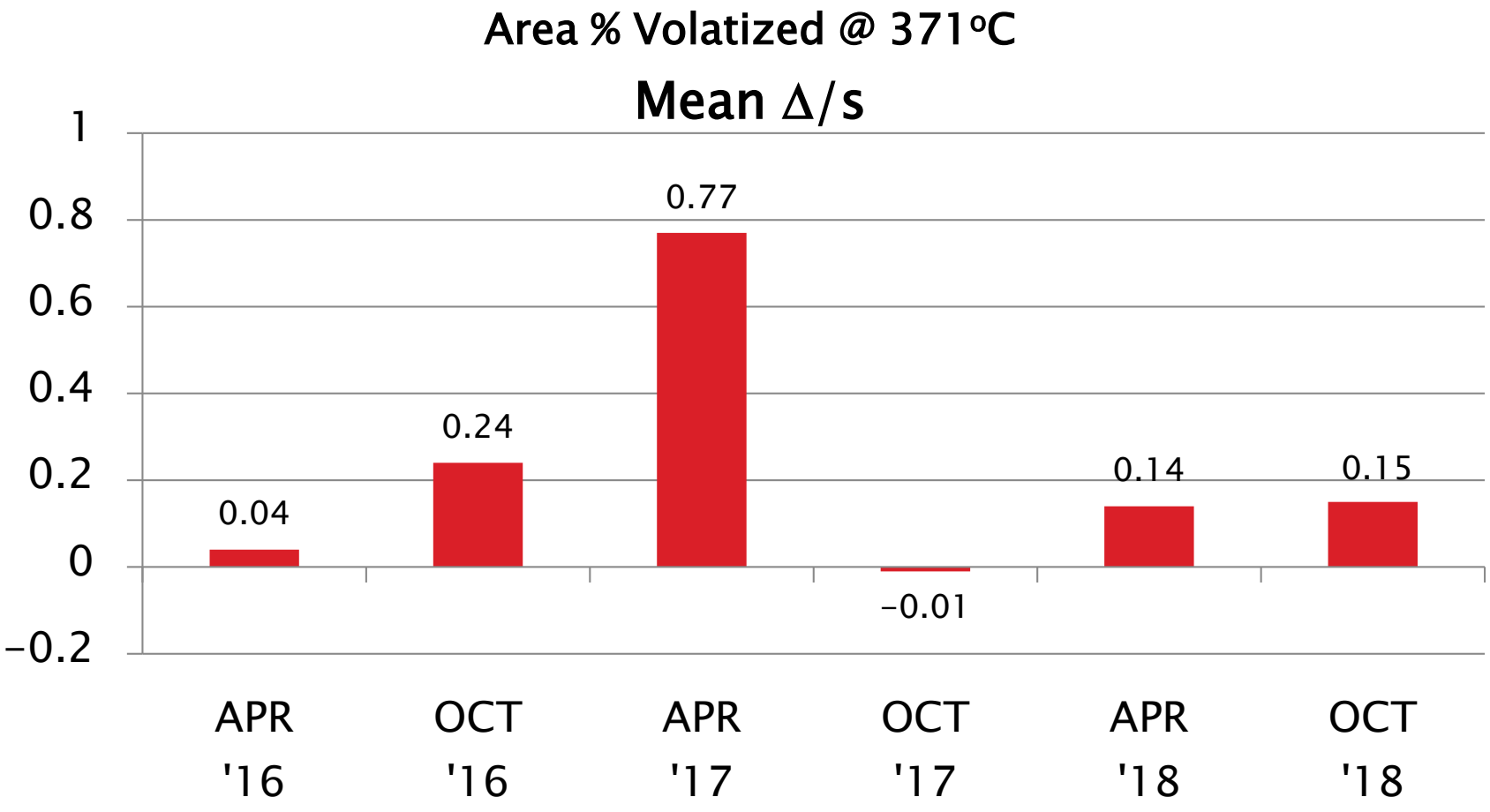
Area % Volatized @ 371°C	n	df	Pooled s	Mean Δ/s
Initial Selected Oils from RR	54	51	0.39	-----
10/1/15 through 3/31/16	13	10	0.19	0.04
4/1/16 through 9/30/16	11	8	0.34	0.24
10/1/16 through 3/31/17	13	10	0.35	0.77
4/1/17 through 9/30/17	15	12	0.37	-0.01
10/1/17 through 3/31/18	15	12	0.26	0.14
4/1/18 through 9/30/18	16	13	0.36	0.15

*Extreme OC result included and excluded

D6417 Precision Estimates



D6417 Severity Estimates

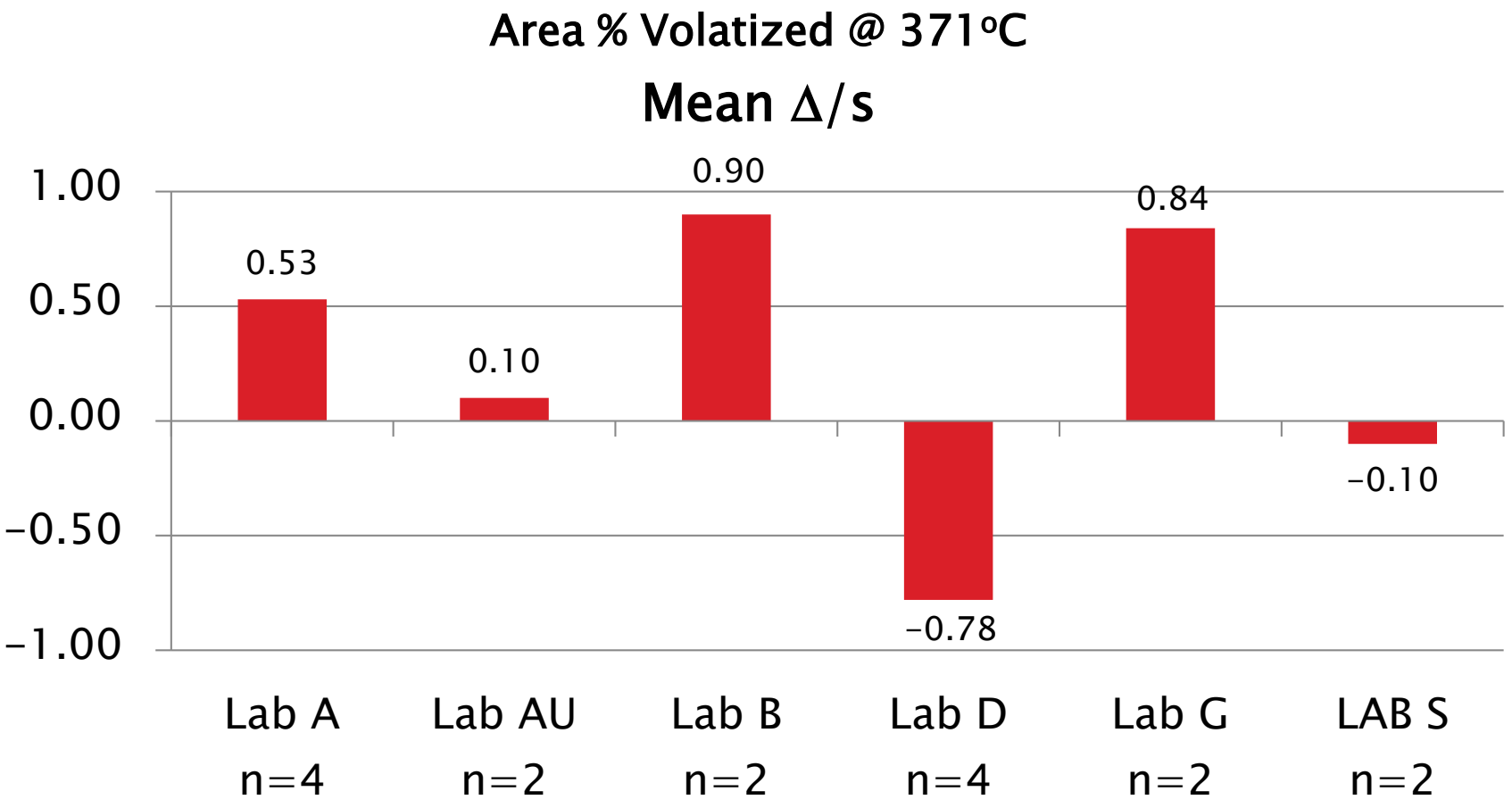


D6417: Estimation of Engine Oil Volatility by Capillary GC

Current Period Severity Estimates by Lab
Area % Volatized @ 371°C

	n	Mean Δ/s
Lab A	4	0.53
Lab AU	2	0.10
Lab B	2	0.90
Lab D	4	-0.78
Lab G	2	0.84
Lab S	2	-0.10

D6417 Lab Severity Estimates

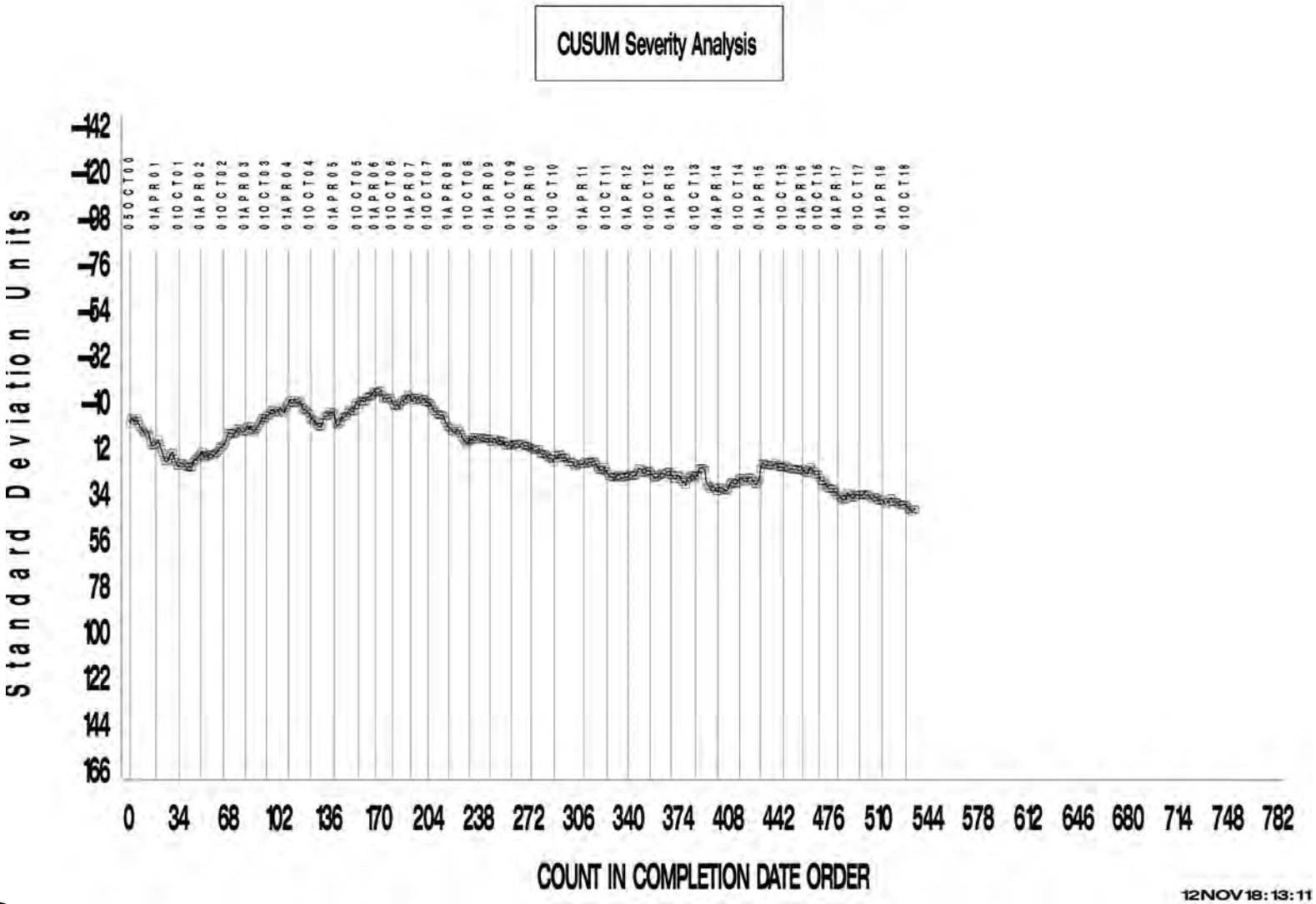


D6417: Estimation of Engine Oil Volatility by Capillary GC

- Precision (Pooled s) is less precise than prior period
  - Comparable to target precision
- Performance (Mean Δ/s) is 0.15 s severe
- CUSUM plot shows overall near on-target performance this period (slightly severe).

D6417 VOLATILITY BY GC INDUSTRY OPERATIONALLY VALID DATA

SAMPLE AREA % VOLATIZED



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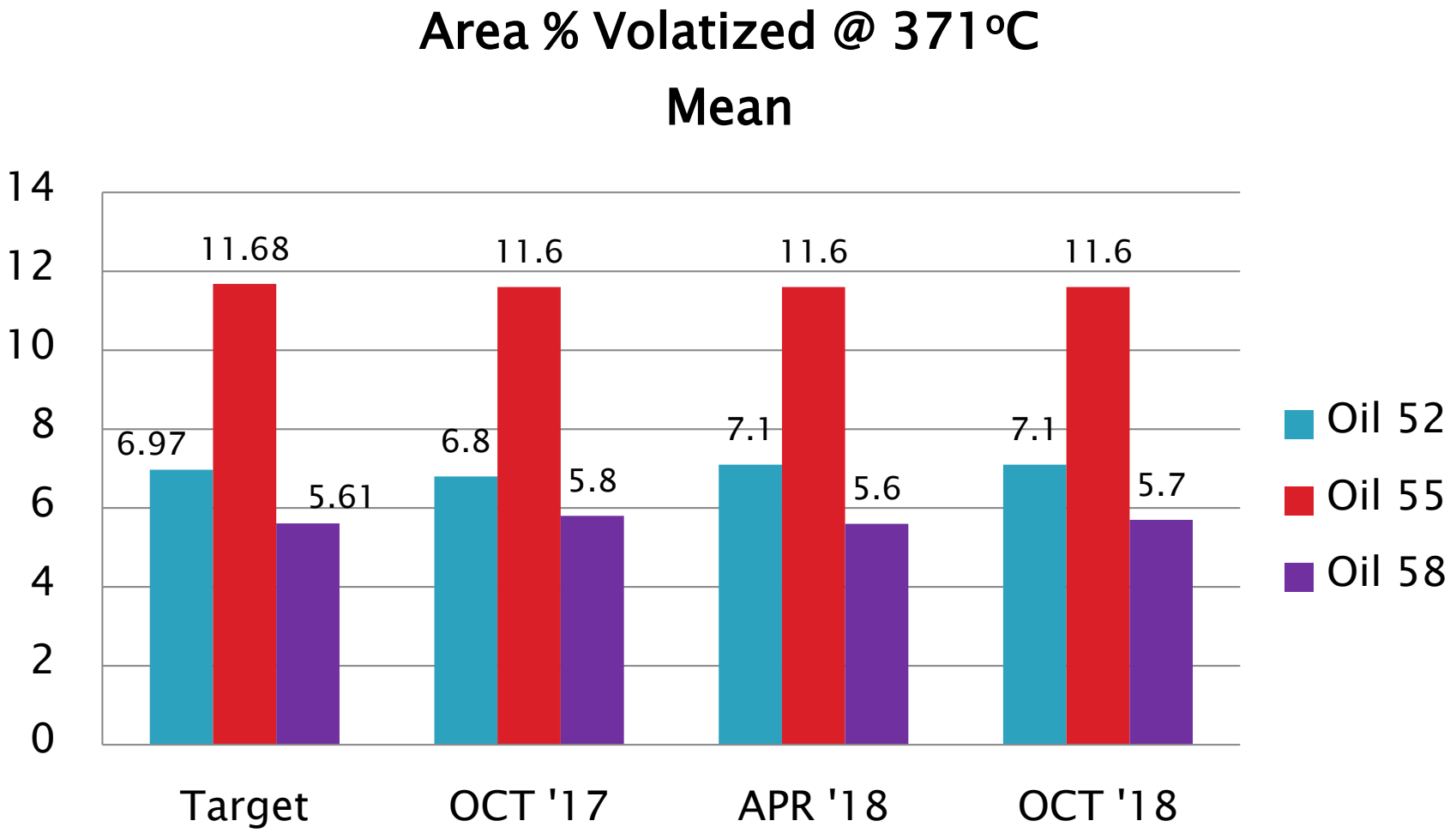
D6417: Estimation of Engine Oil Volatility by Capillary GC

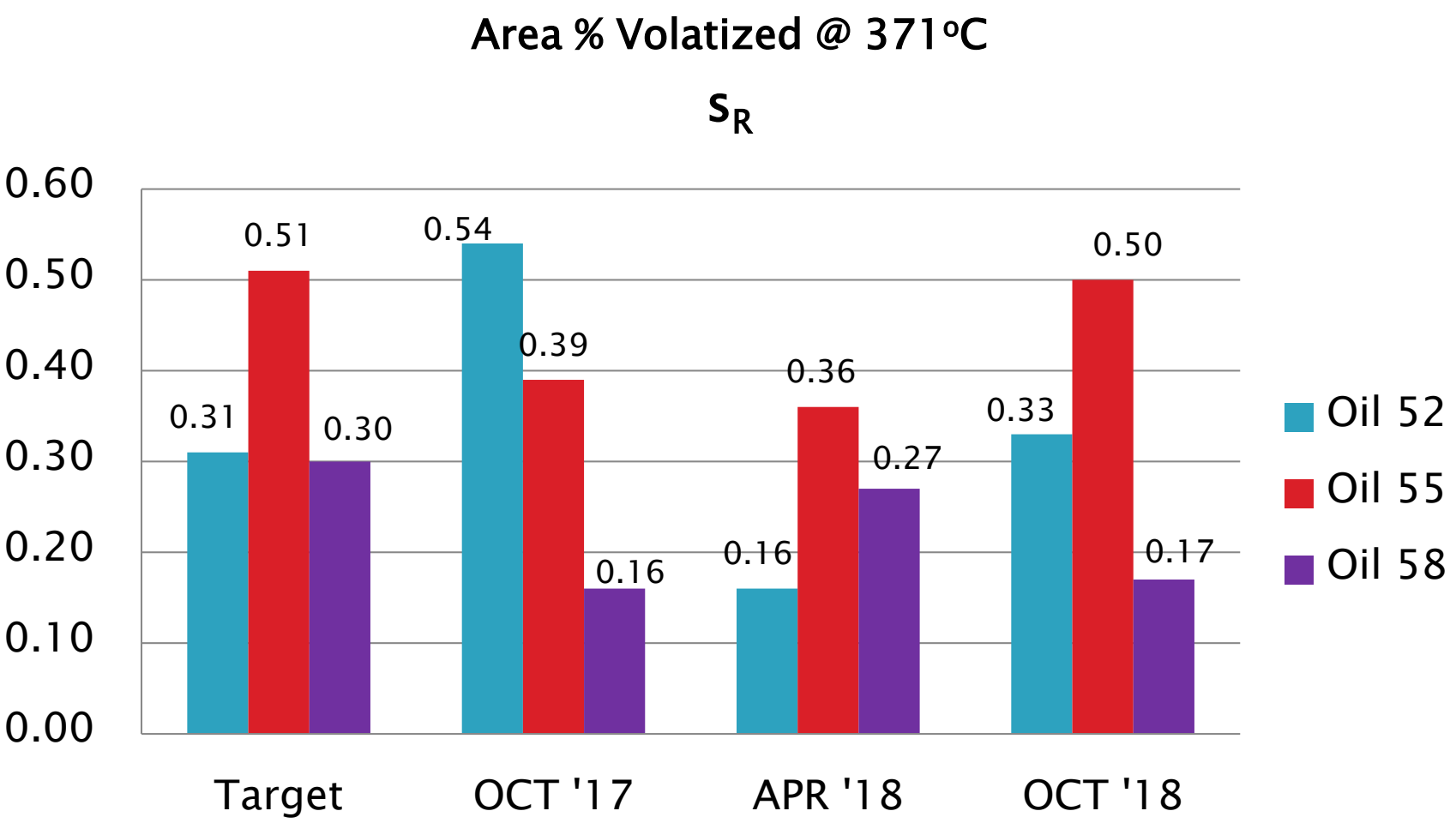
Area % Volatized @ 371°C
Performance by Oil

	Targets			4/1/17- 9/30/17				10/1/17 - 3/31/18				4/1/18- 9/30/18			
Oil Code	n	Mean	s_R	n	Mean	s_R	Mean Δ/s	n	Mean	s_R	Mean Δ/s	n	Mean	s_R	Mean Δ/s
52	18	6.97	0.31	4	6.8	0.54	-0.63	6	7.1	0.16	0.37	4	7.1	0.33	0.34
55	18	11.68	0.51	5	11.6	0.39	-0.08	4	11.6	0.36	-0.16	6	11.6	0.50	-0.06
58	18	5.61	0.30	6	5.8	0.16	0.47	5	5.6	0.27	0.10	6	5.7	0.17	0.24

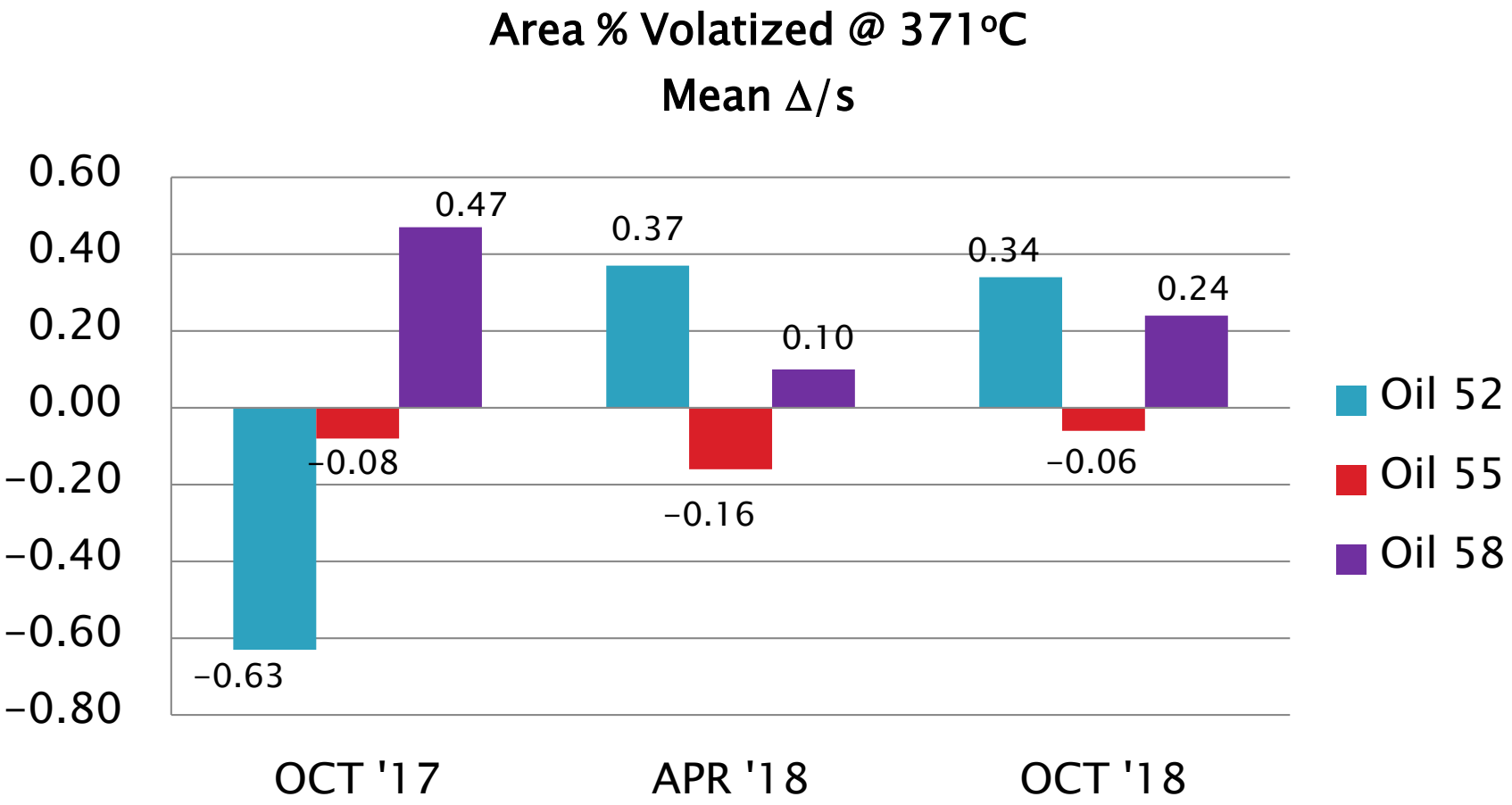
D6417 Performance by Oil



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	142
Failed Calibration Test	OC	7
Operationally Invalidated by Lab	LC, XC	2
Operationally Invalidated After Initially Reported as Valid	RC	3
Non-Blind Instrument Shakedown	NN	3
Replacement Reference Oil RR	AG	13
Total		**170**

Number of Labs Reporting Data: 11
Fail Rate of Operationally Valid Tests: 5%

D5800: Evaporation Loss of Lubricating Oil by Noack Method

Statistically Unacceptable Tests (OC)	No. Of Tests
Ei Level 3 Precision Alarm Mild	1
Ei Level 3 Precision Alarm Severe	1
Zi Level 2 Severity Severe	5
Zi Level 2 Severity Mild	0

- Four OC tests were on four different rigs at four labs.

- Another three OC tests were at lab J, with two consecutive Zi Level 2 severe results on the same instrument.

- Five operationally invalid runs reported this period:
  - Two tests with QC sample either not run, or volatility result was off-spec, on day of TMC calibration (LC, RC)
  - Two procedure D tests where lab reports using wrong orifice size (RC)
  - One test aborted due to pump failure (XC)

D5800: Evaporation Loss of Lubricating Oil by Noack Method

- Three non-blind shakedown runs to troubleshoot instruments.

- Thirteen (and counting) industry donated runs to evaluate proposed replacement QC check oil batch VOLD18.

- There were two technical updates issued this report period.

  - Memo 18-017, June 13, 2018: Updated Test Method D5800-18

  - Memo 18-028, August 30, 2108: Updated Test Method D5800-18A

- 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	-----
10/1/15 through 3/31/16	57	54	0.50	1.08
4/1/16 through 9/30/16	62	59	0.60	0.99
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

*Extreme OC result included and excluded

D5800: Evaporation Loss of Lubricating Oil by Noack Method

Performance Comparison by Procedure & Model

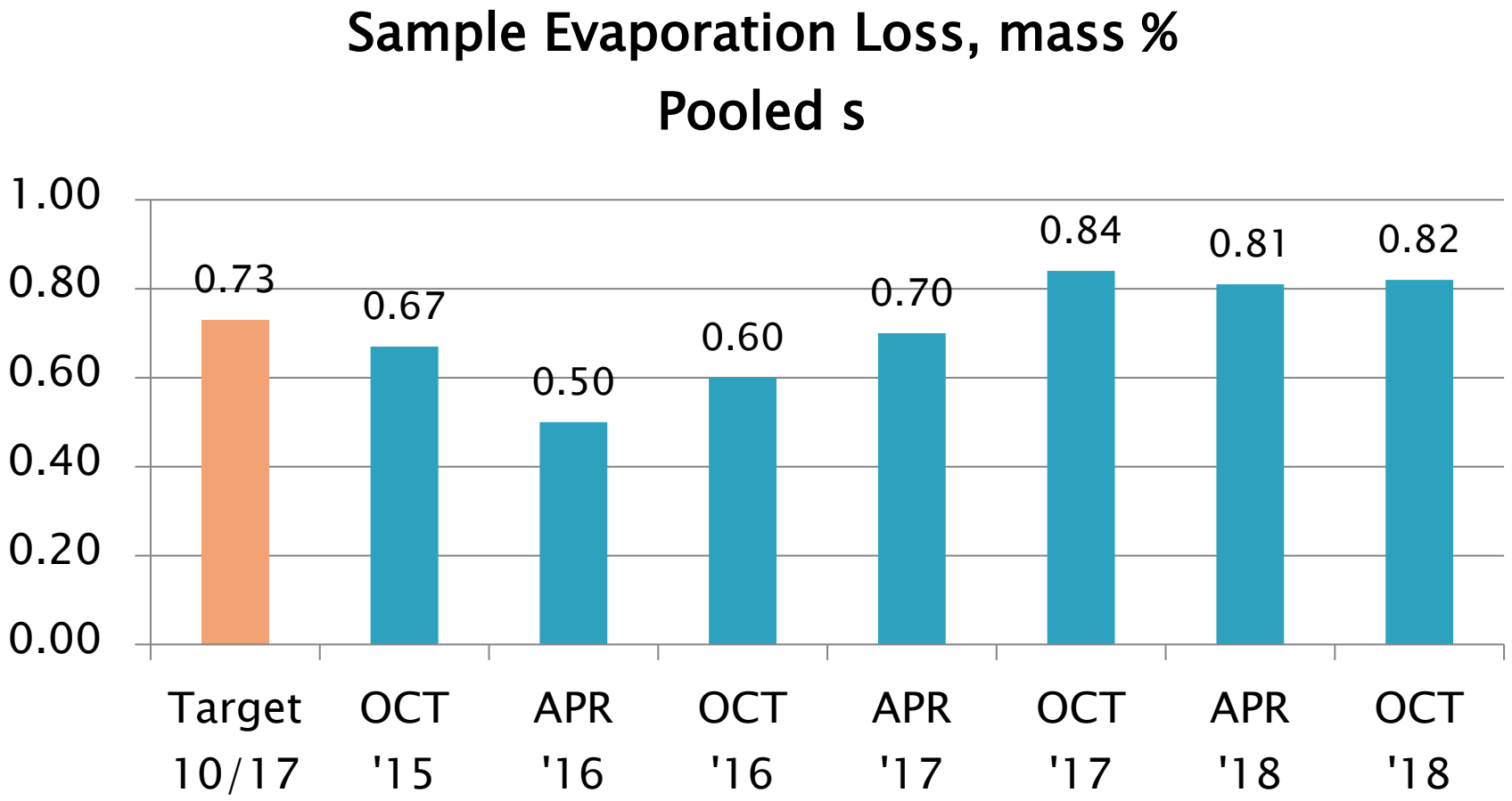
Sample Evaporation Loss, Mass %

	n	df	Pooled s	Mean Δ/s
Procedure B	128	125	0.72	0.61
Procedure C	16	13	0.88	-0.99
Procedure D	5	2	0.57	-0.41

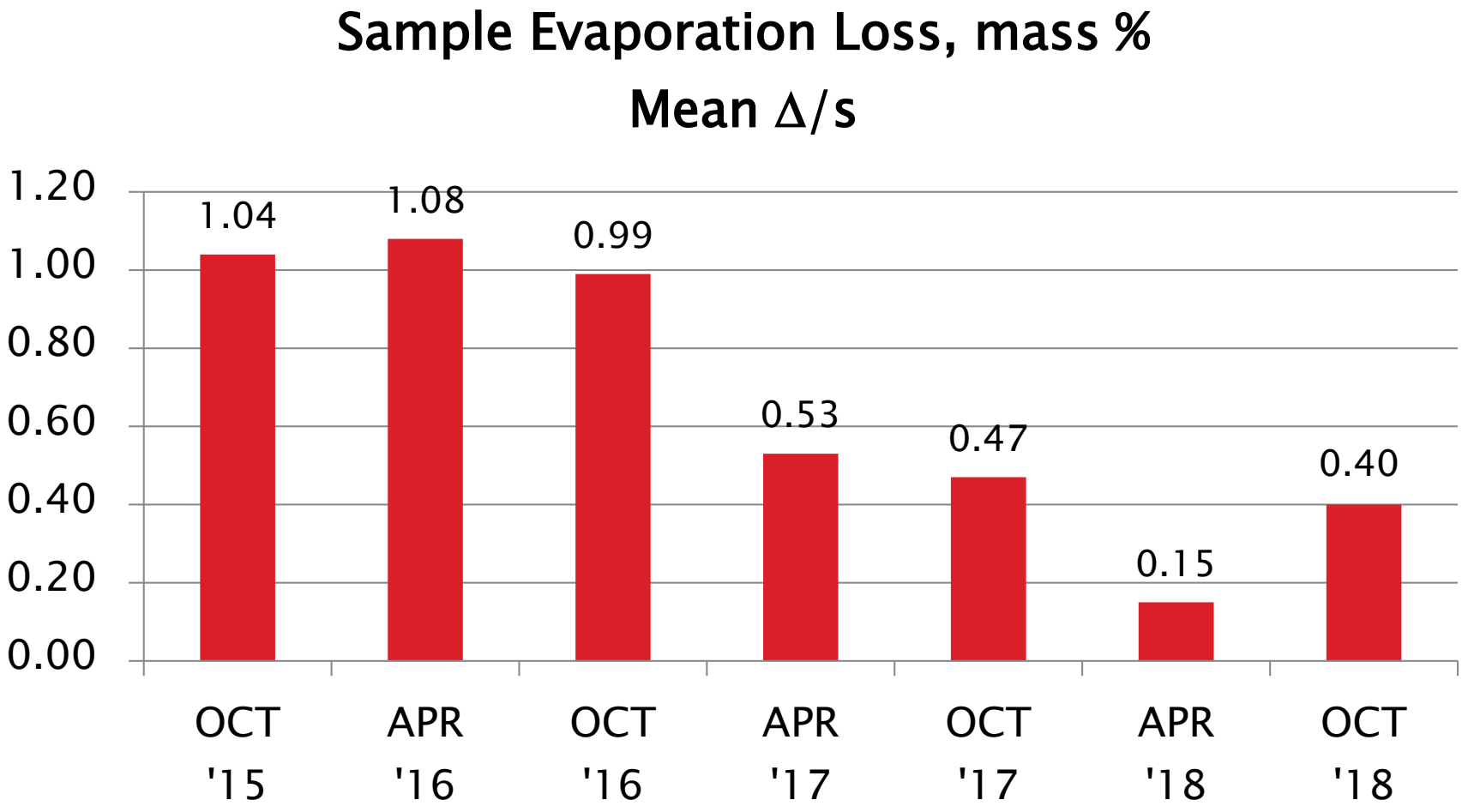
Model	n	df	Pooled s	Mean Δ/s
NCK2	11	8	0.36	0.25
NCK25G	117	114	0.75	0.64
NS2	5	2	0.57	-0.41
SVT1	16	13	0.88	-0.99

2 NCK2 Rigs
26 NCK25G Rigs
3 NS2 Rigs
3 SVT1 Rigs

D5800 Precision Estimates



D5800 Severity Estimates



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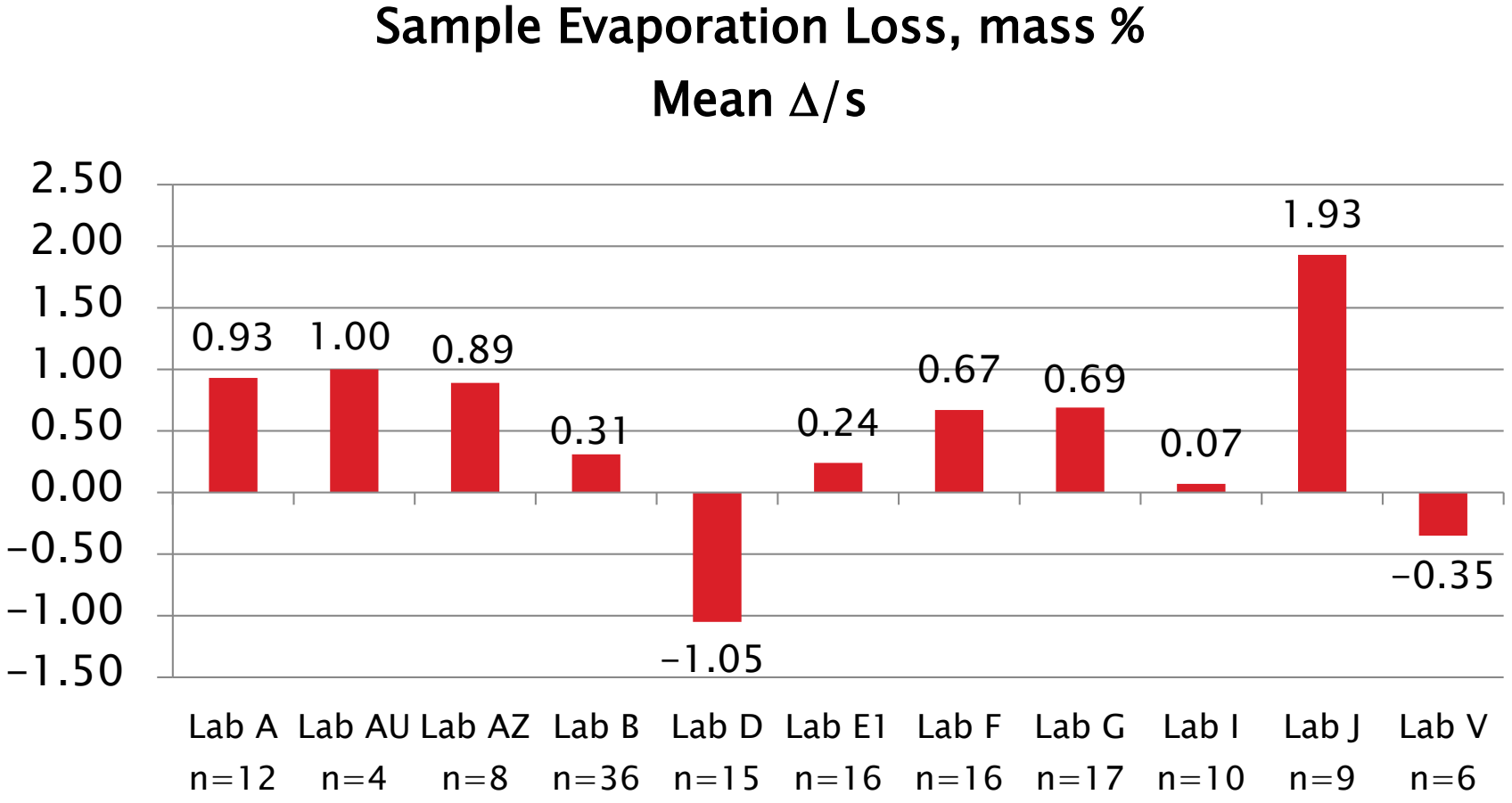
D5800: Evaporation Loss of Lubricating Oil by Noack Method

Current Period Severity Estimates by Lab
Sample Evaporation Loss, mass %

Lab	n	Mean Δ/s	Lab	n	Mean Δ/s
Lab A	12	0.93	Lab F	16	0.67
Lab AU	4	1.00	LAB G	17	0.69
Lab AZ	8	0.89	Lab I	10	0.07
Lab B	36	0.31	Lab J	9	1.93
Lab D	15	-1.05	Lab V	6	-0.35
Lab E1	16	0.24			

D5800 Lab Severity Estimates



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D5800: Evaporation Loss of Lubricating Oil by Noack Method

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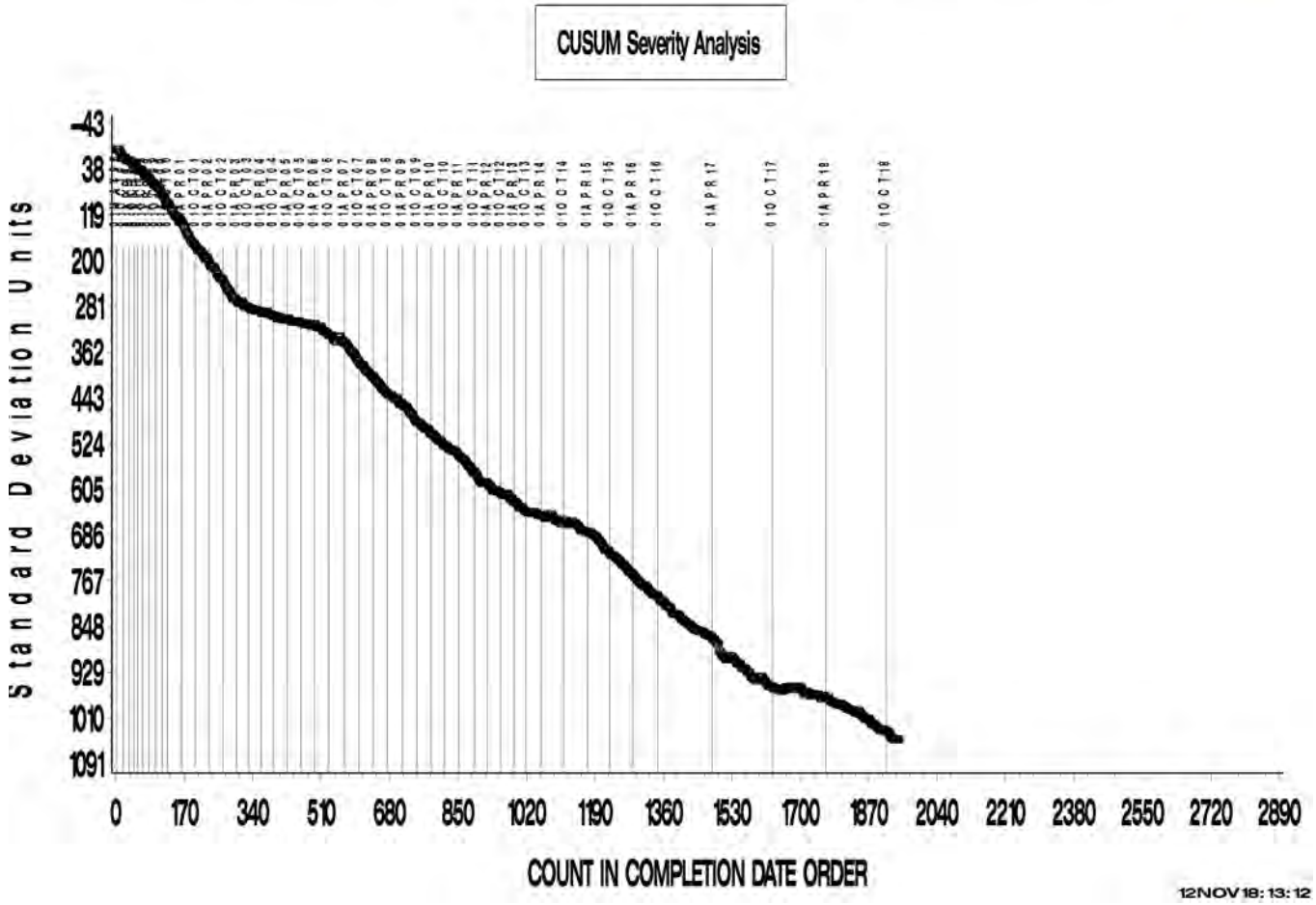
- Performance (Mean Δ/s) is 0.40 s severe.
- Lab G, Rig 5, reported one result more than -5 s mild (oil VOLE12), followed by a number of passing calibrations during the period. Precision and severity are shown with this result included and excluded, though it has little overall impact due to the high number of D5800 results reported for the period.
- Fail rate of operationally valid tests (AC & OC) has dropped to 5% or less for the most recent four report periods using EWMA LTMS, compared to 26% under the Shewhart severity only system.
- CUSUM plot showed some leveling (mean 0.15 s severe) last period for the first time since a brief period in 2014, but a modest increase in severity returns this period (mean 0.40 s severe). With EWMA LTMS monitoring, since 20161019, D5800 non-reference results are severity adjusted by instrument, with SA's updated by LTMS calibration evaluation.

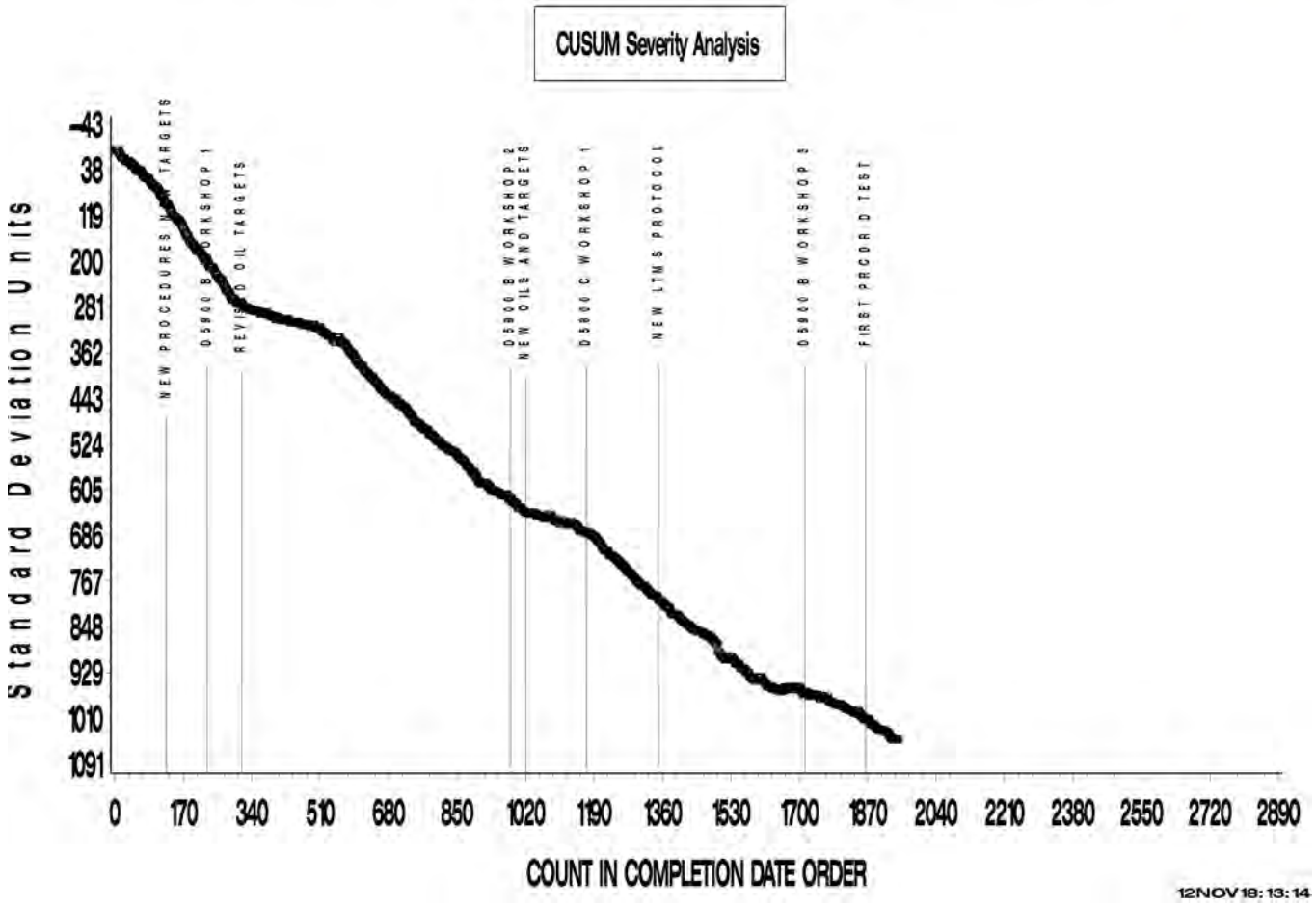
D5800 VOLATILITY BY NOACK INDUSTRY OPERATIONALLY VALID DATA

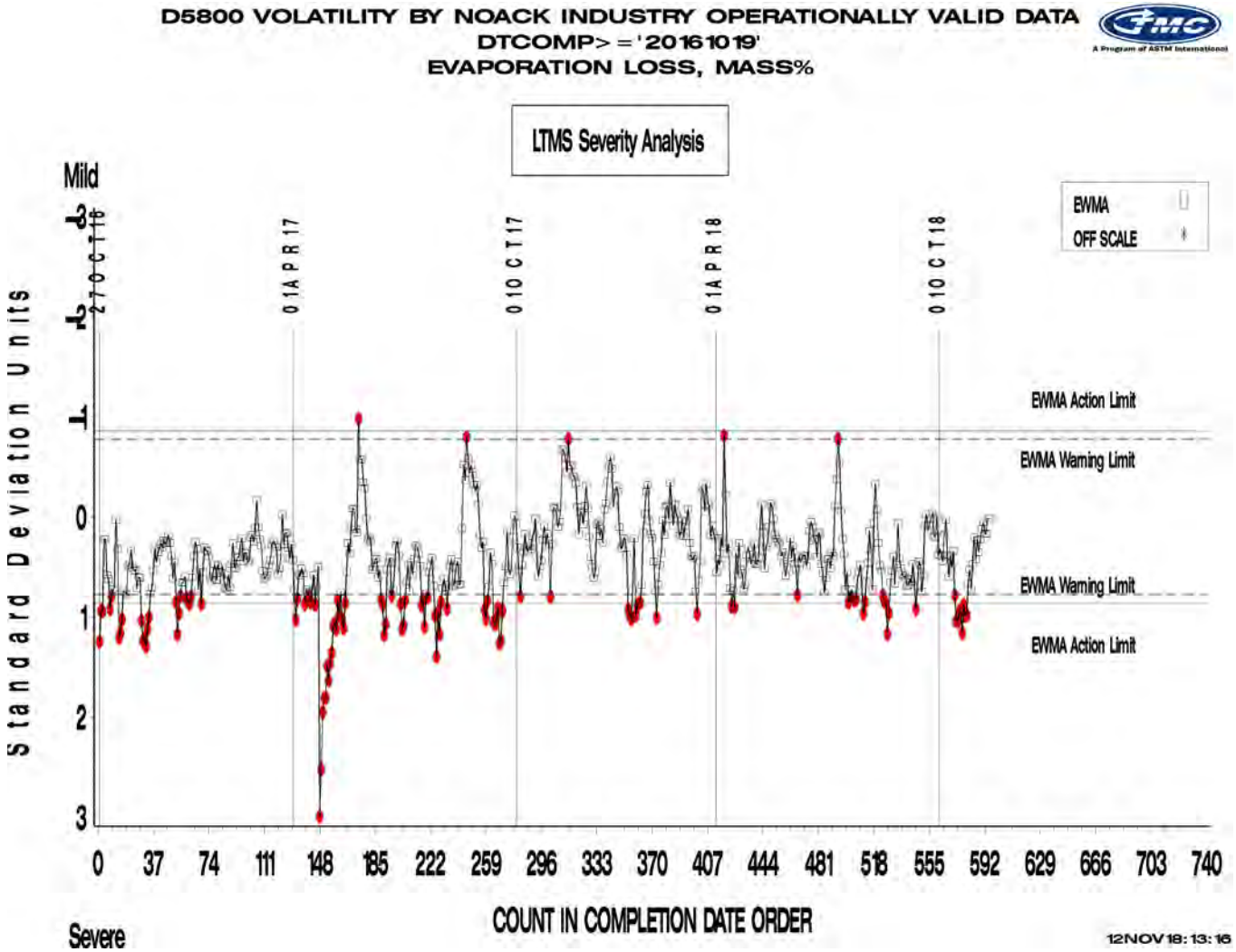
EVAPORATION LOSS, MASS%



D5800 VOLATILITY BY NOACK INDUSTRY OPERATIONALLY VALID DATA

EVAPORATION LOSS, MASS%




D5800 VOLATILITY BY NOACK INDUSTRY OPERATIONALLY VALID DATA
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EVAPORATION LOSS, MASS%
LTMS Severity Analysis
Mild
Severe
Standard Deviation Units
EWMA
OFF SCALE
EWMA Action Limit
EWMA Warning Limit
EWMA Warning Limit
EWMA Action Limit
27OCT16
01APR17
01OCT17
01APR18
01OCT18
3
2
1
0
1
2
3
0 37 74 111 148 185 222 259 296 333 370 407 444 481 518 555 592 629 666 703 740
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D5800 VOLATILITY BY NOACK INDUSTRY OPERATIONALLY VALID DATA
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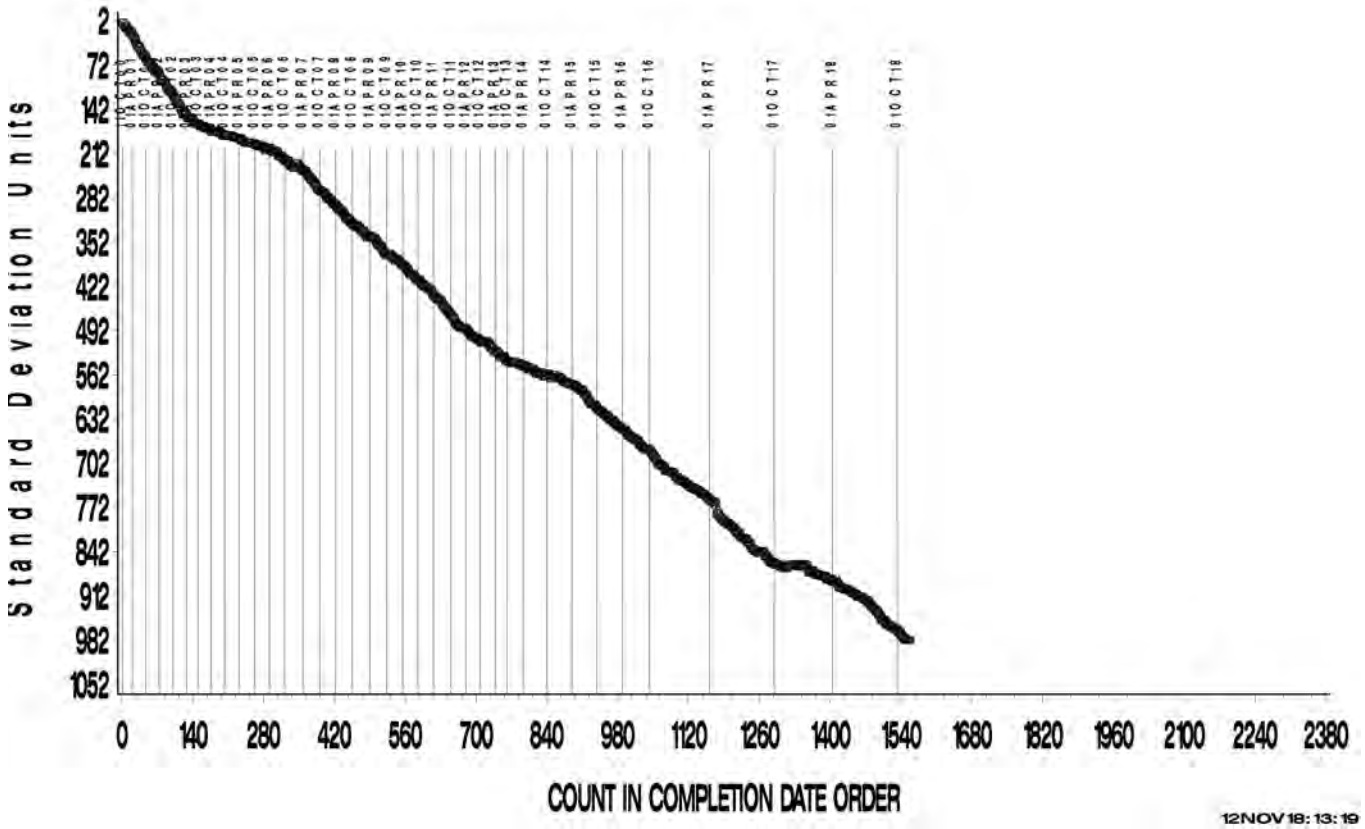
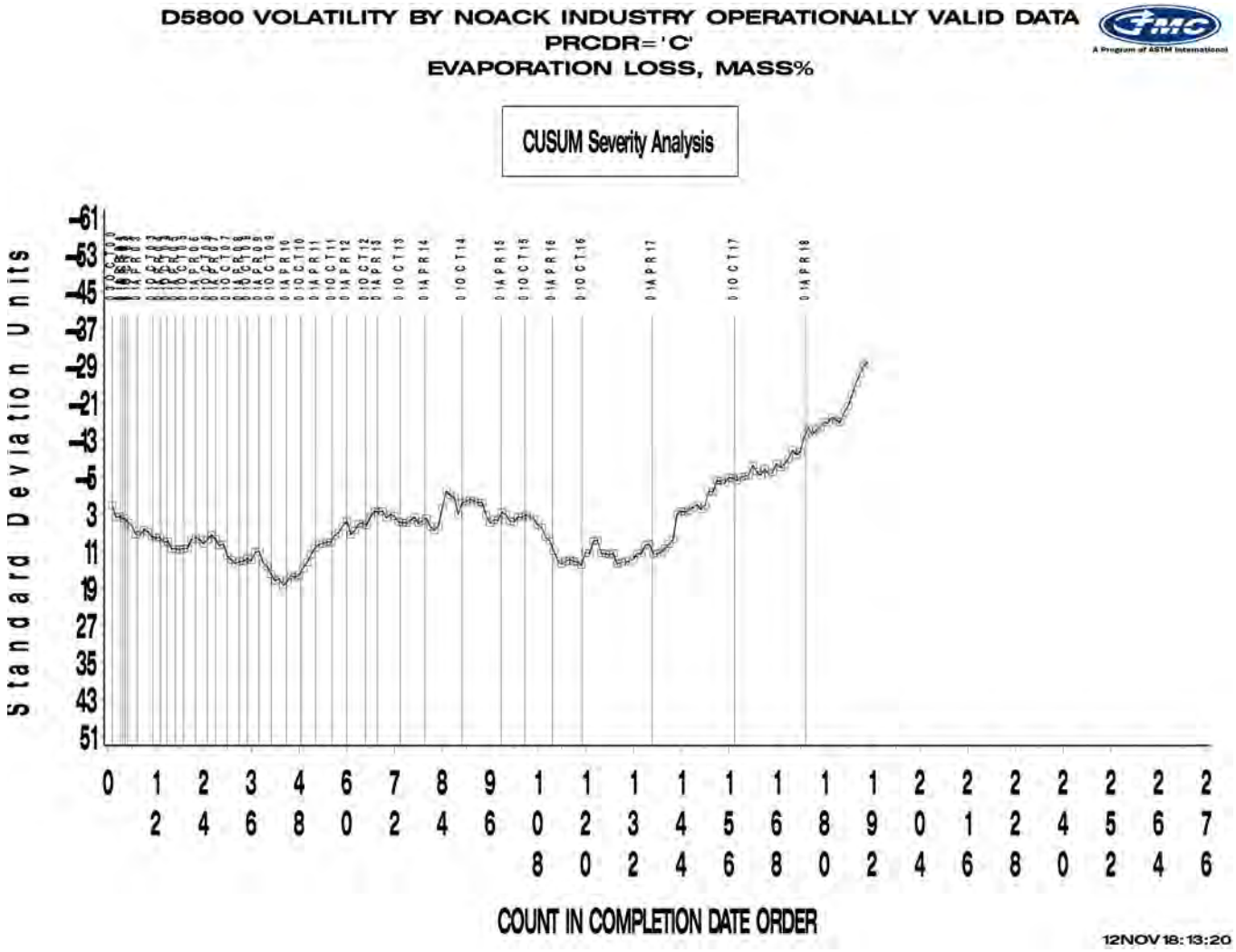
EVAPORATION LOSS, MASS%

CUSUM Severity Analysis




D5800 VOLATILITY BY NOACK INDUSTRY OPERATIONALLY VALID DATA
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EVAPORATION LOSS, MASS%
CUSUM Severity Analysis
Standard Deviation Units
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D5800 VOLATILITY BY NOACK INDUSTRY OPERATIONALLY VALID DATA
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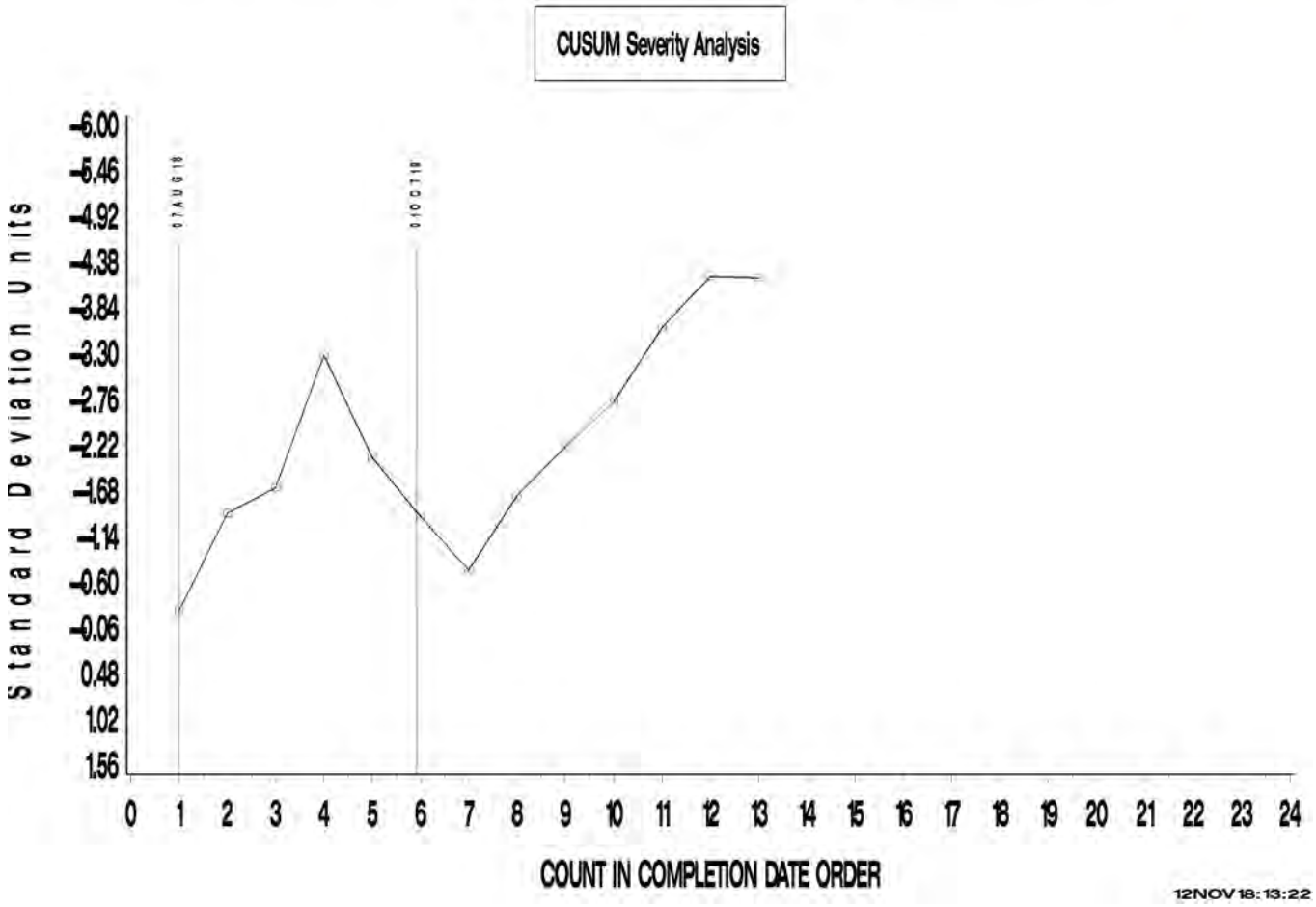
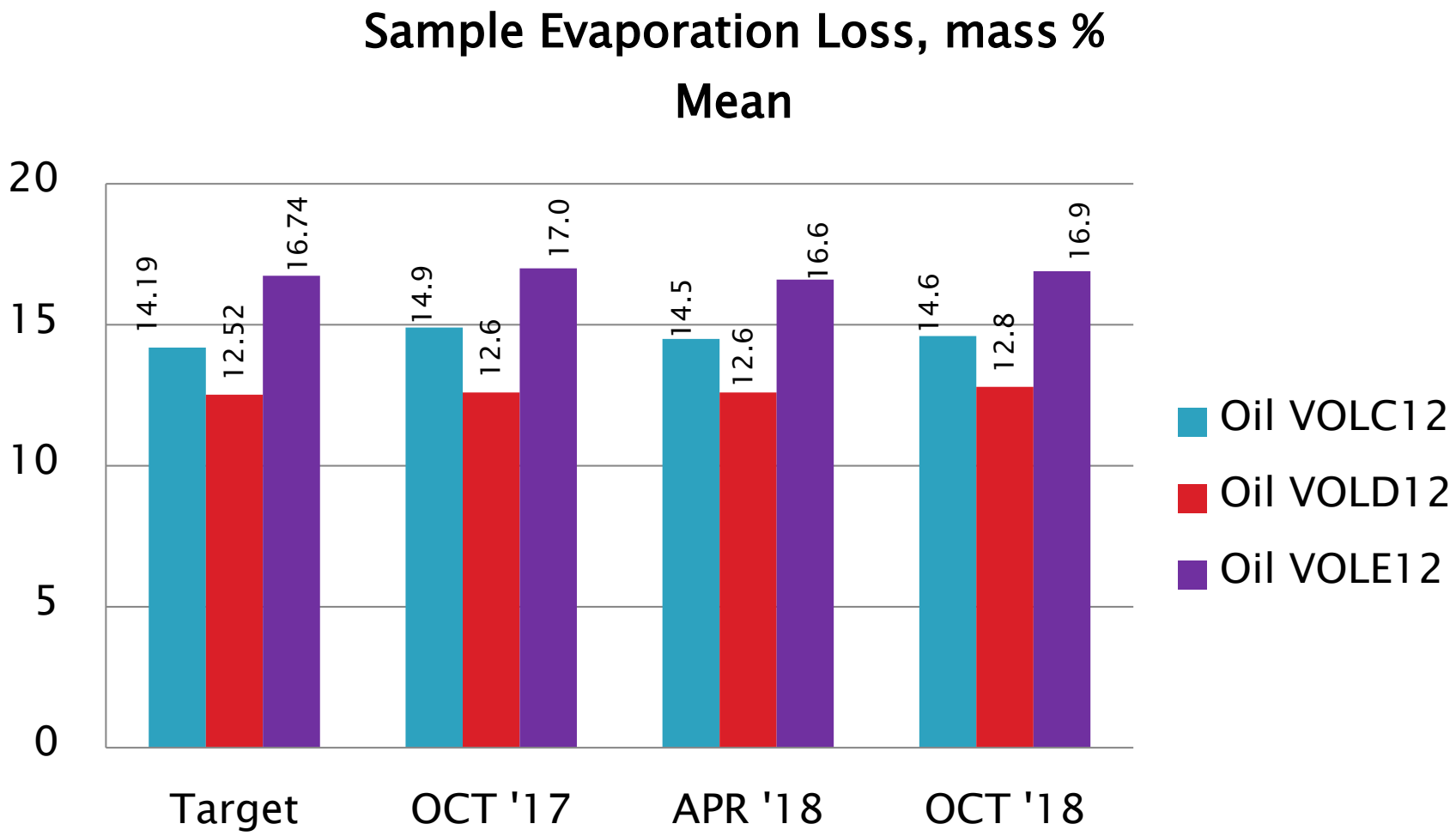


D5800: Evaporation Loss of Lubricating Oil by Noack Method

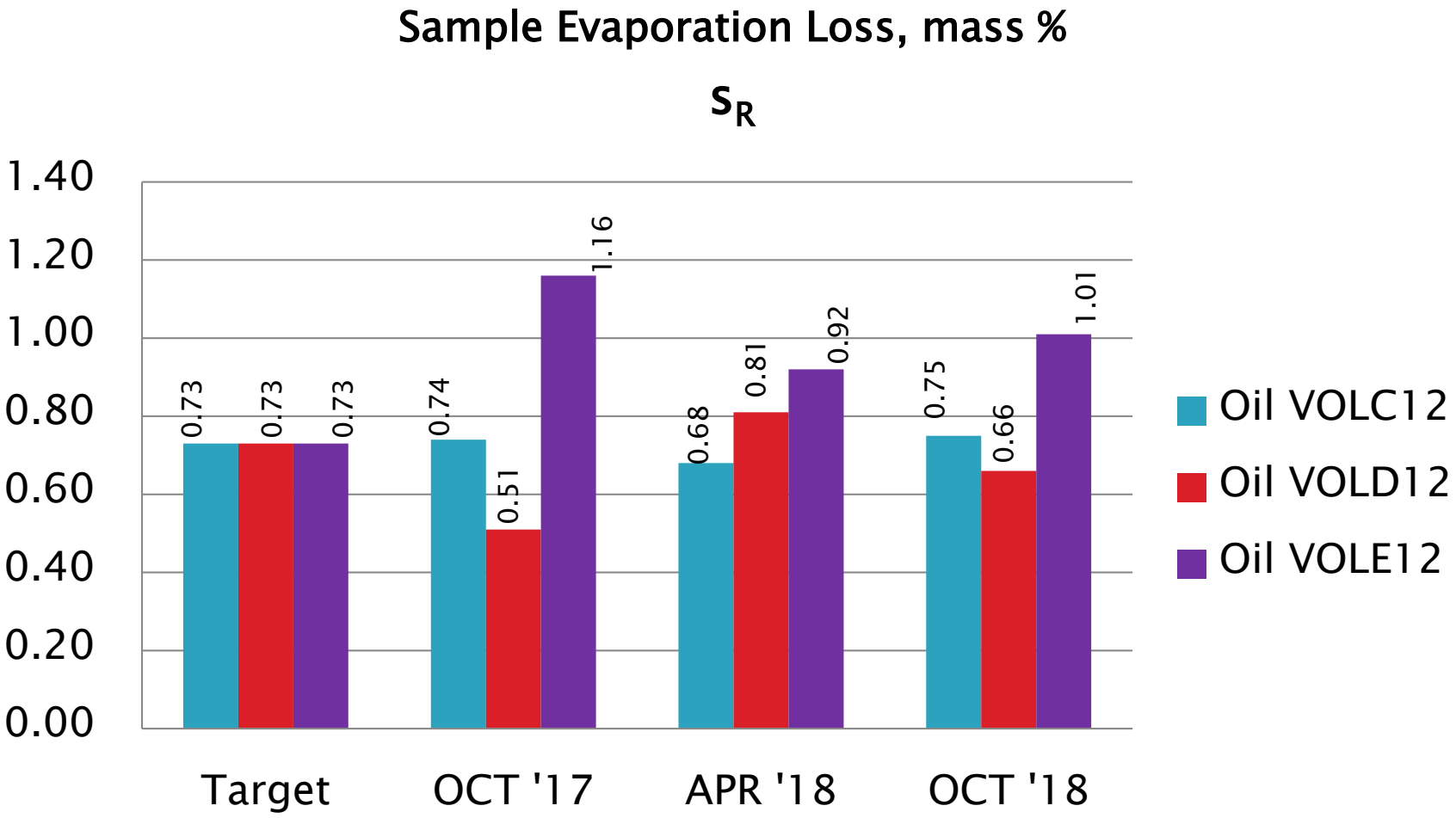
Sample Evaporation Loss, mass %
Performance by Oil

	Targets			4/1/17 – 9/30/17				10/1/17– 3/31/18				4/1/18 – 9/30/18			
Oil Code	n	Mean	s_R	n	Mean	s_R	Mean Δ/s	n	Mean	s_R	Mean Δ/s	n	Mean	s_R	Mean Δ/s
VOLC12	24	14.19	0.73	46	14.9	0.74	0.92	44	14.5	0.68	0.43	52	14.6	0.75	0.54
VOLD12	27	12.52	0.73	51	12.6	0.51	0.14	45	12.6	0.81	0.15	46	12.8	0.66	0.45
VOLE12	27	16.74	0.73	49	17.0	1.16	0.40	44	16.6	0.92	-0.13	51	16.9	1.01	0.22

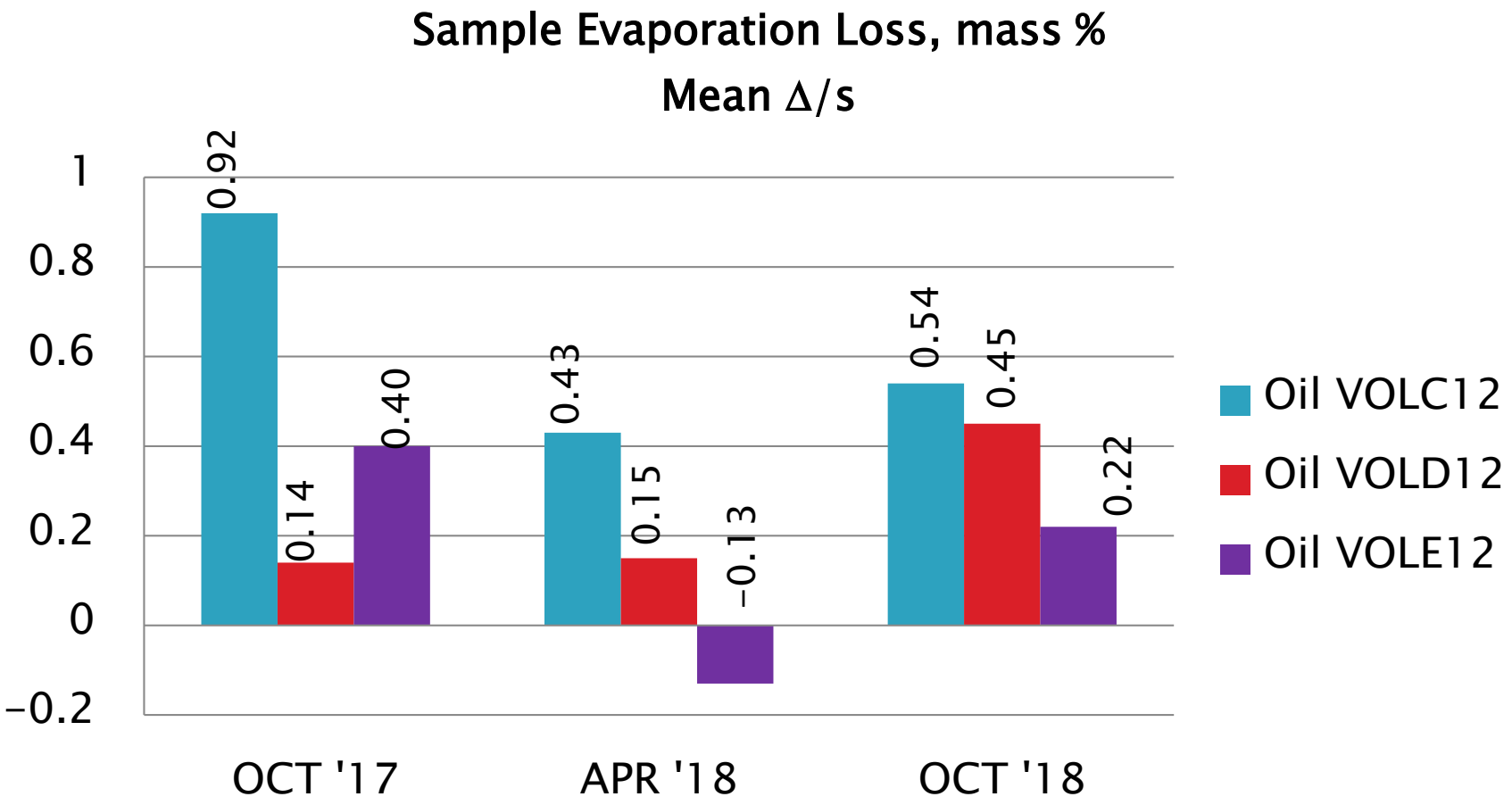
D5800 Performance by Oil



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	30
Failed Calibration Test	OC	2
Operationally Invalidated by Lab	LC, XC	1
Operationally Invalidated After Initially Reported as Valid	RC	1
Replacement Reference Oil RR	AG, LG, XG	44
Total		**78**

Number of Labs Reporting Data: 9
Fail Rate of Operationally Valid Tests: 6%

D5133: Gelation Index

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

- Two operationally invalid calibration runs reported this period:
  - One aborted due to data acquisition failure (XC).
  - One declared invalid because lab failed to run an internal calibration check on the rig within the past year (RC).

- Forty-four industry donated runs to evaluate proposed replacement reference oils for TMC oil 62.

D5133: Gelation Index

- Lab/rig AM 1 (new rig) ran numerous shakedowns last period to confirm performance of all heads.
  - Lab has not yet proceeded to a blind calibration.

- No TMC technical updates were issued this period

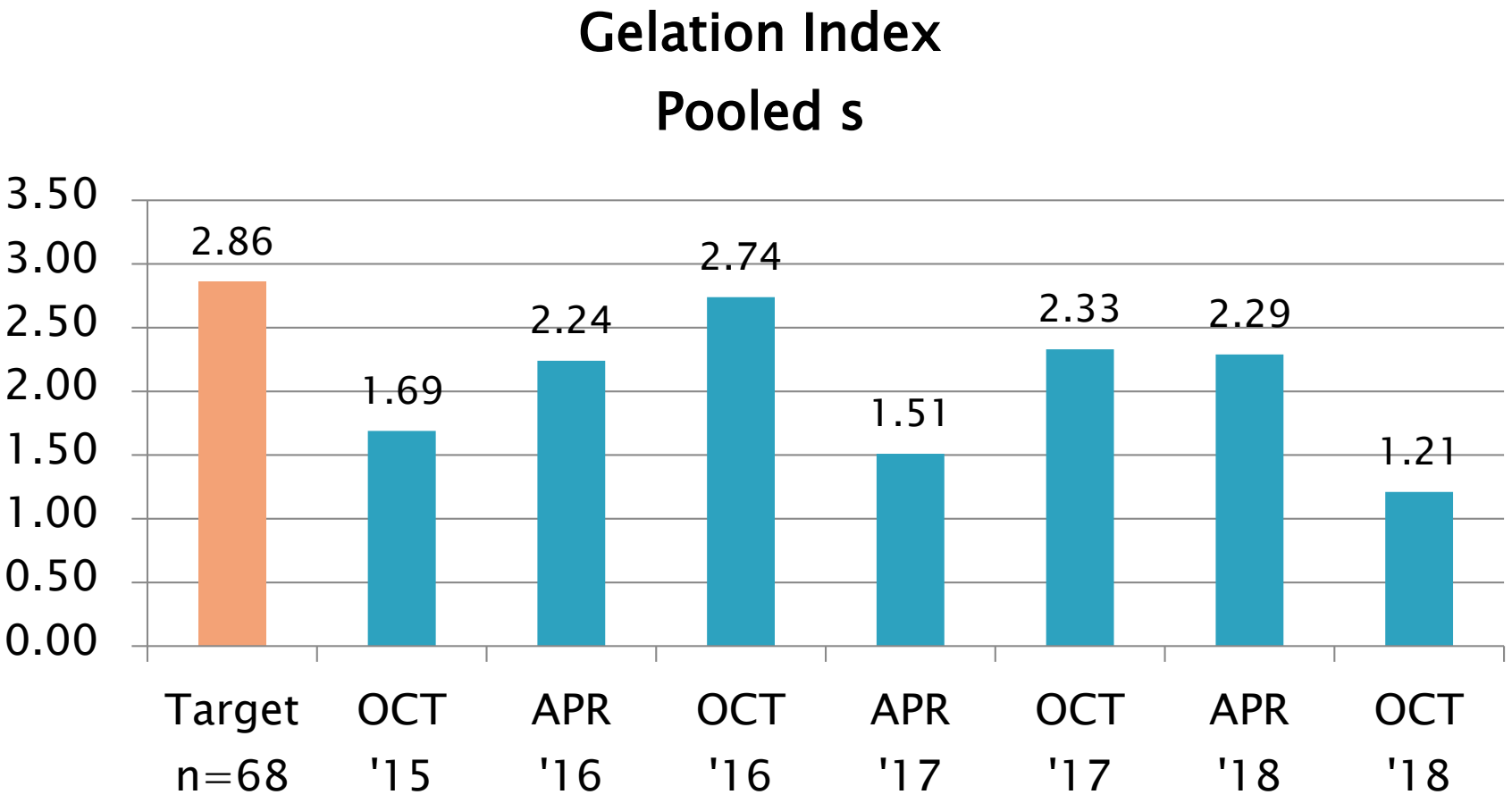
D5133: Gelation Index

Period Precision and Severity Estimates

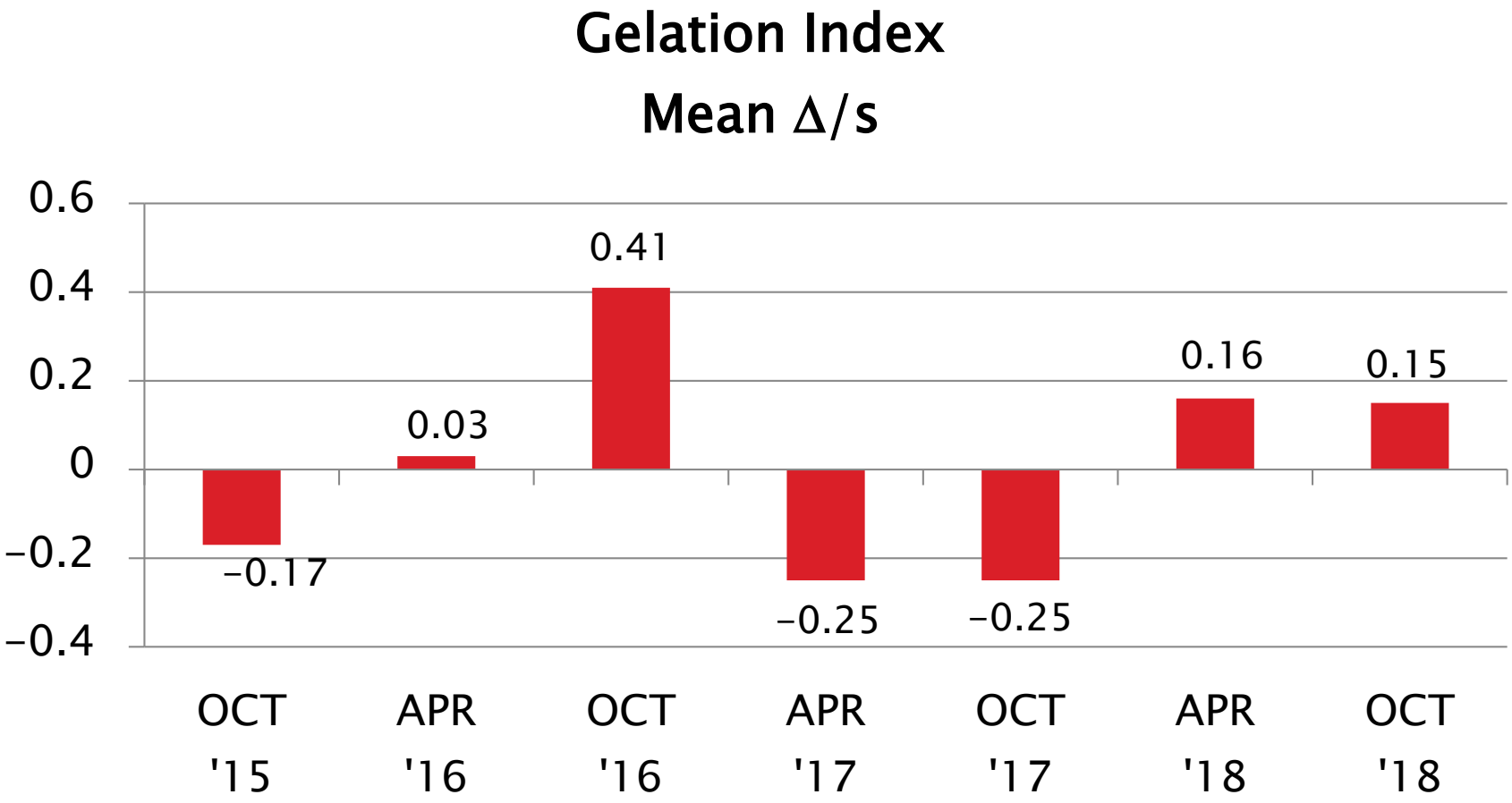
Gelation Index	n	df	Pooled s	Mean Δ/s
Current Targets 7/15/2003	68	65	2.86	-----
10/1/15 through 3/31/16	31	28	2.24	0.03
4/1/16 through 9/30/16	31	28	2.74	0.41
10/1/16 through 3/31/17	35	32	1.51	-0.25
4/1/17 through 9/30/17* 4/1/17 through 9/30/17*	30 29	27 26	4.69 2.33	-0.08 -0.25
10/1/17 through 3/31/18	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

*Extreme OC result included and excluded

D5133 Precision Estimates



D5133 Severity Estimates



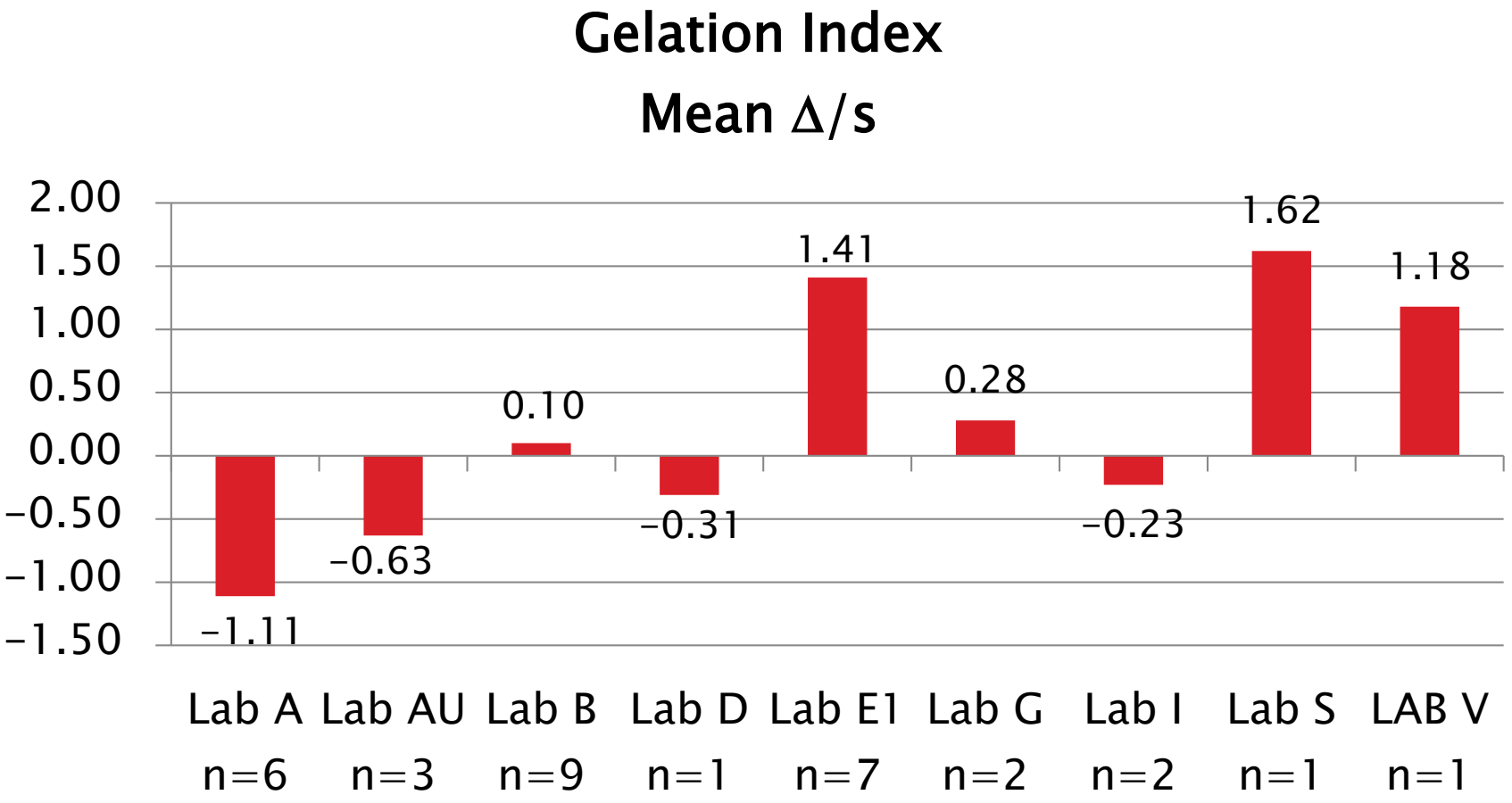
D5133: Gelation Index

Current Period Severity Estimates by Lab

Gelation Index

	n	Mean Δ/s
Lab A	6	-1.11
Lab AU	3	-0.63
Lab B	9	0.10
Lab D	1	-0.31
Lab E1	7	1.41
Lab G	2	0.28
Lab I	2	-0.23
Lab S	1	1.62
Lab V	1	1.18

D5133 Lab Severity Estimates



D5133: Gelation Index

- Fail rate of operationally valid tests is 6% this period. Fail rates the prior three periods had been between 10% and 26%. Five periods back the fail rate was also 6%.
- Overall severity is 0.15 s severe (on target at -0.02 s mild with one extreme result from Instrument E1 2 excluded).
- Precision (Pooled s), is more precise than target precision, and more precise than all report periods since at least April 2016, even with one extreme result included.
- Lab E1, Rig 2, reported one result more than 5 s severe (oil 1009), both preceded and followed by passing calibrations. However, the same instrument had two failing results last period that were 4 s severe, and the same lab (E1) last period reported three consecutive failing runs on their Rig 1 (non-gelling oil 58), and later, two consecutive fails on oil 1009.

D5133: Gelation Index

- The calibration performance of instrument E1 2 this period and last, instrument E1 1 last period, as well as past similar experiences with other instruments, 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 these instruments, after demonstrating multiple failing results, should subsequently be considered properly calibrated based on just one passing test result on just one viscometer head.
- The precision on oil 62 is much better than target precision for that oil this period, while oil 1009 precision this period is notably less precise than target.
- Oli 62 is in low supply, a round robin has been completed to evaluate two oils as possible replacements. The surveillance panel has not yet convened to discuss the results.

D5133 GELATION INDEX INDUSTRY OPERATIONALLY VALID DATA

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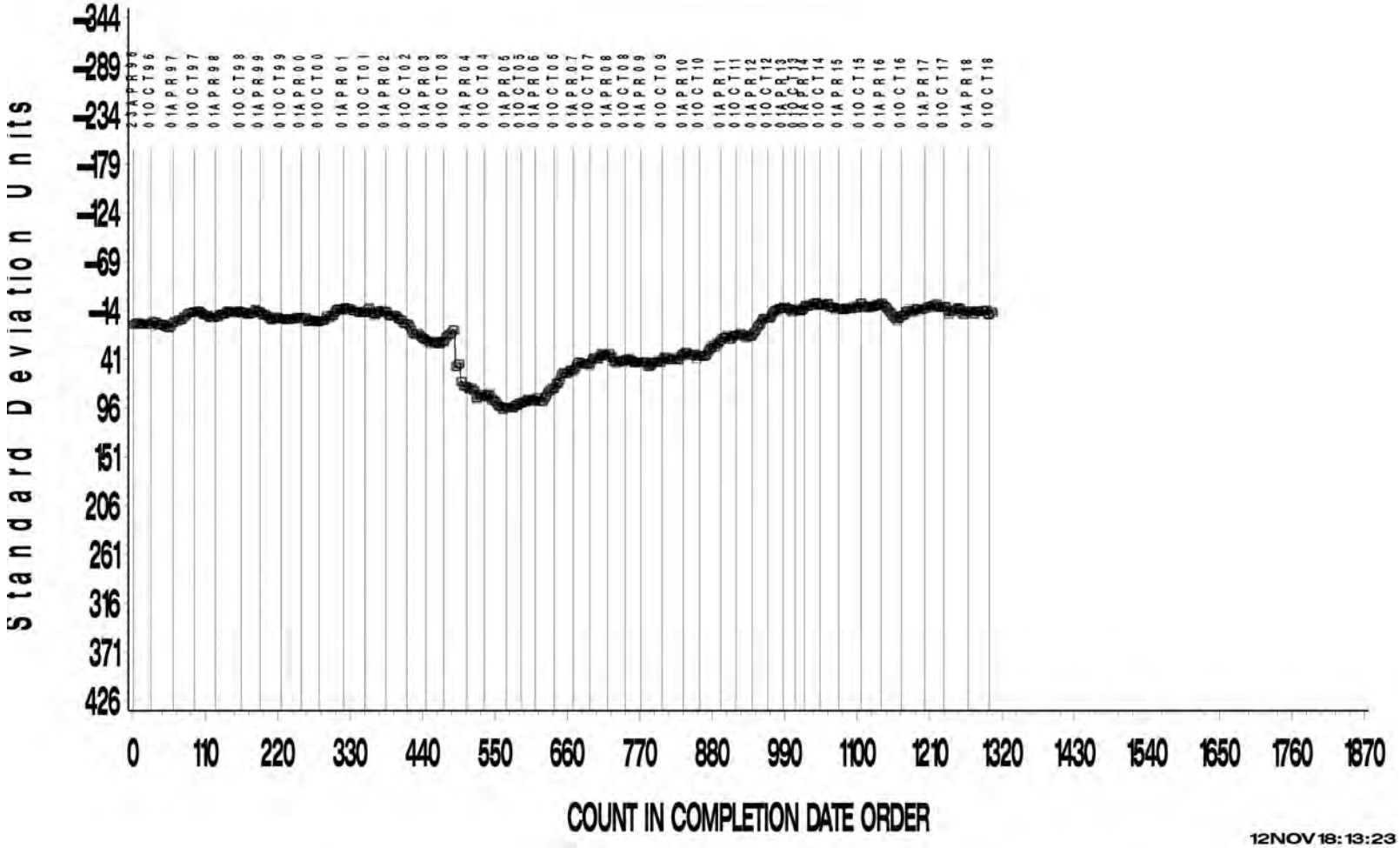
GELATION INDEX

CUSUM Severity Analysis



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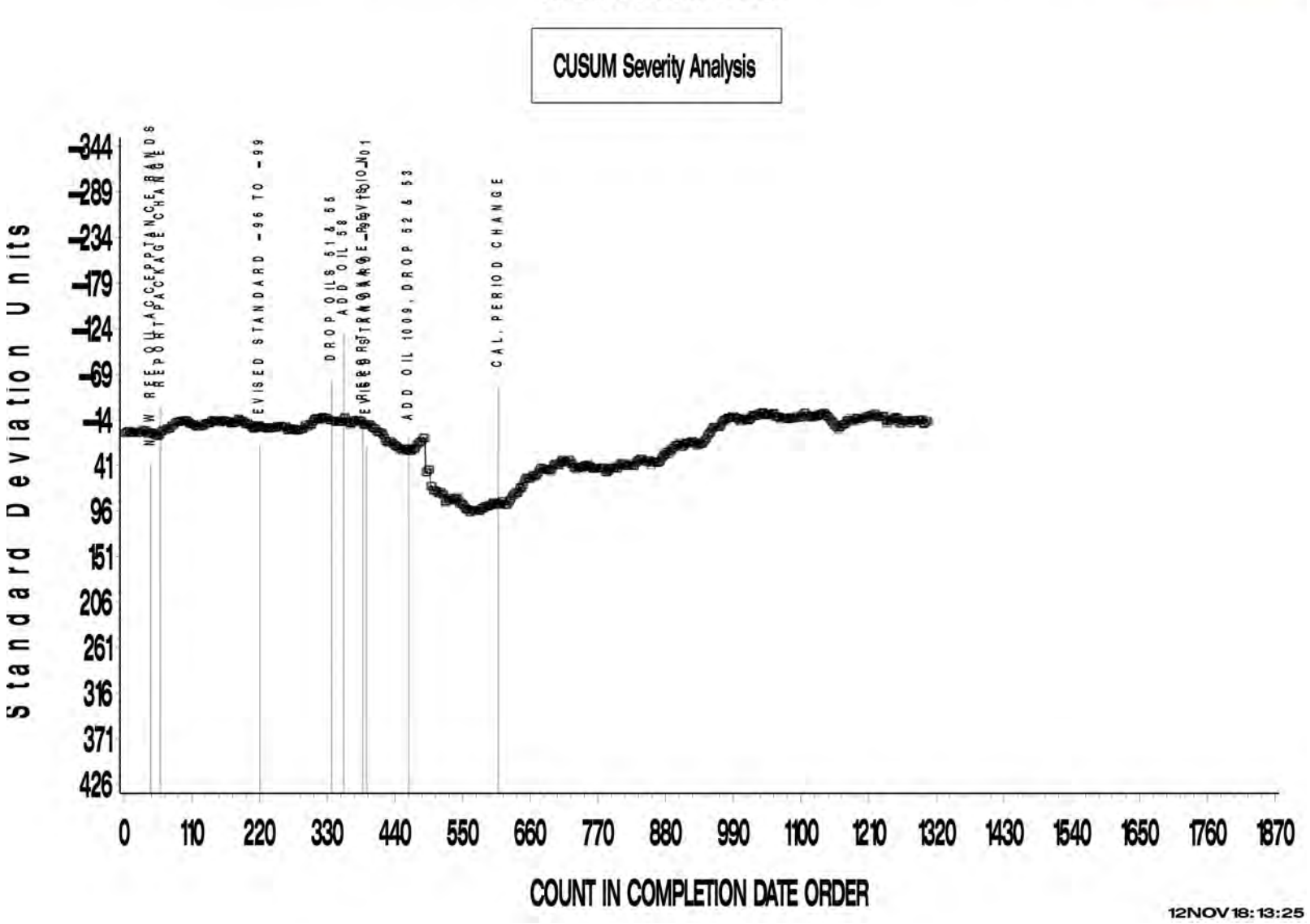
D5133 GELATION INDEX INDUSTRY OPERATIONALLY VALID DATA



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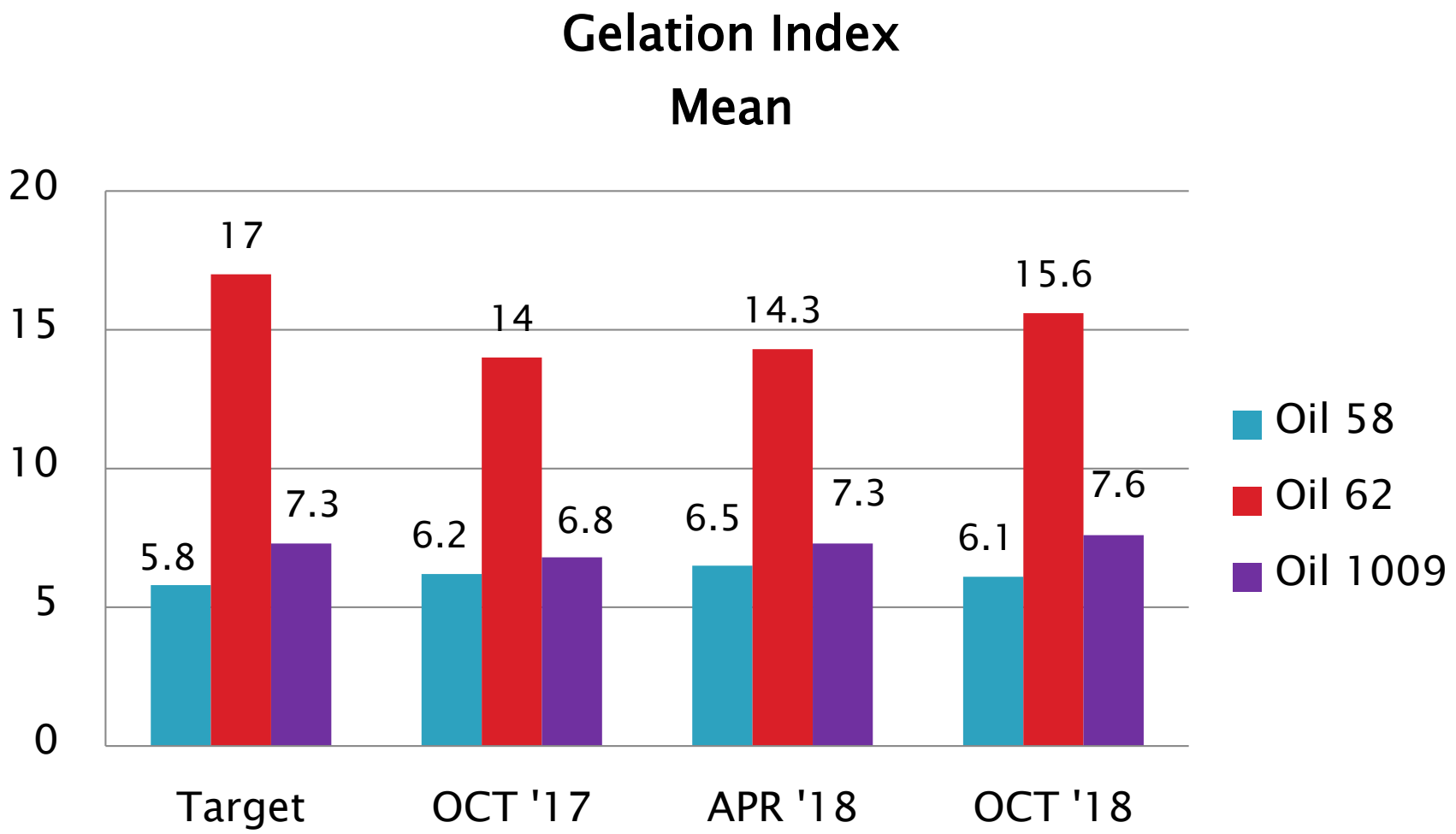
D5133 Performance by Oil

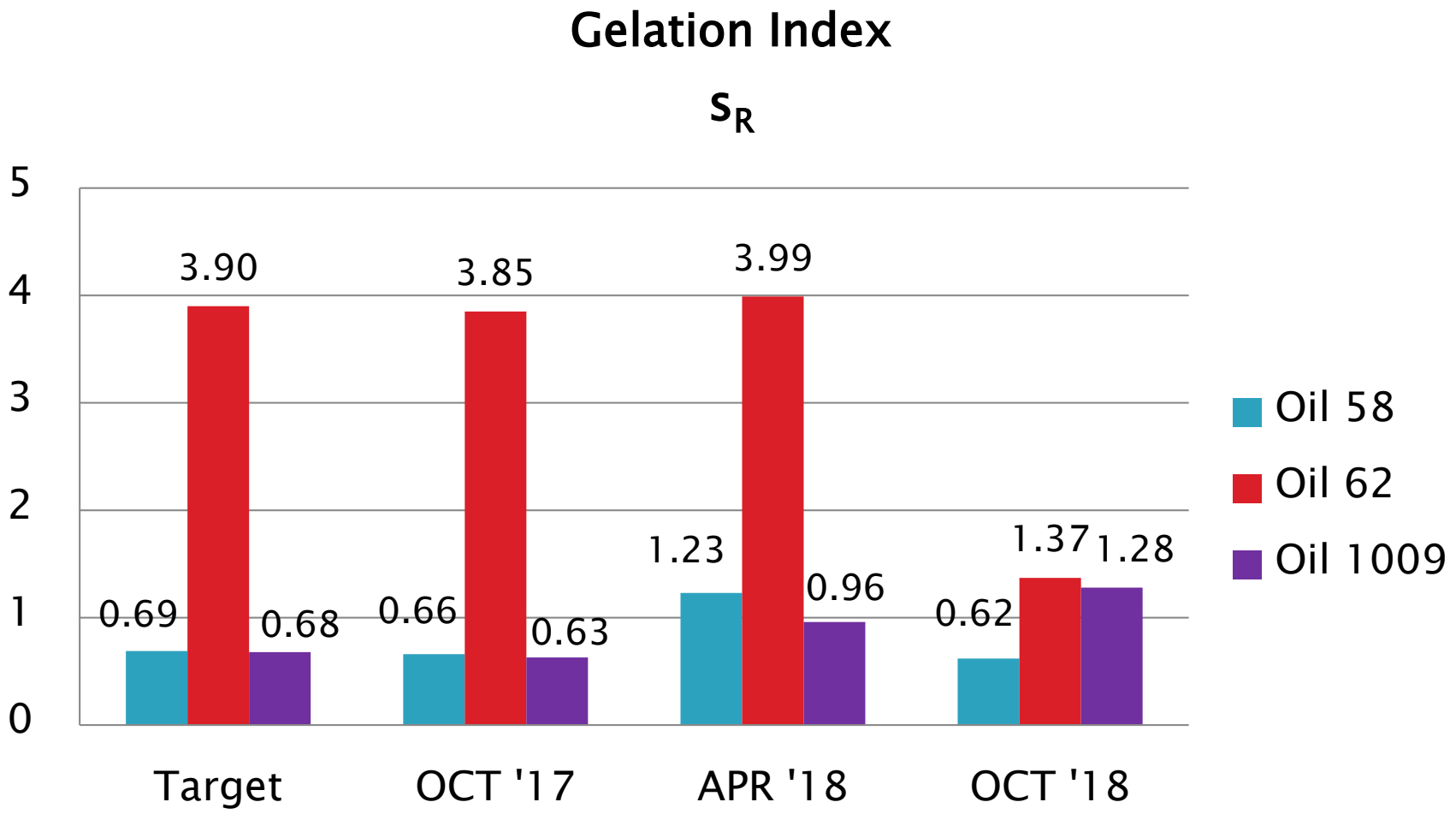
Gelation Index
Performance by Oil

	Targets			4/1/17– 9/30/17				10/1/17– 3/31/18				4/1/18– 9/30/18			
Oil Code	n	Mean	s_R	n	Mean	s_R	Mean Δ/s	n	Mean	s_R	Mean Δ/s	n	Mean	s_R	Mean Δ/s
58	17	5.8	0.69	11	6.2	0.66	0.55	13	6.5	1.23	1.00	7	6.1	0.62	0.41
62	35	17.0	3.90	10	14.0	3.85	-0.77	10	14.3	3.99	-0.69	11	15.6	1.37	-0.35
1009	16	7.30	0.68	8	6.8	0.63	-0.70	13	7.3	0.96	-0.02	14	7.6	1.28	0.41

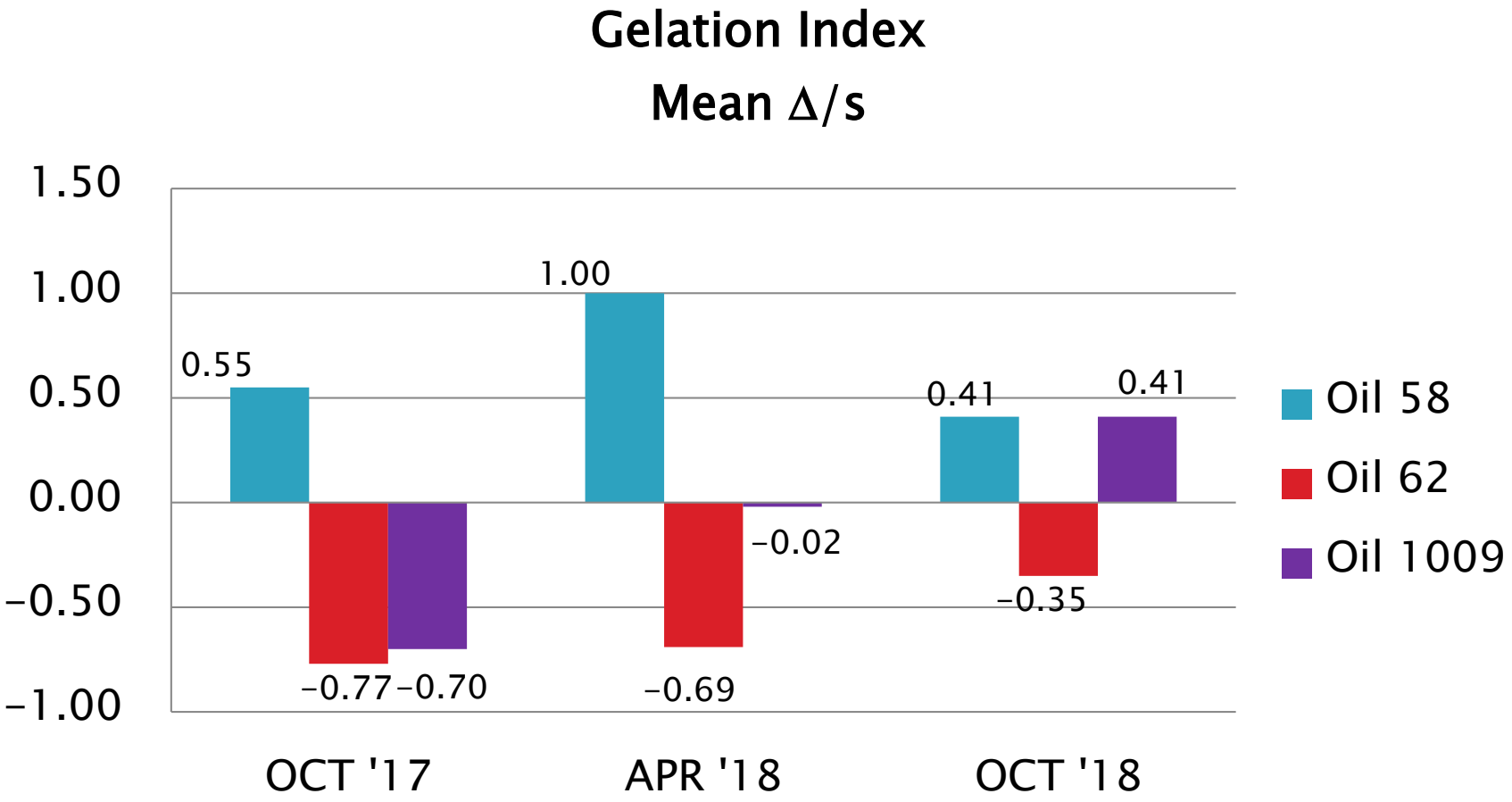
D5133 Performance by Oil



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	21
Failed Calibration Test	OC	0
Operationally Invalidated by Lab	LC, XC	0
Operationally Invalidated After Initially Reported as Valid	RC	2
Total		**23**

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

D6335: Deposits by TEOST-33C

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

- No statistically invalid tests reported this period.

- Two consecutive very severe failing runs were reported on the same instrument (D 2), initially as operationally valid runs.
  - Lab subsequently disqualified these runs as operationally invalid (RC) due to unrepairable instrument pressure control problems, and took the instrument out of service.

- One TMC technical update was issued this report period:
  - Memo 18-032, October 9, 2018, Updated Test Method D6335-18
- Calibration requirement updates are issued as LTMS document updates

D6335: Deposits by TEOST-33C

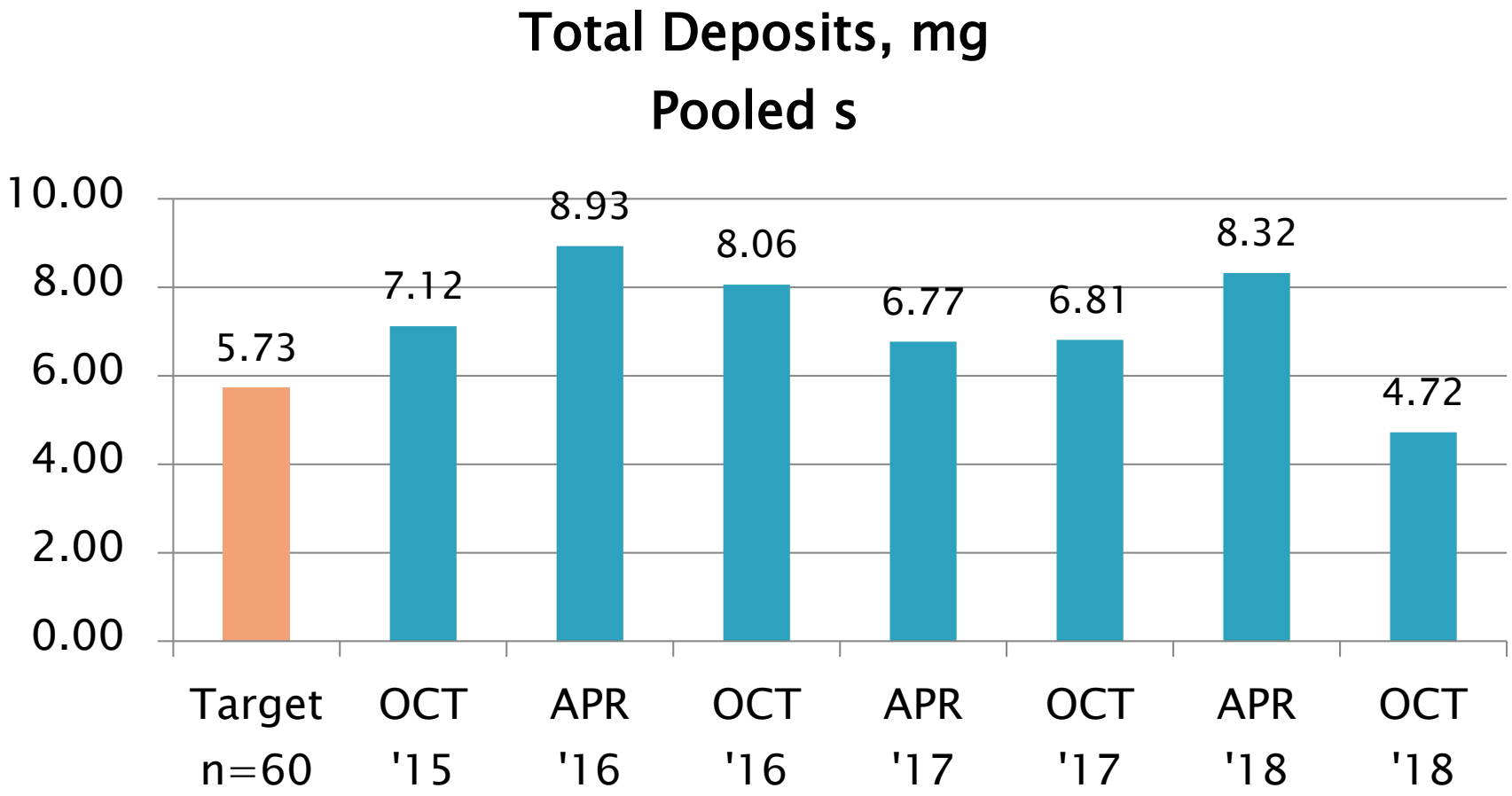
Period Precision and Severity Estimates

Total Deposits, mg	n	df	Pooled s	Mean Δ/s
Updated Targets 20130415	60	58	5.73	-----
4/1/15 through 9/30/15	16	14	7.12	-0.11
10/1/15 through 3/31/16	21	19	8.93	-0.43
4/1/16 through 9/30/16	21	19	8.06	-0.68
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

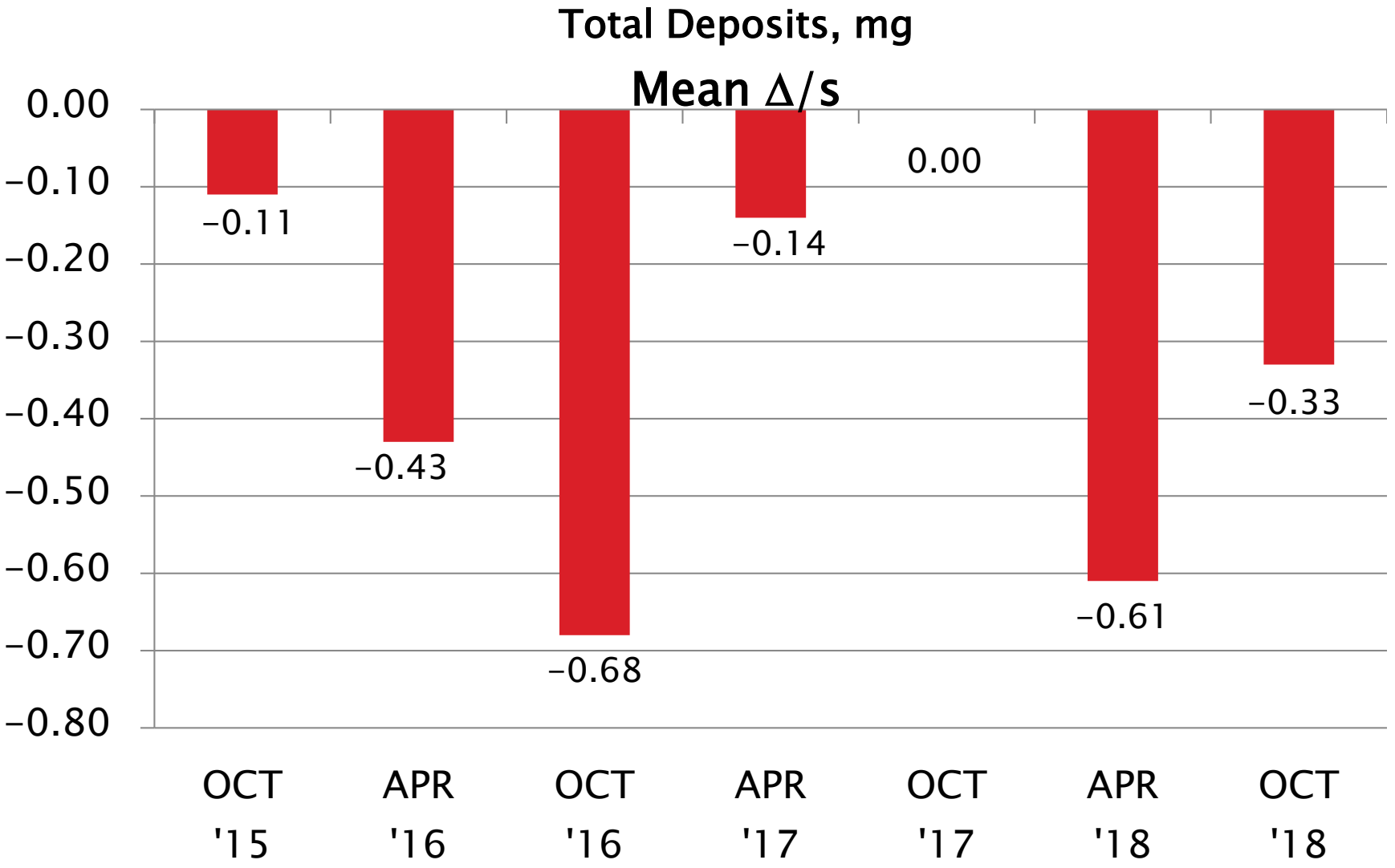
*Three consecutive OC results on same rig included and excluded.

**Single result of -4.6 s mild included and excluded

D6335 Precision Estimates



D6335 Severity Estimates

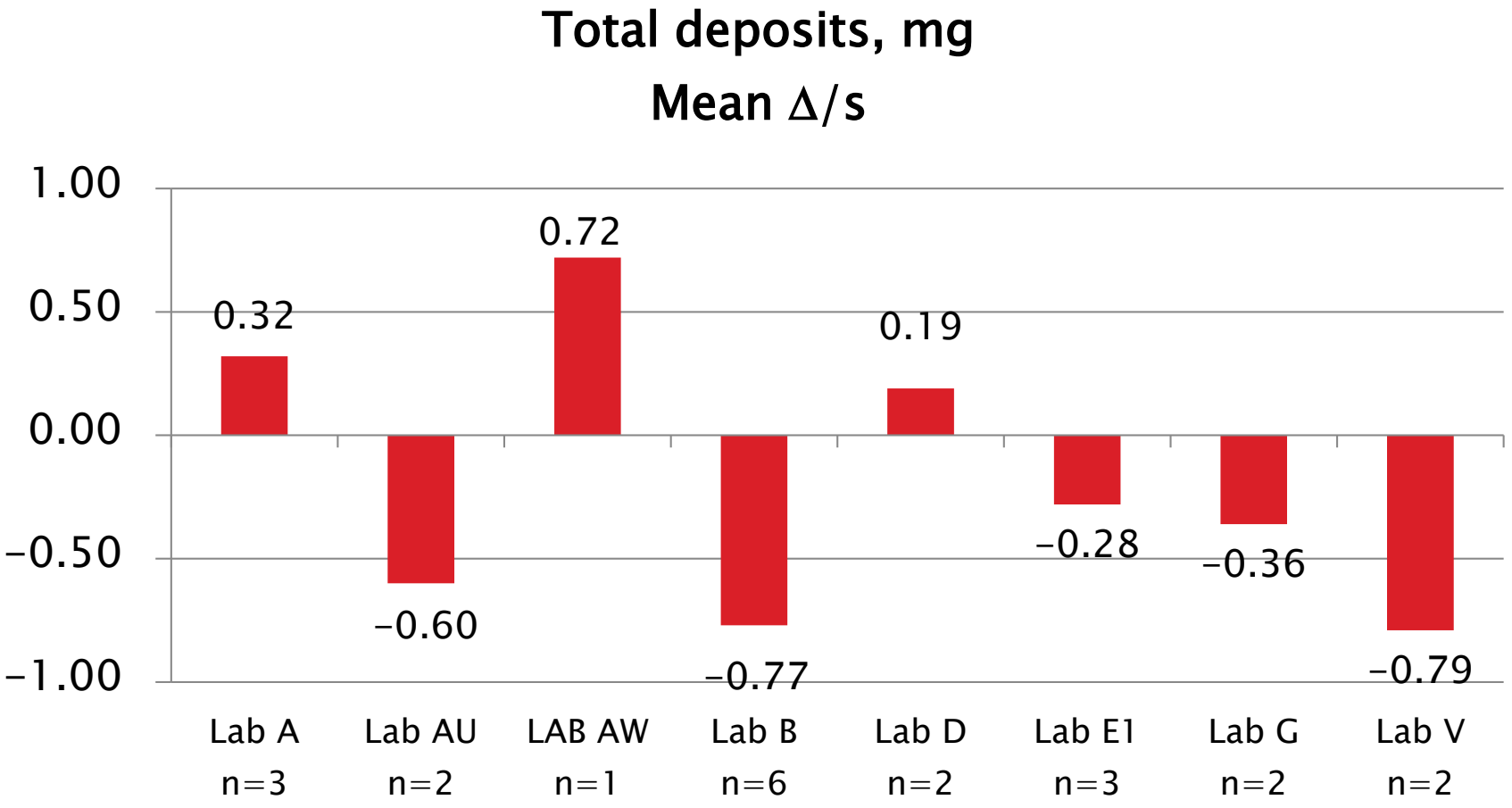


D6335: Deposits by TEOST-33C

Current Period Severity Estimates by Lab
Total Deposits, mg

	n	Mean Δ/s
Lab A	3	0.32
Lab AU	2	-0.60
Lab AW	1	0.72
Lab B	6	-0.77
Lab D	2	0.19
Lab E1	3	-0.28
Lab G	2	-0.36
Lab V	2	-0.79

D6335 Lab Severity Estimates



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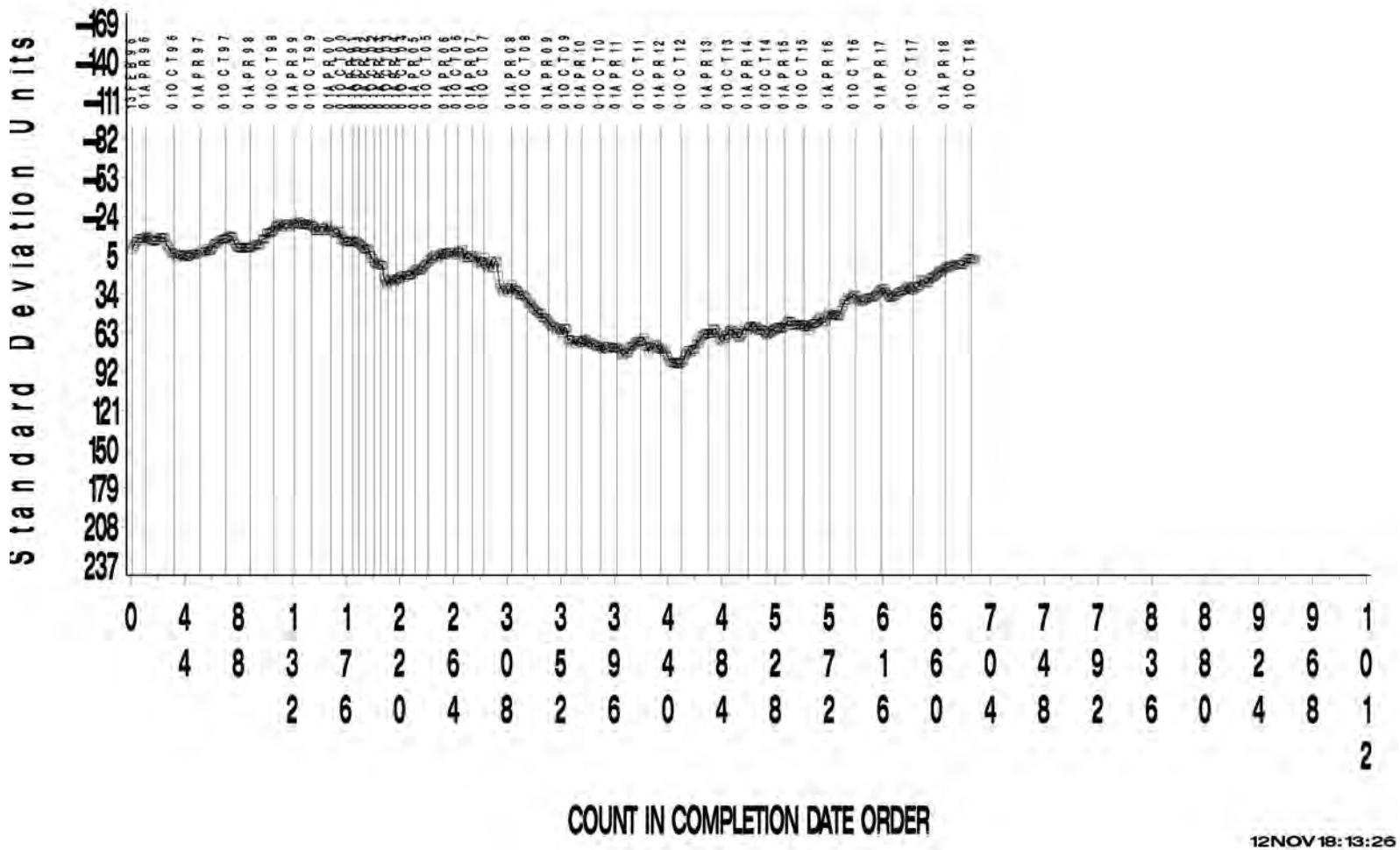
D6335: Deposits by TEOST-33C

- Precision (Pooled s) is substantially more precise than prior periods, and more precise than target precision for the first time since at least 2015.
- Performance (Mean Δ/s) is -0.33 s mild.
- One test reported as using Rod Batch L, all other tests this period report using Rod Batch M.
- Round robin on replacement oil 75-1 is completed, waiting on surveillance panel action.

TEOST –33C INDUSTRY OPERATIONALLY VALID DATA

TOTAL DEPOSITS MG

CUSUM Severity Analysis



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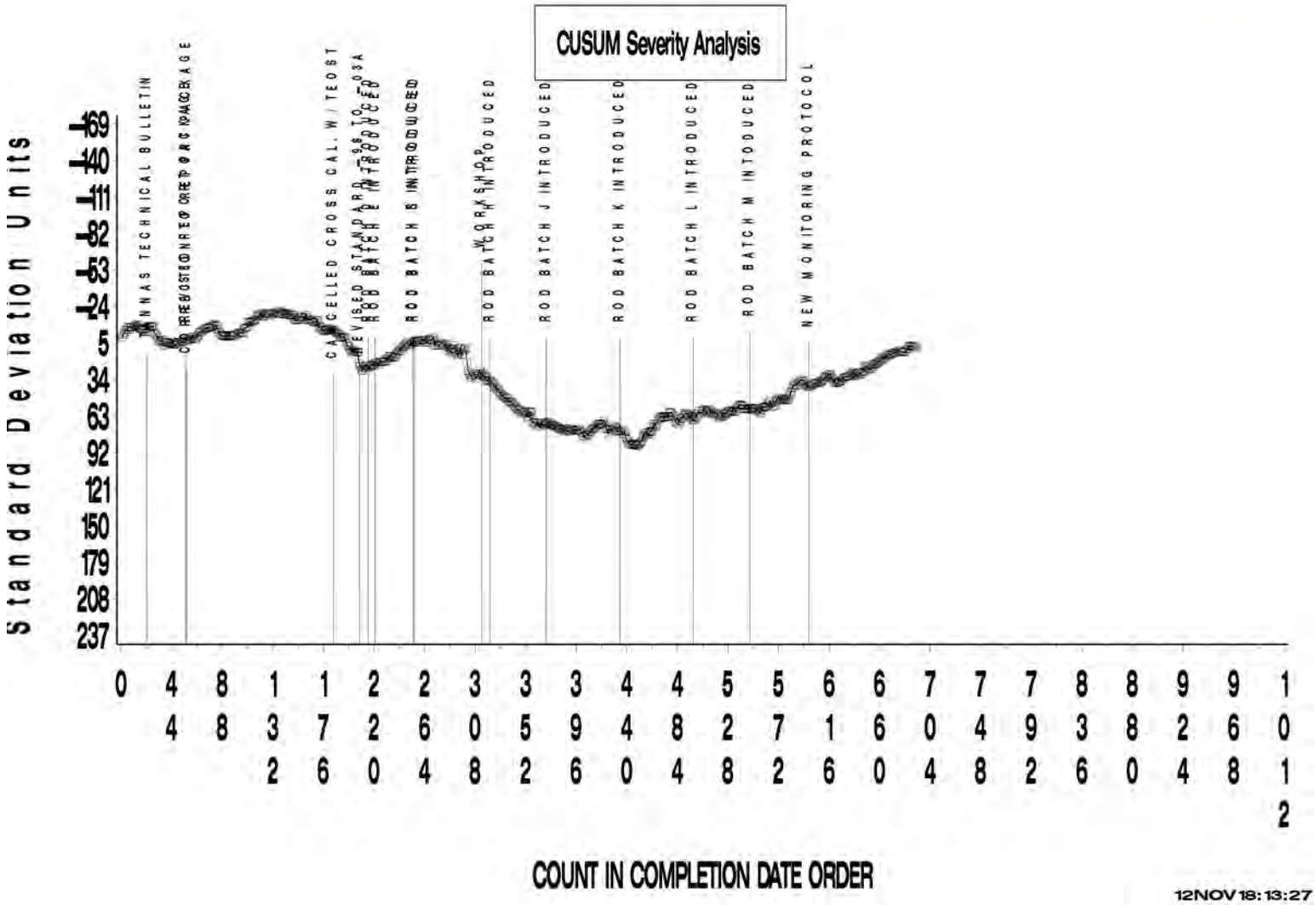
TEOST –33C INDUSTRY OPERATIONALLY VALID DATA

TOTAL DEPOSITS MG



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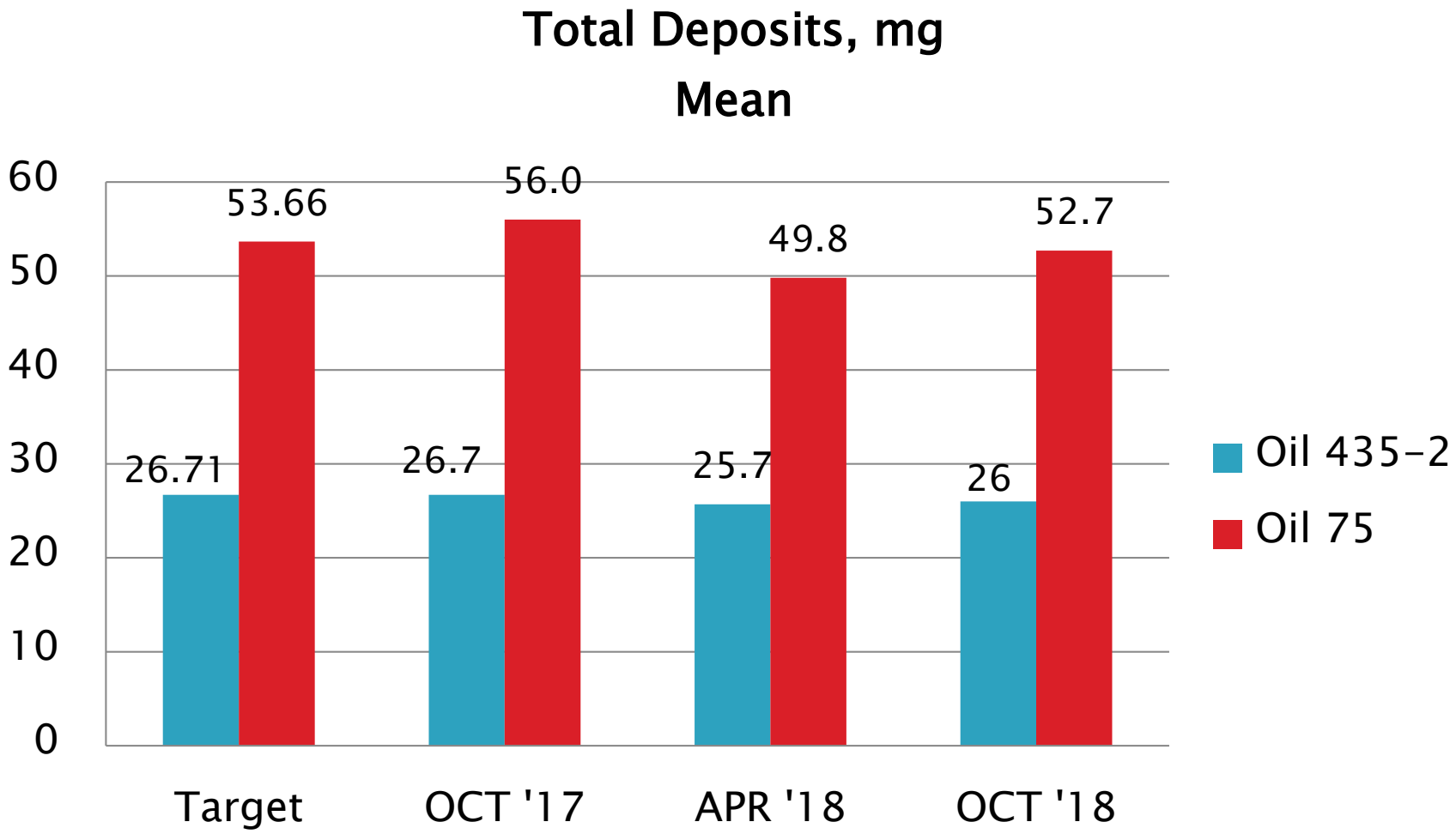
D6335 Performance by Oil

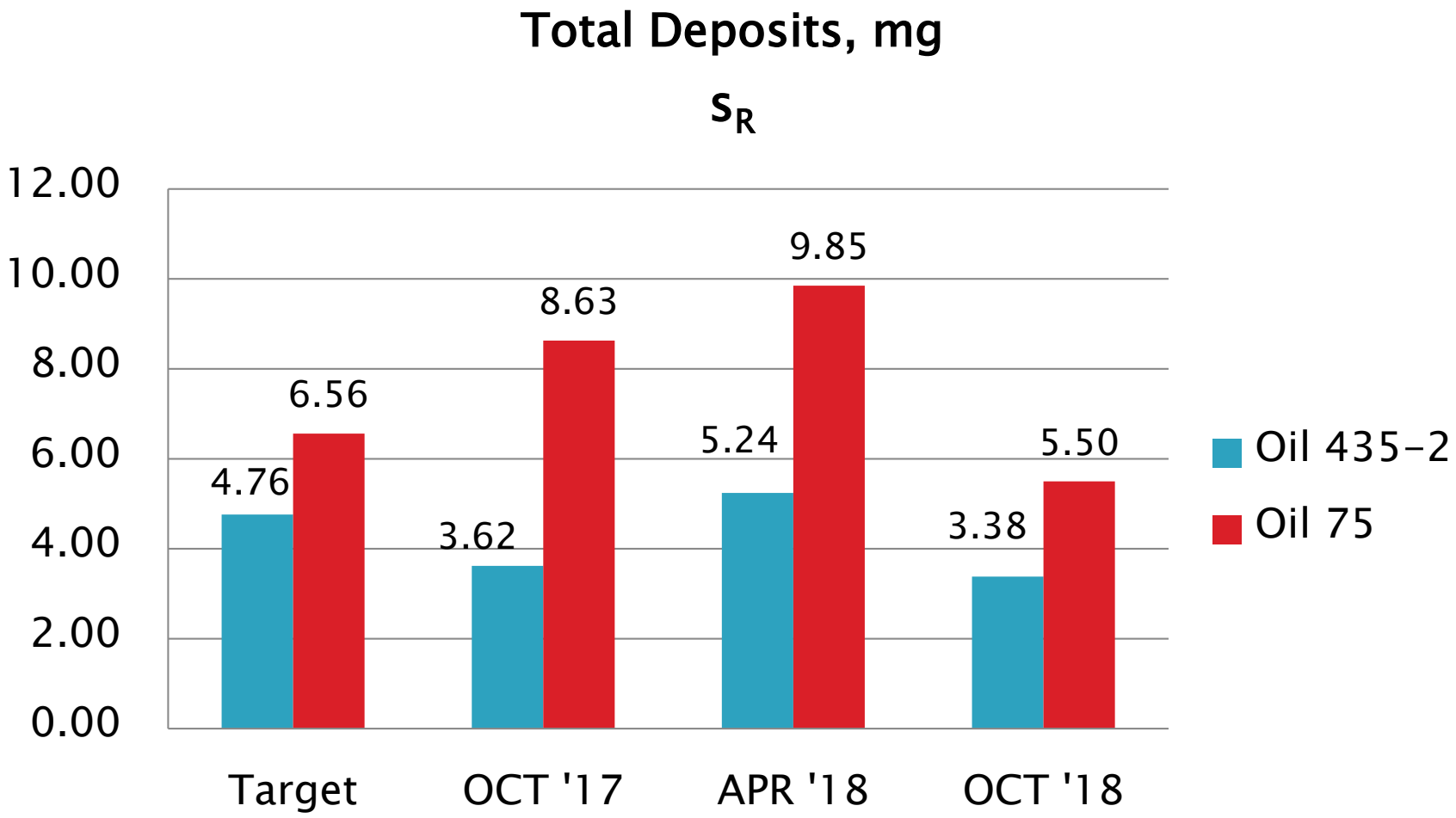
Total Deposits, mg
Performance by Oil

	Targets 20130415			4/1/17– 9/30/17				10/1/17 – 3/31/18				4/1/18– 9/30/18			
Oil Code	n	Mean	s_R	n	Mean	s_R	Mean Δ/s	n	Mean	s_R	Mean Δ/s	n	Mean	s_R	Mean Δ/s
435-2	30	26.71	4.76	12	26.7	3.62	-0.42	11	25.7	5.24	-0.64	9	26.0	3.38	-0.57
75	30	53.66	6.56	14	56.0	8.63	0.36	16	49.8	9.85	-0.58	12	52.7	5.50	-0.15

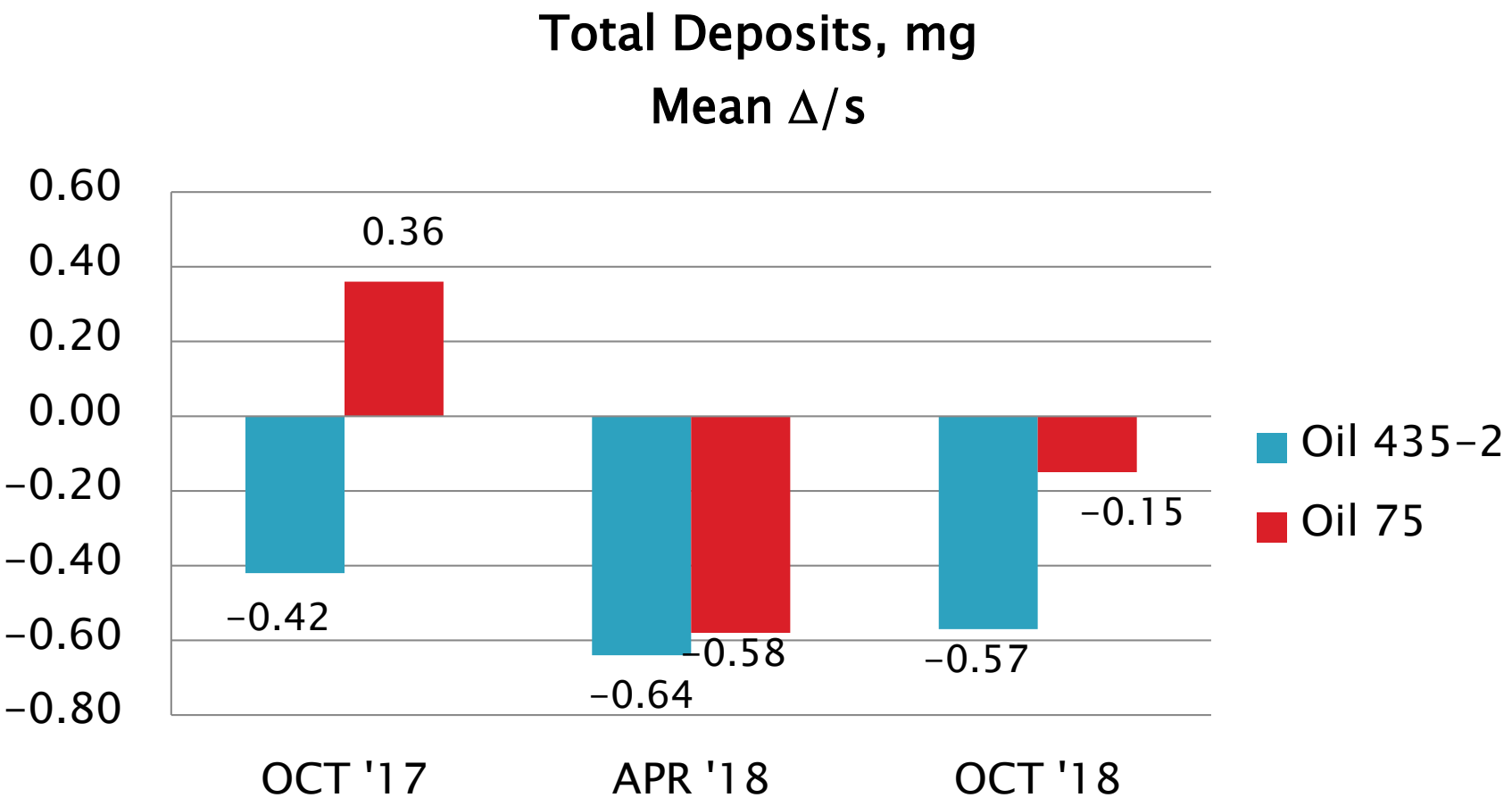
D6335 Performance by Oil



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	92
Failed Calibration Test	OC	3
Operationally Invalidated by Lab	LC, XC	2
Operationally Invalidated After Initially Reported as Valid	RC	0
Replacement Catalyst Screeners	AG	8
Total		**105**

Number of Labs Reporting Data: 11
Fail Rate of Operationally Valid Tests: 3%

D7097: Deposits by MHT TEOST

Statistically Unacceptable Tests (OC)	No. Of Tests
Total Deposits Mild	0
Total Deposits Severe	3

- One result reported as operationally valid is 8.9 s severe (Instrument G5). Overall statistics are shown with this result included and excluded, period statistics by catalyst batch and by oil exclude this data point as exceptionally severe.
  - Rig G5 did pass calibration on subsequent calibration attempts, but lab reports no operational reason found for the exceptionally severe result.

- Two operationally invalid calibration test reported this period:
  - Contamination of filtered deposits with external debris (XC)
  - Feed tube setup incorrectly installed (XC)

- Eight donated runs to screen new catalyst batch (AG)

- No TMC technical updates were issued this report period.
- Calibration requirement updates are issued as LTMS document updates

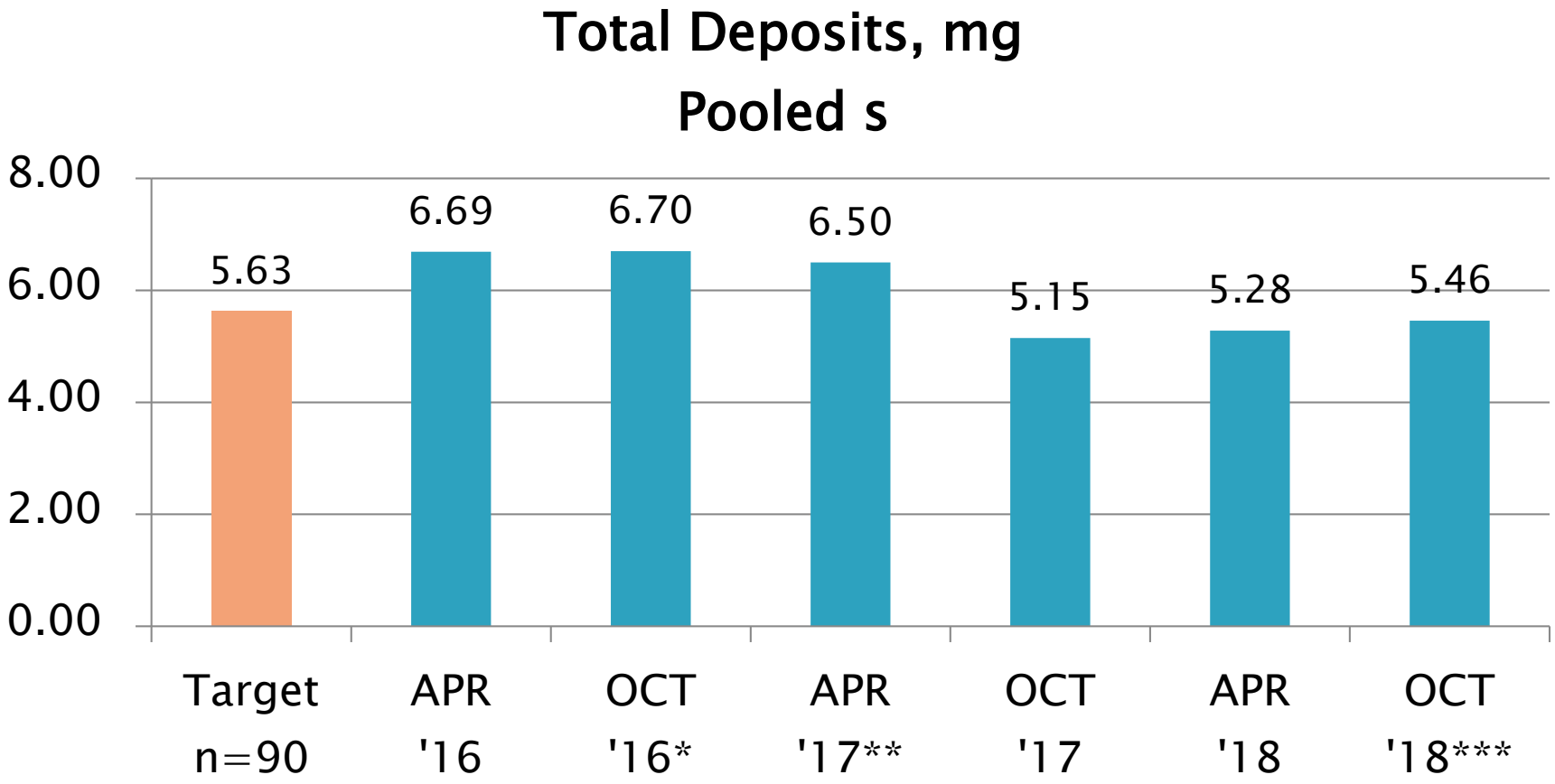
D7097: Deposits by MHT TEOST

Period Precision and Severity Estimates

Total Deposits, mg	n	df	Pooled s	Mean Δ/s
Current Targets 7/31/2006	90	87	5.63	-----
4/1/16 through 9/30/16*	96	94	15.8	0.53
4/1/16 through 9/30/16*	93	91	6.70	0.13
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

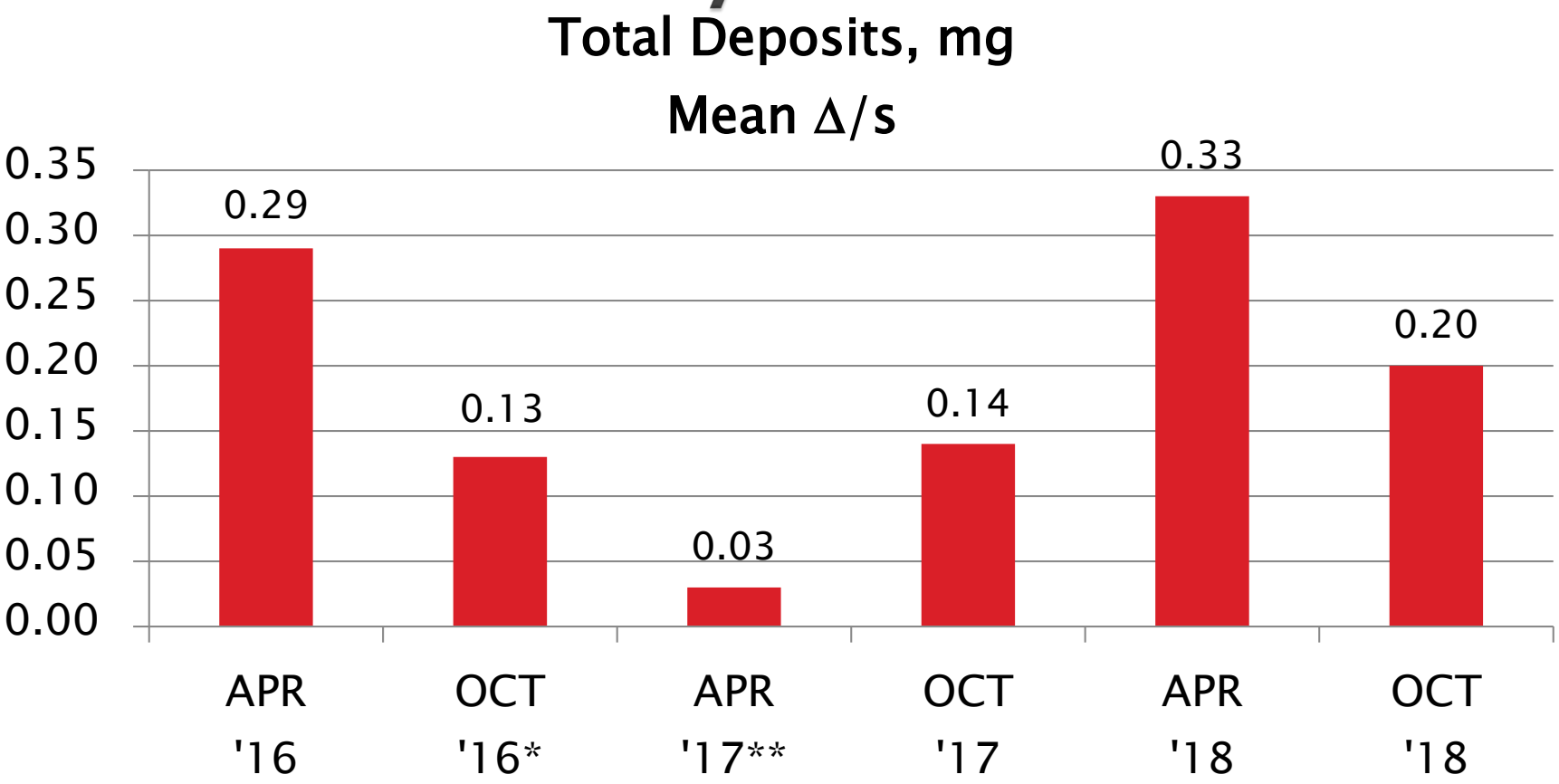
*Three severe OC tests from instrument P1 included and excluded
**Eight 2TESTCAL tests from instrument J2 included and excluded
***One severe OC test from instrument G5 included and excluded

D7097 Precision Estimates



*Three severe OC tests from instrument P1 excluded
**Eight tests instrument J2 excluded (failed to calibrate)
***One severe OC test from instrument G5 excluded

D7097 Severity Estimates



*Three severe OC tests from instrument P1 excluded
**Eight tests instrument J2 excluded (failed to calibrate)
***One severe OC test from instrument G5 excluded

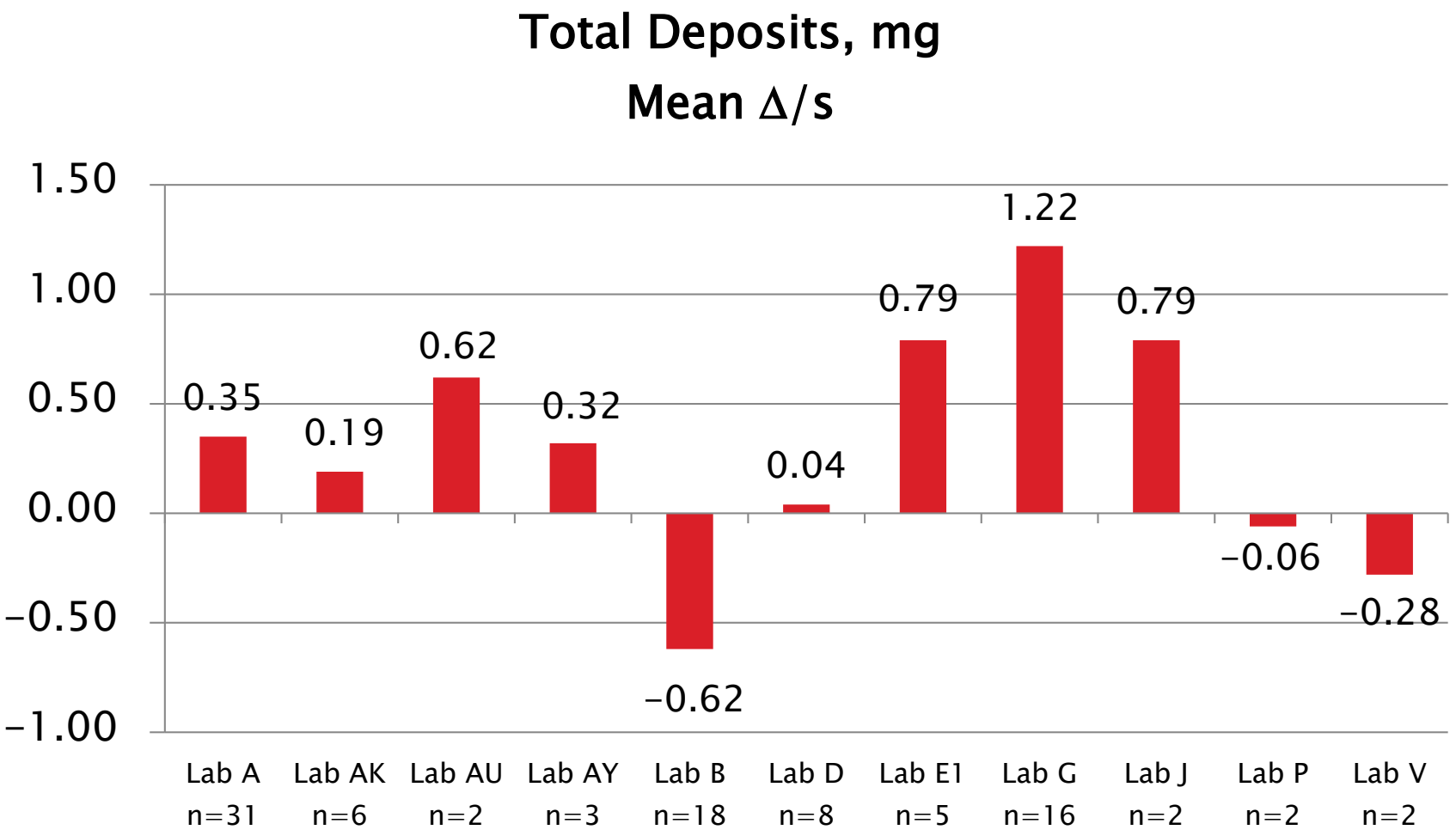
D7097: Deposits by MHT TEOST

Current Period Severity Estimates by Lab
Total Deposits, mg

Lab	n	Mean Δ/s	Lab	n	Mean Δ/s
Lab A	31	0.35	Lab E1	5	0.79
Lab AK	6	0.19	Lab G*	16	1.22 0.71
Lab AU	2	0.62	Lab J	2	0.79
Lab AY	3	0.32	Lab P	2	-0.06
Lab B	18	-0.62	Lab V	2	-0.28
Lab D	8	0.04			

*One severe OC test from lab G included and excluded

D7097 Lab Severity Estimates



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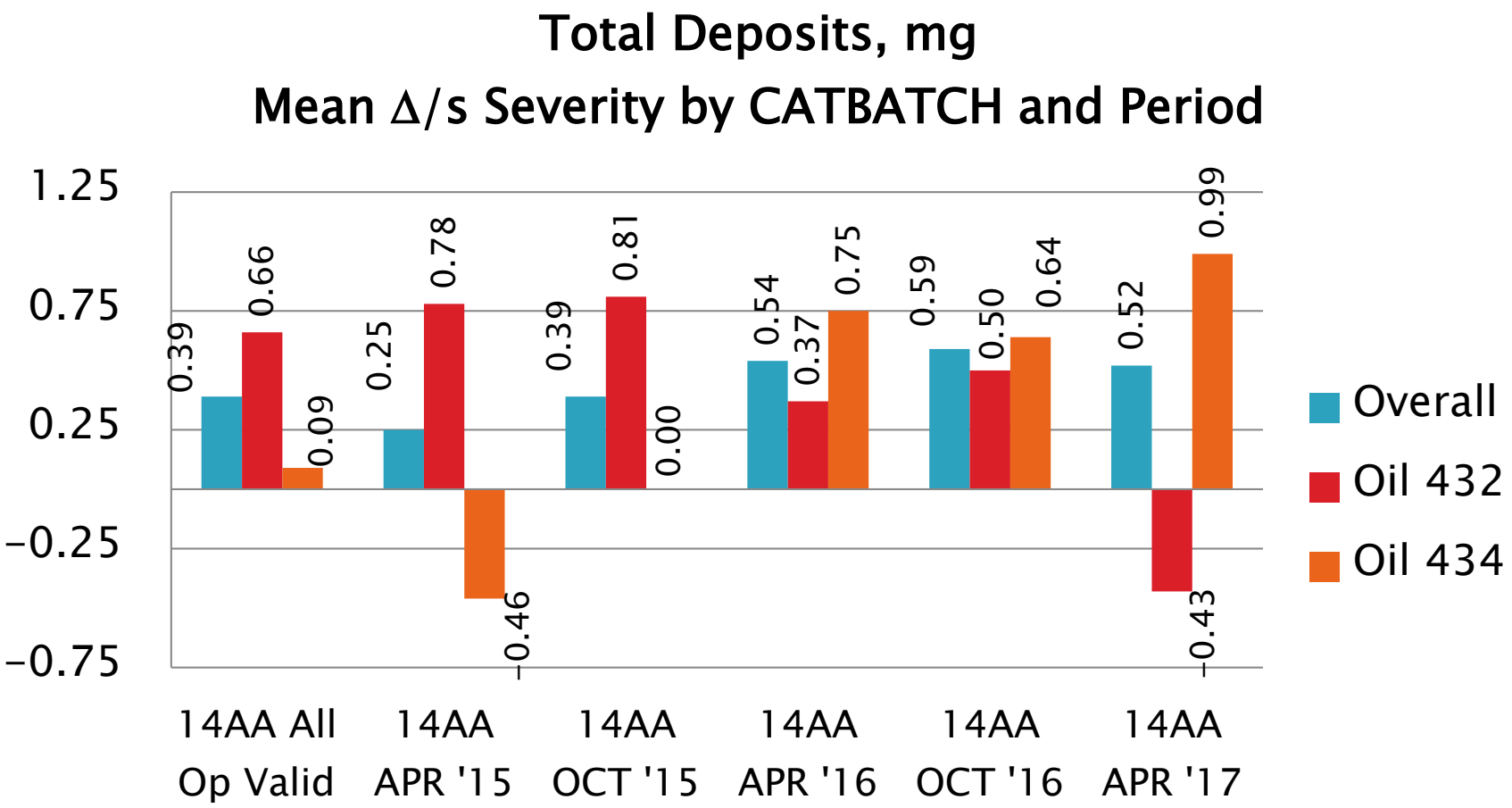
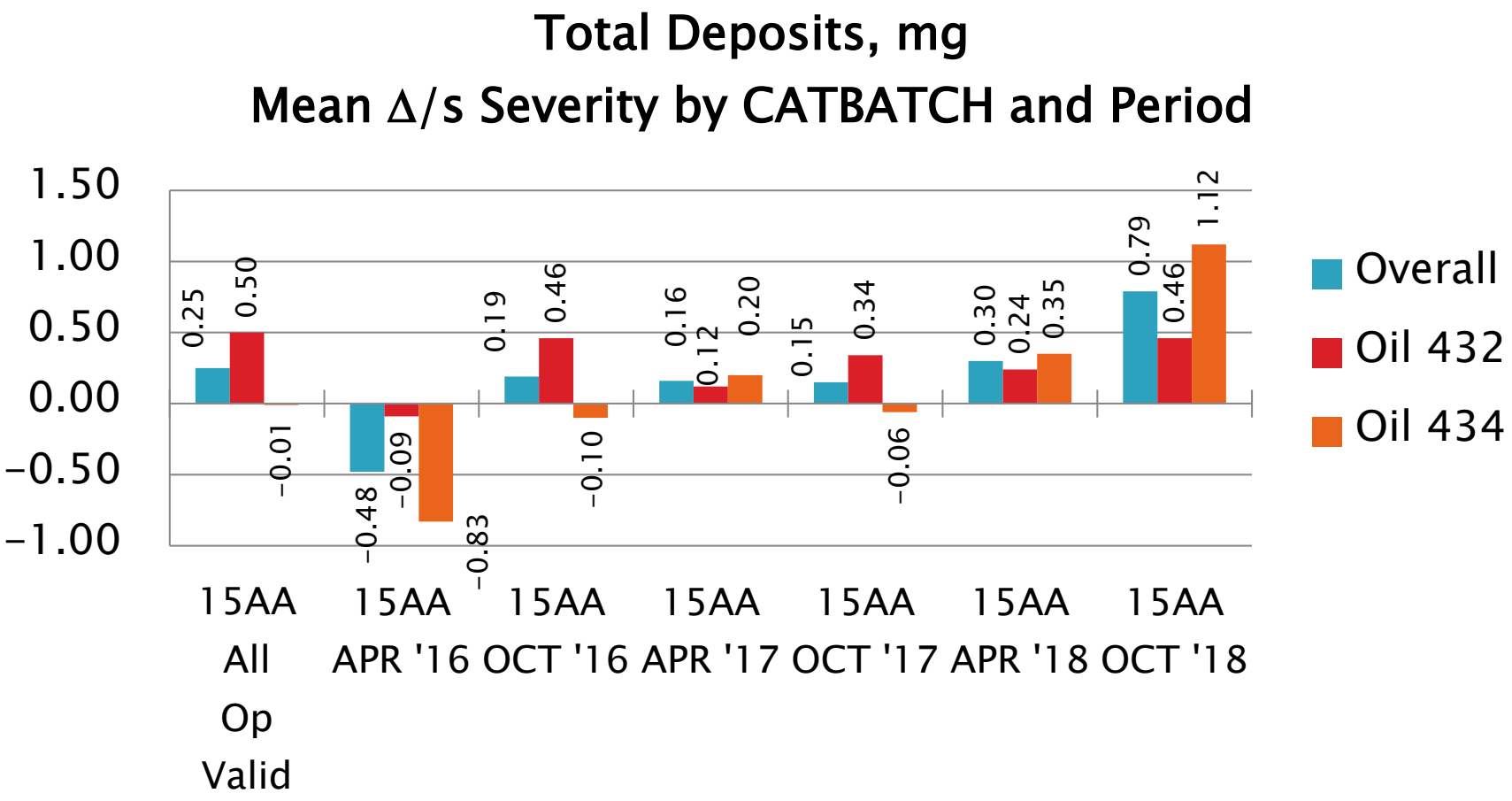
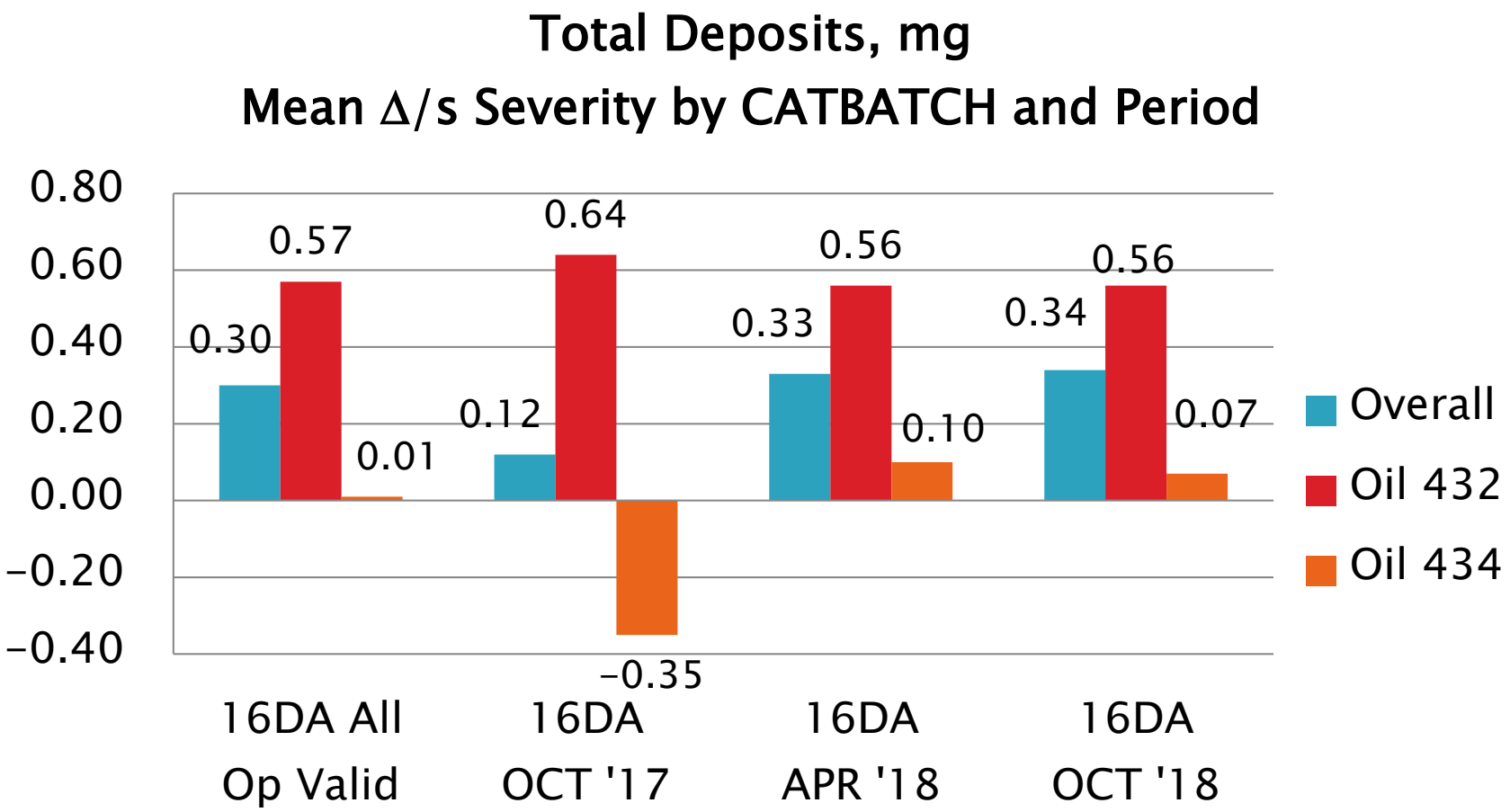
D7097: Deposits by MHT TEOST



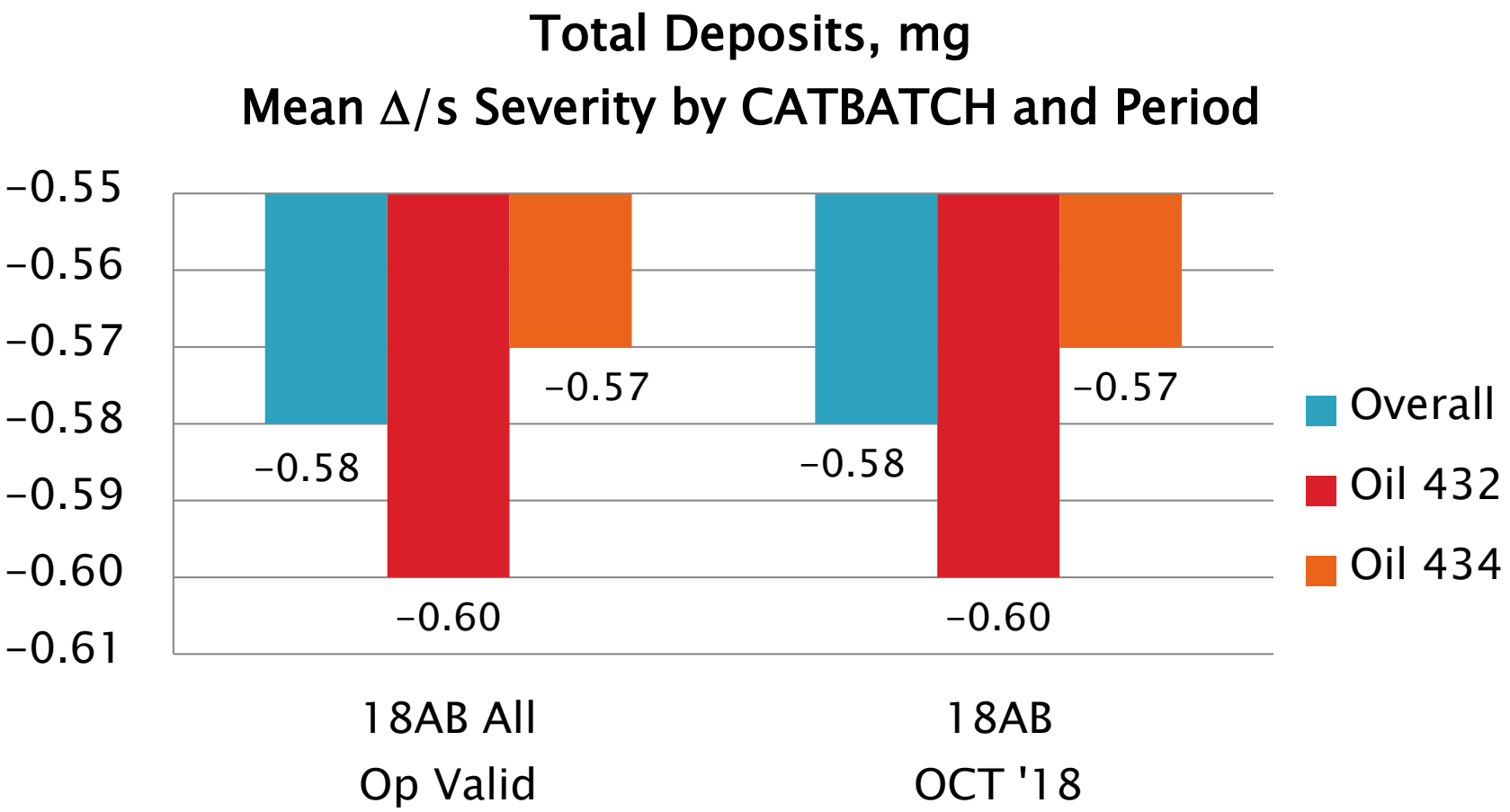
D7097: Deposits by MHT TEOST



D7097: Deposits by MHT TEOST



D7097: Deposits by MHT TEOST



D7097: Deposits by MHT TEOST

- Excluding one extreme result 8.9 s severe:
  - Precision (Pooled s) is less precise than last report period
    - More precise than target precision for three consecutive report periods
    - Improved precision last three report periods, compared to prior report periods, is coincident with use of new end cap flask seals
  - Performance (Mean Δ/s) is 0.20 s severe.
- All operationally valid tests this period report using Rod Batch M
- All operationally valid calibration tests this period report using Catalyst Batch 15AA (n=2), 16DA (n=77) or 18AB (n=15).

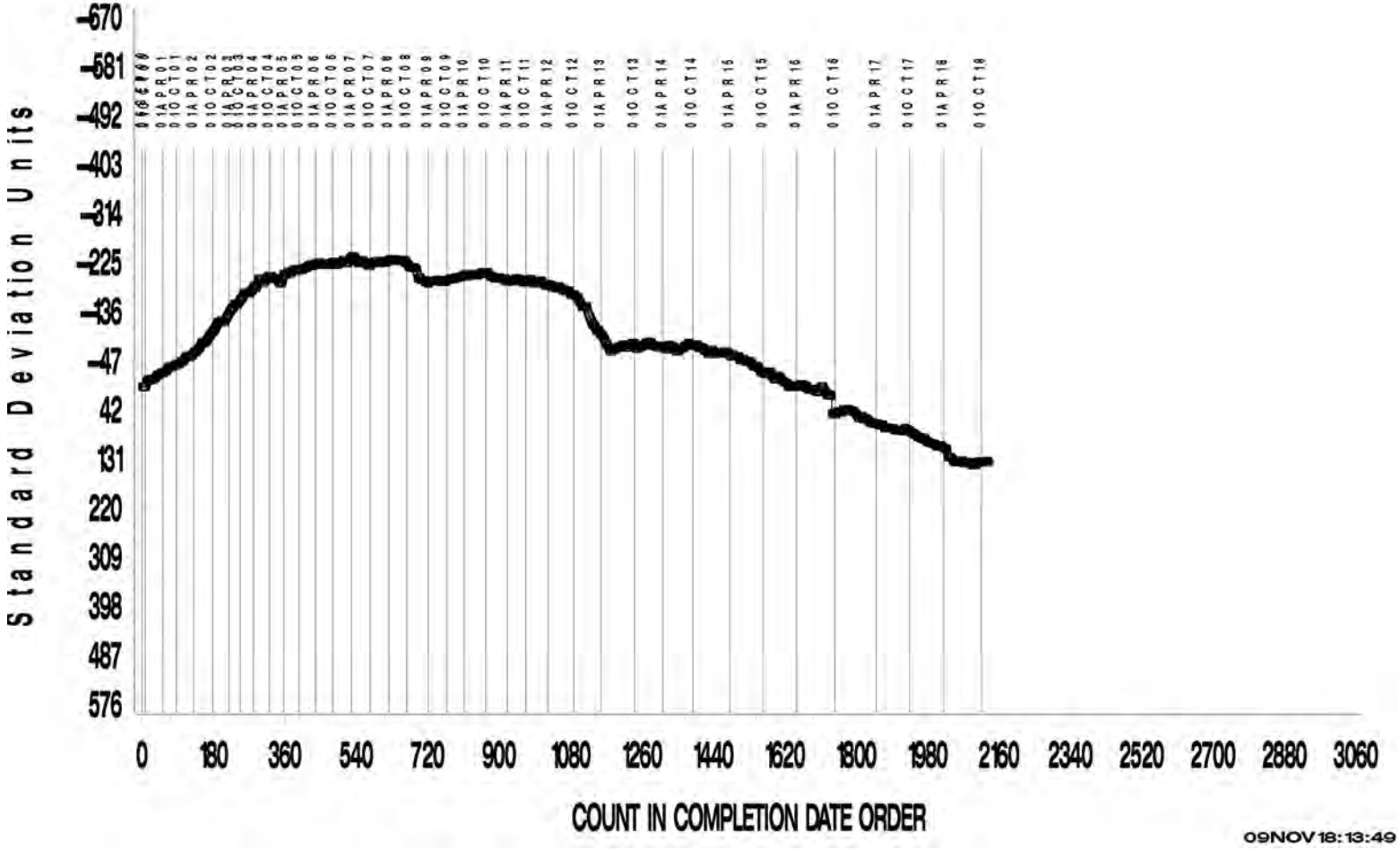
D7097: Deposits by MHT TEOST

- Severity of the newest catalyst batch 18AB (n=15) appears to be about 0.6 s mild on both reference oils.

MHT—4 TEOST INDUSTRY OPERATIONALLY VALID DATA

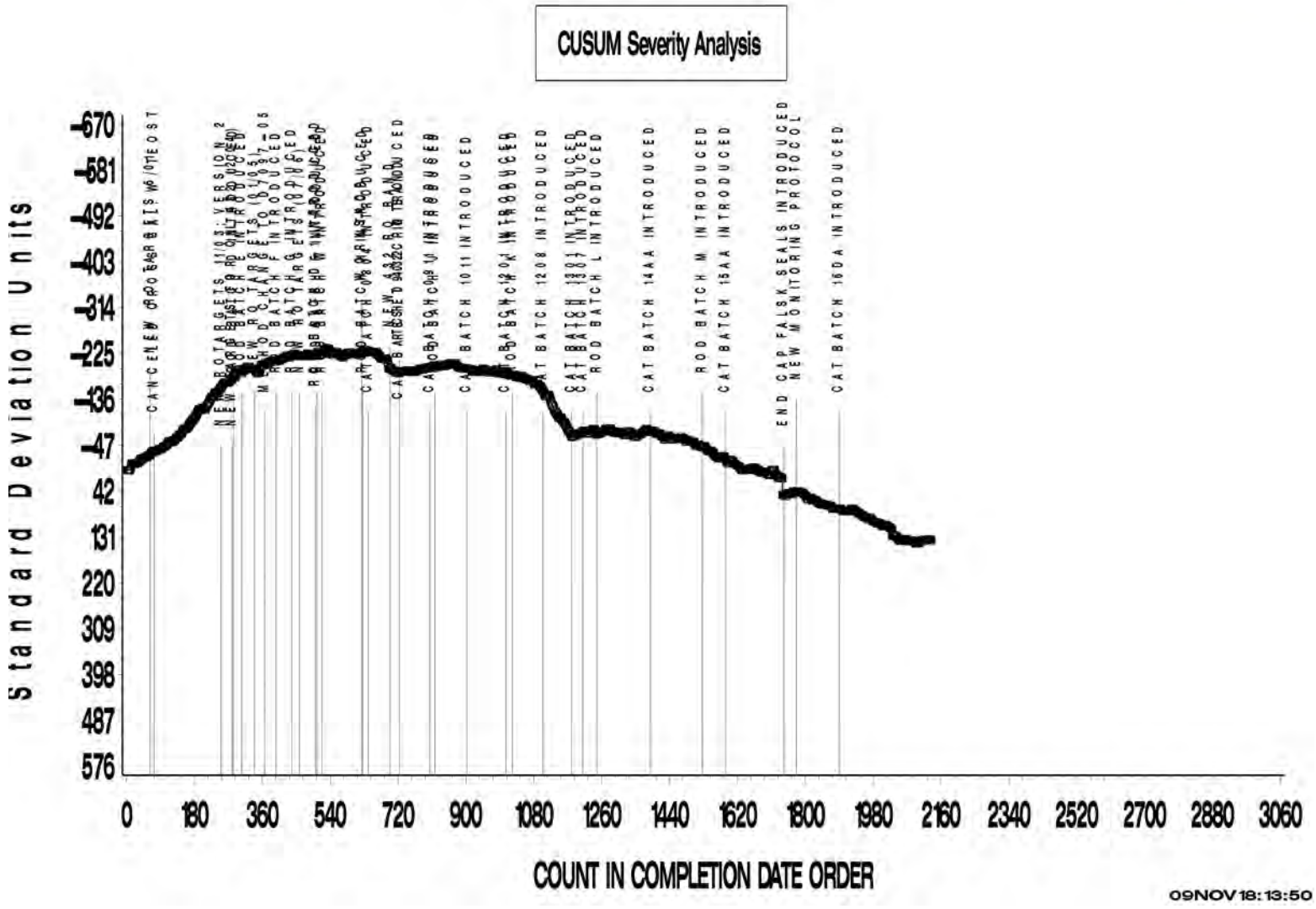
TOTAL DEPOSITS MG

CUSUM Severity Analysis



MHT—4 TEOST INDUSTRY OPERATIONALLY VALID DATA

TOTAL DEPOSITS MG



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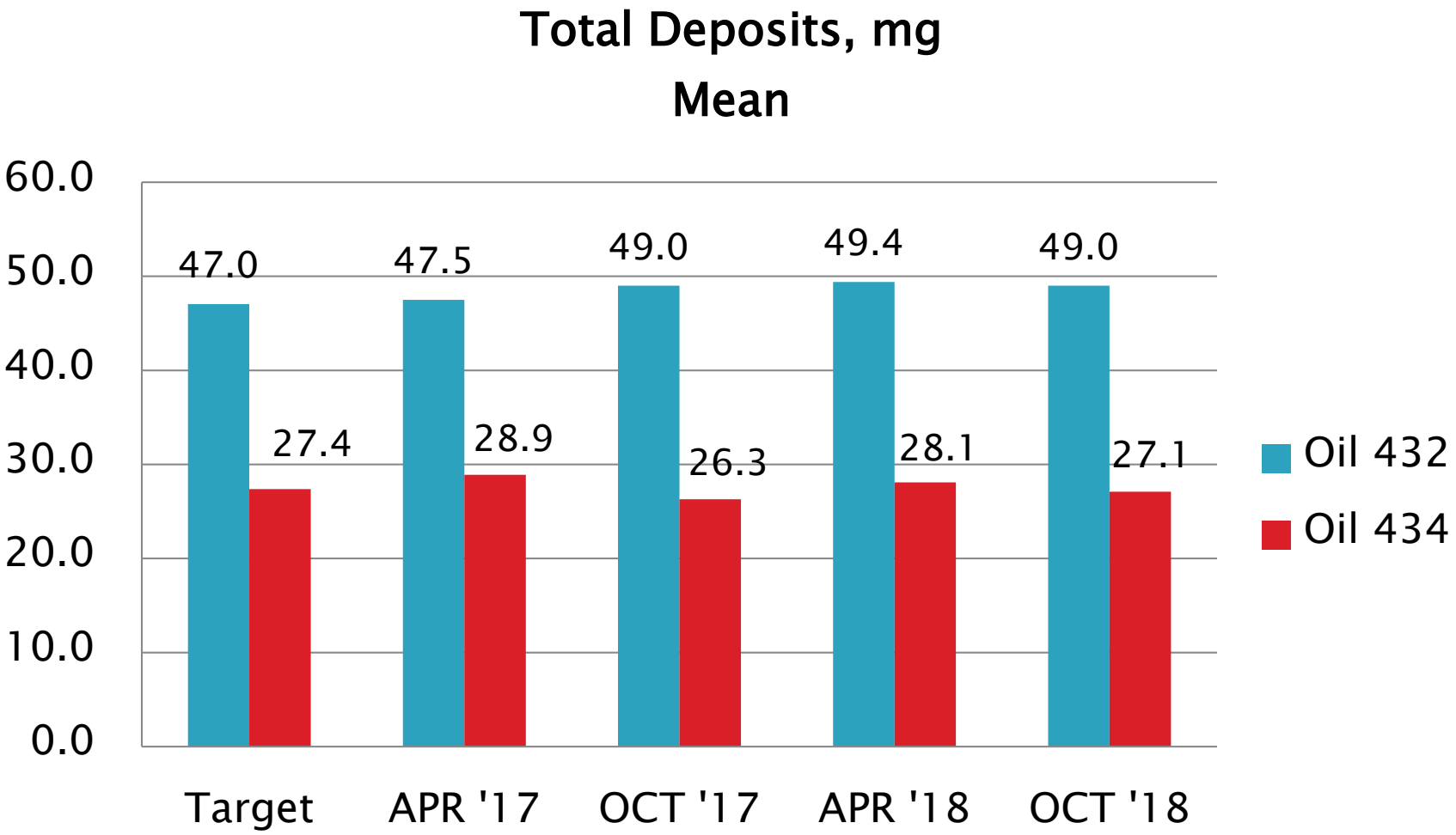
D7097 Performance by Oil

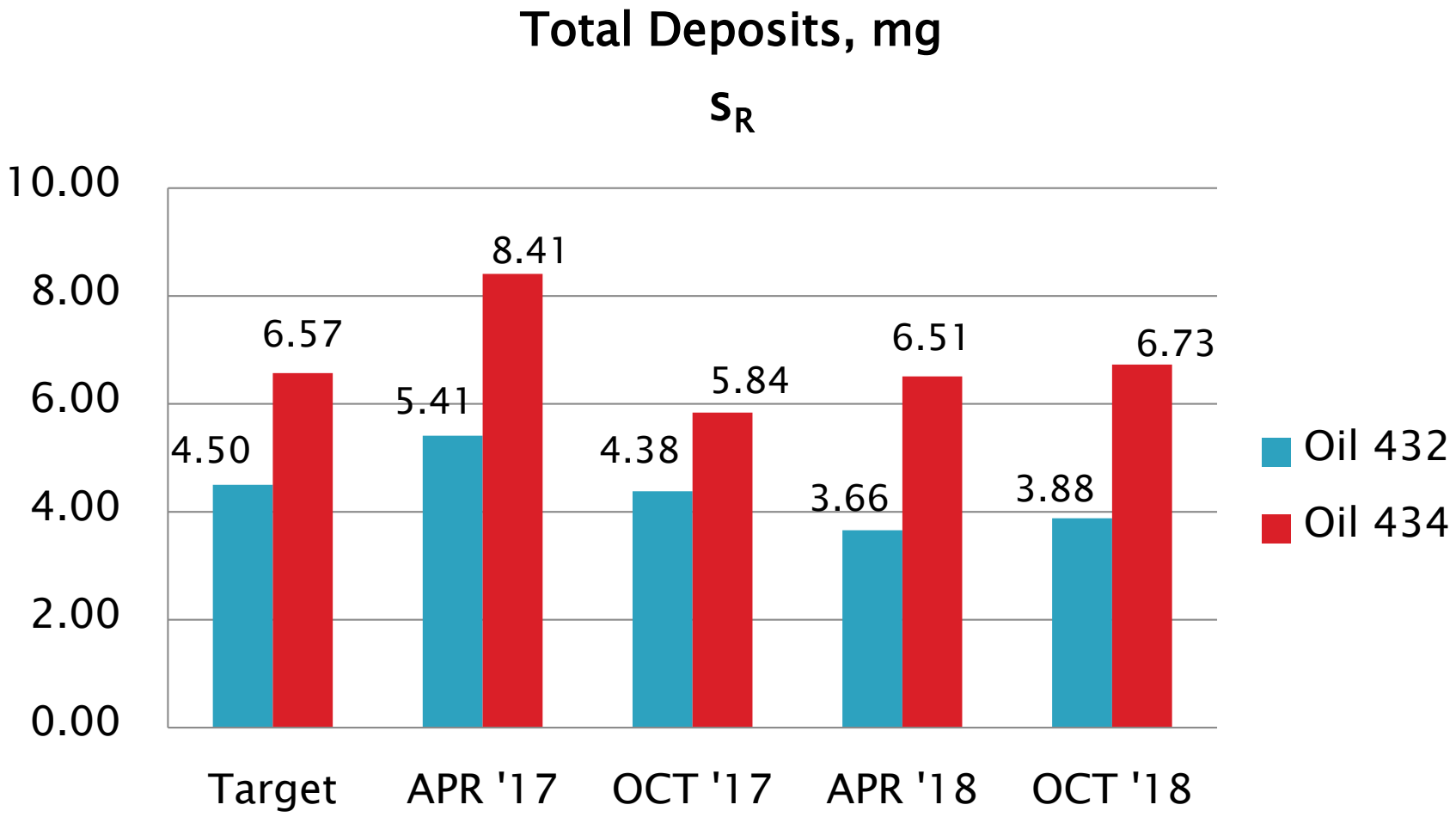
Total Deposits, mg
Performance by Oil

	Targets			4/1/17- 9/30/17				10/1/17 – 3/31/18				4/1/18- 9/30/18			
Oil Code	n	Mean	s_R	n	Mean	s_R	Mean Δ/s	n	Mean	s_R	Mean Δ/s	n	Mean	s_R	Mean Δ/s
432	30	47.04	4.50	42	49.0	4.38	0.44	44	49.4	3.66	0.53	48	49.0	3.88	0.44
434	30	27.37	6.57	41	26.3	5.84	-0.17	44	28.1	6.51	0.12	46	27.1	6.73	-0.05

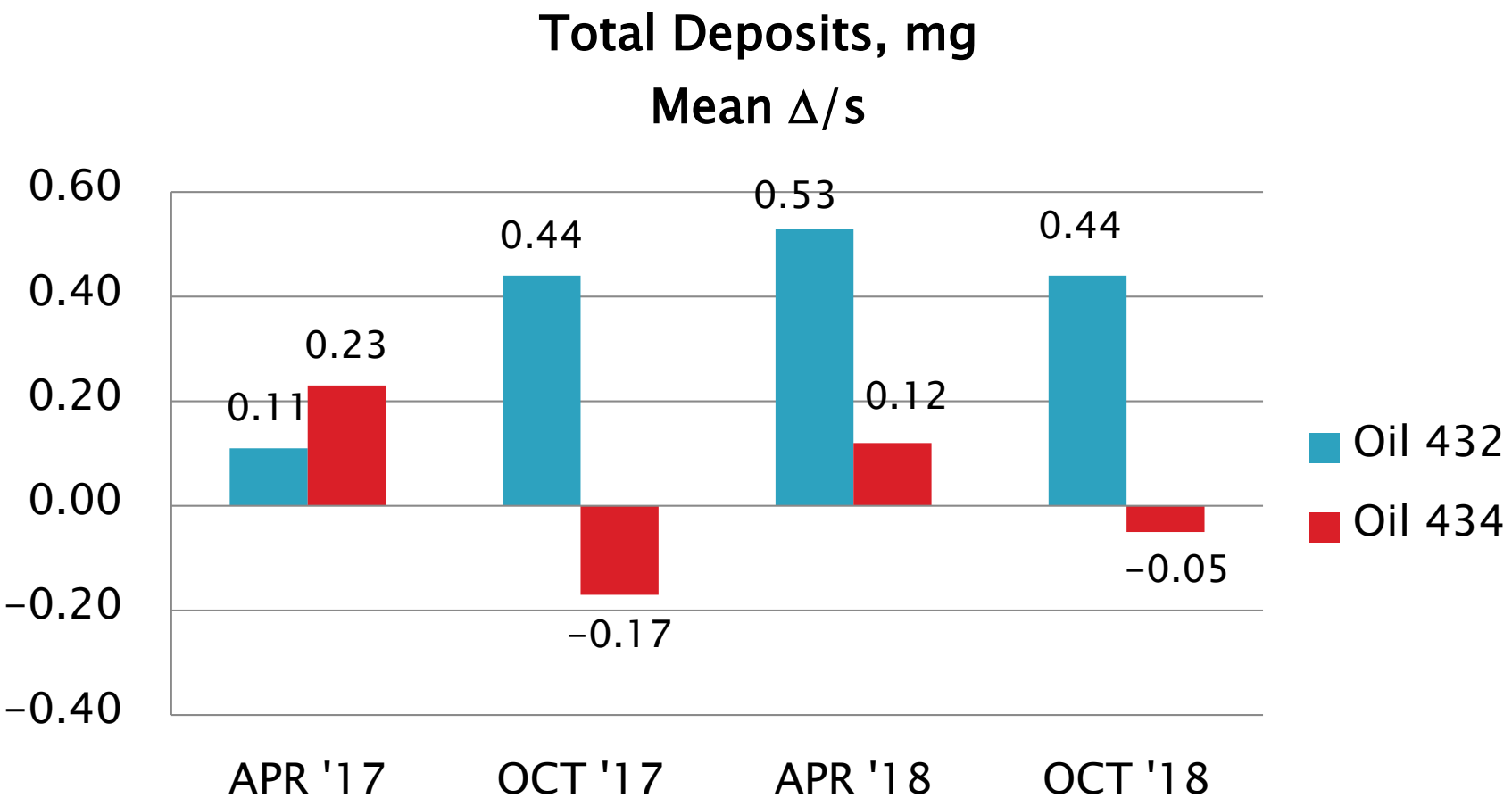
D7097 Performance by Oil



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	7
Failed Calibration Test	OC	0
Operationally Invalidated by Lab	LC, XC	0
Replacement Reference Oil RR	AG	26
Total		**47**

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

D6082: High Temperature Foam

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

- No statistically or operationally invalid calibration runs were reported this period.

- 26 Donated runs reported this period to evaluate two potential replacement reference oils for oil 1007

- One TMC technical update was issued this report period:
  - D6082 Calibration Requirements Update v 20180807
- Future calibration requirement updates will now be issued as LTMS document updates

D6082: High Temperature Foam

Period Precision and Severity Estimates Oil 1007

Foam Tendency, ml	n	Mean	Pooled s	Mean Δ/s
Current Targets	28	65.71	19.28	-----
10/1/14 through 3/31/15	10	61	12	-0.26
4/1/15 through 9/30/15	11	59	16	-0.36
10/1/15 through 3/31/16	8	58	10	-0.45
4/1/16 through 9/30/16	12	59	18	-0.38
10/1/16 through 3/31/17	14	54	19	-0.62
4/1/17 through 9/30/17	12	69	10	0.17
10/1/17 through 3/31/18*	14	66	17	-0.02
10/1/17 through 3/31/18*	13	62	11	-0.19
4/1/18 through 9/30/18	14	65	9	-0.07

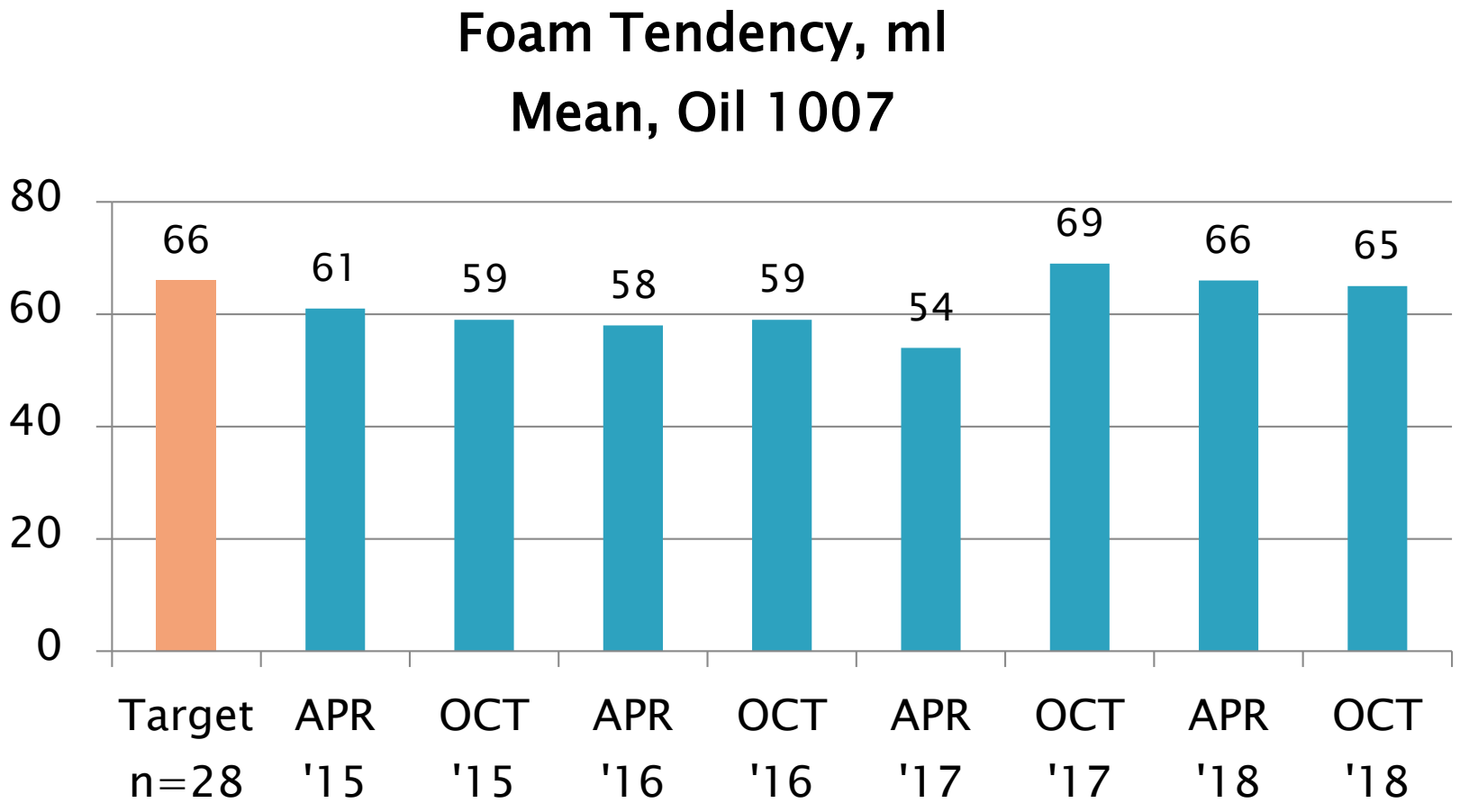
*Single OC result Yi=2.3 s severe included and excluded

D6082: High Temperature Foam

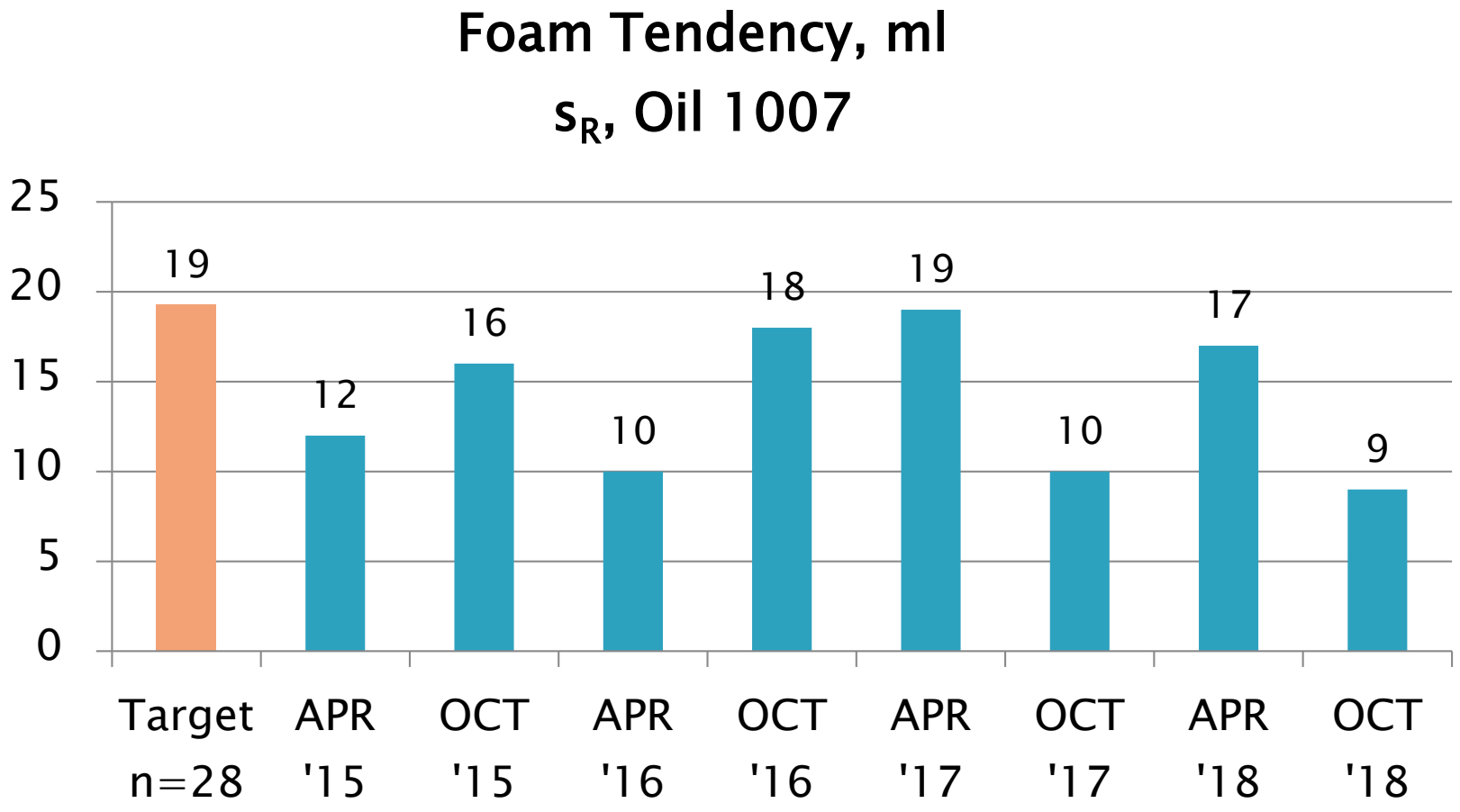
Period Precision and Severity Estimates Oil 1007

Foam Stability @ 1 min, ml	n	Mean	s
Current Targets	28	0.00	0.00
10/1/14 through 3/31/15	10	No non-zero occurrences	
4/1/15 through 9/30/15	11	No non-zero occurrences	
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	

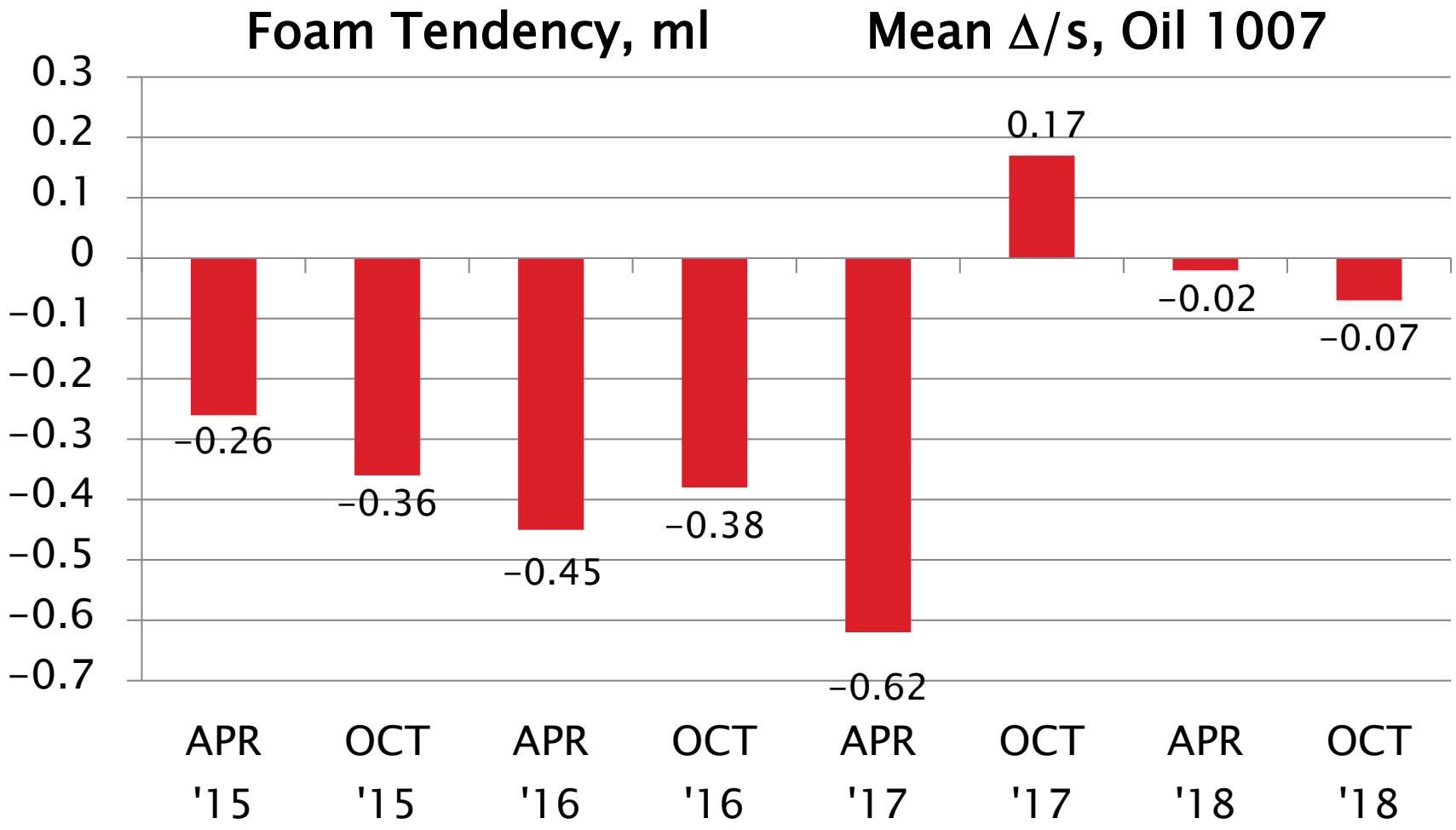
D6082: High Temperature Foam



D6082: High Temperature Foam



D6082: High Temperature Foam

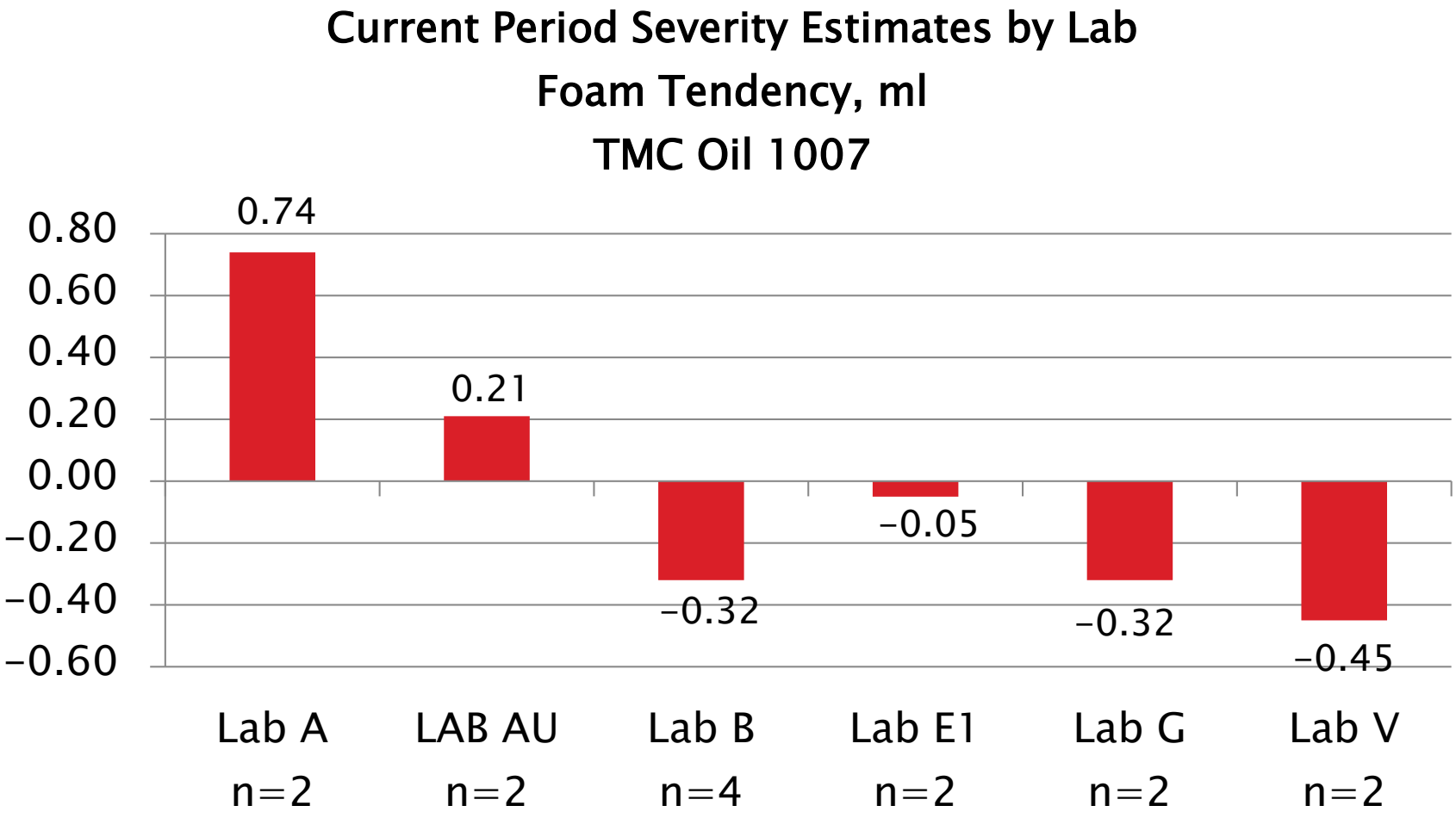


D6082: High Temperature Foam

Current Period Severity Estimates by Lab
Foam Tendency, ml
TMC Oil 1007

	n	Mean Δ/s
Lab A	2	0.74
Lab AU	2	0.21
Lab B	4	-0.32
Lab E1	2	-0.05
Lab G	2	-0.32
Lab V	2	-0.45

D6082: High Temperature Foam



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D6082: High Temperature Foam

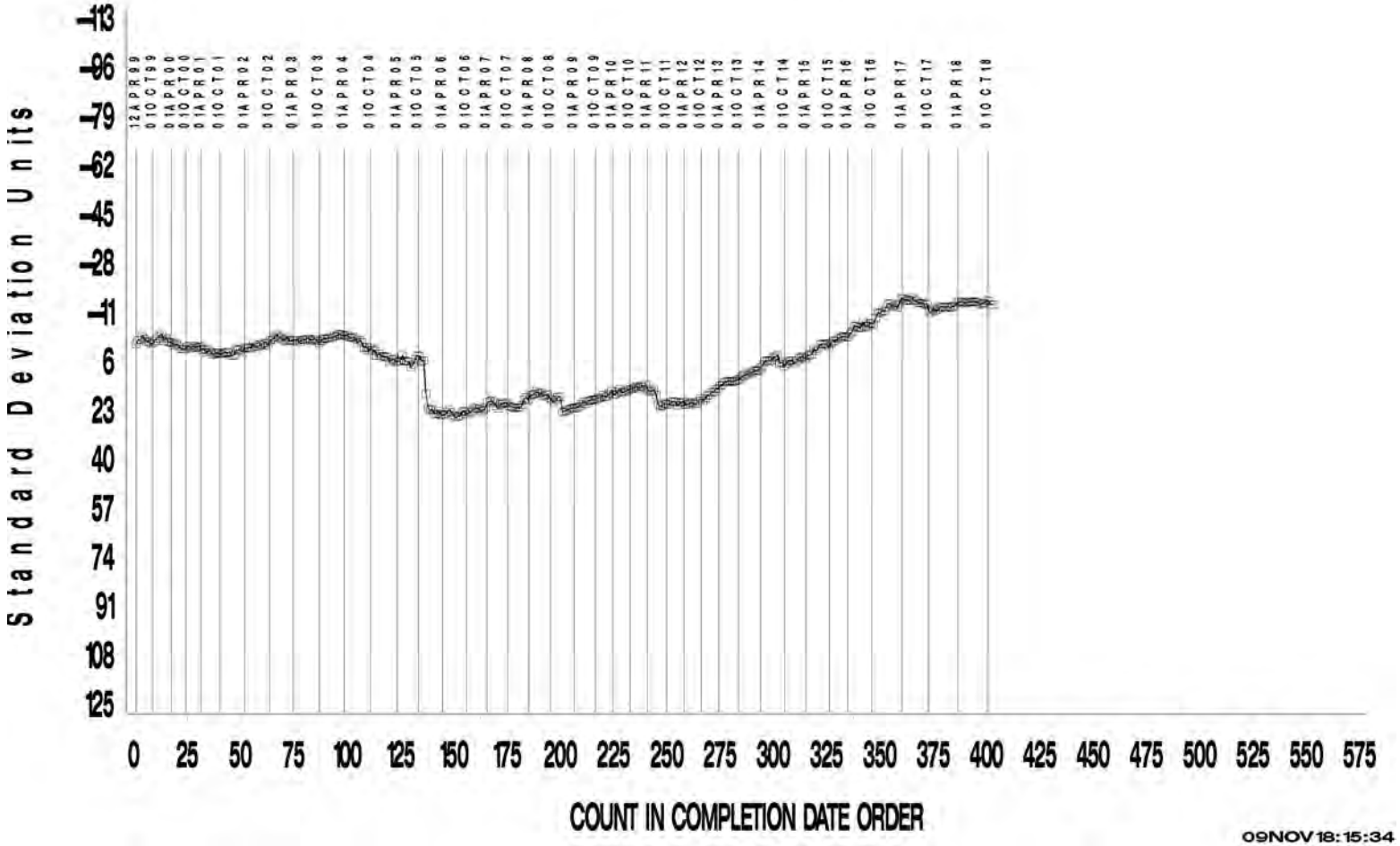
- Foam Tendency Precision (Pooled s) is more precise than the prior report period
  - Significantly better than target precision
- Performance (Mean Δ/s) is on target (slight mild bias)
- No non-zero occurrences of Foam Stability
- All severe oil discrimination runs (on TMC oil 66) demonstrated acceptable discrimination.

D6082 HIGH TEMPERATURE FOAM INDUSTRY OPERATIONALLY VALID DA'

IND= '1007'

FOAM TENDENCY

CUSUM Severity Analysis



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Return to Executive Summary

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	1
Total		**9**

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 invalid tests reported this period
- One operationally invalid test reported this period:
  - Difference between final two ash weighings off-spec (RC)
- No TMC technical updates issued this period

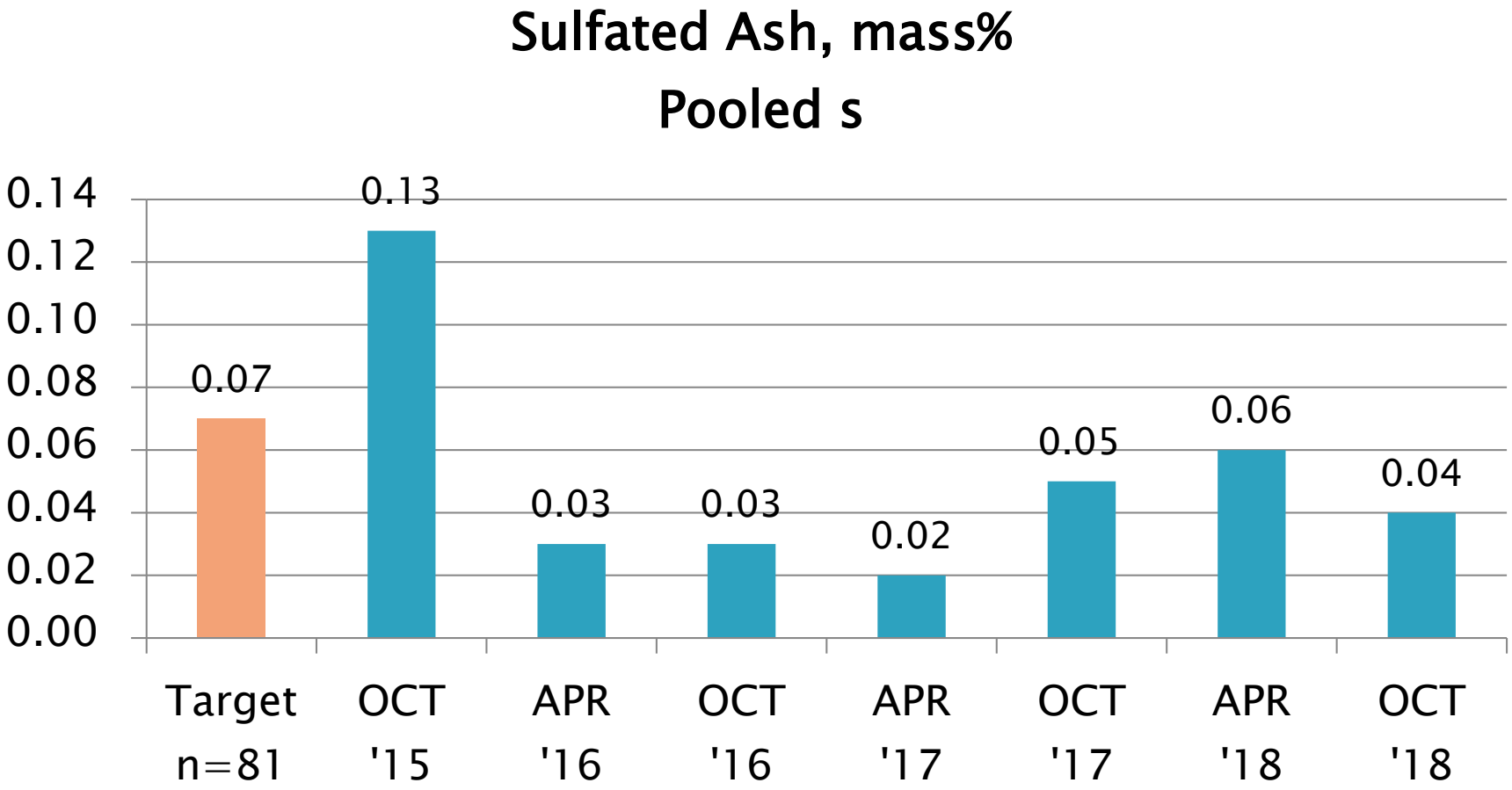
D874: Sulfated Ash

Period Precision and Severity Estimates

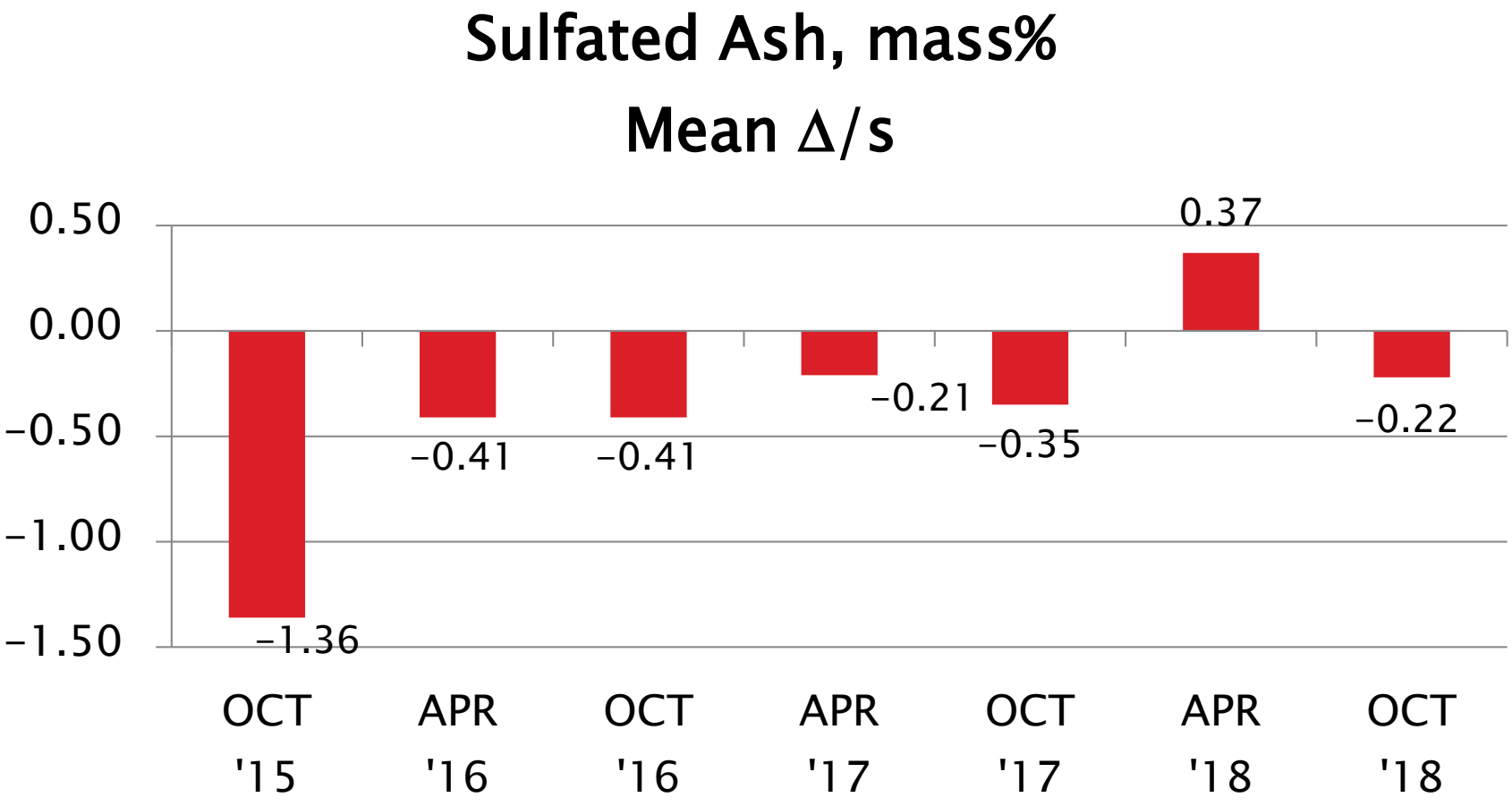
Total Deposits, mg	n	df	Pooled s	Mean Δ/s
Current Targets	81	78	0.07	-----
4/1/15 through 9/30/15*	8	5	0.13	-1.36
4/1/15 through 9/30/15*	7	4	0.05	-0.36
10/1/15 through 3/31/16	7	4	0.03	-0.41
4/1/16 through 9/30/16	6	3	0.03	-0.41
10/1/16 through 3/31/17	7	4	0.02	-0.21
4/1/17 through 9/30/17	8	5	0.05	-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

*Period statistics with and without extreme result included

D874: Sulfated Ash



D874: Sulfated Ash

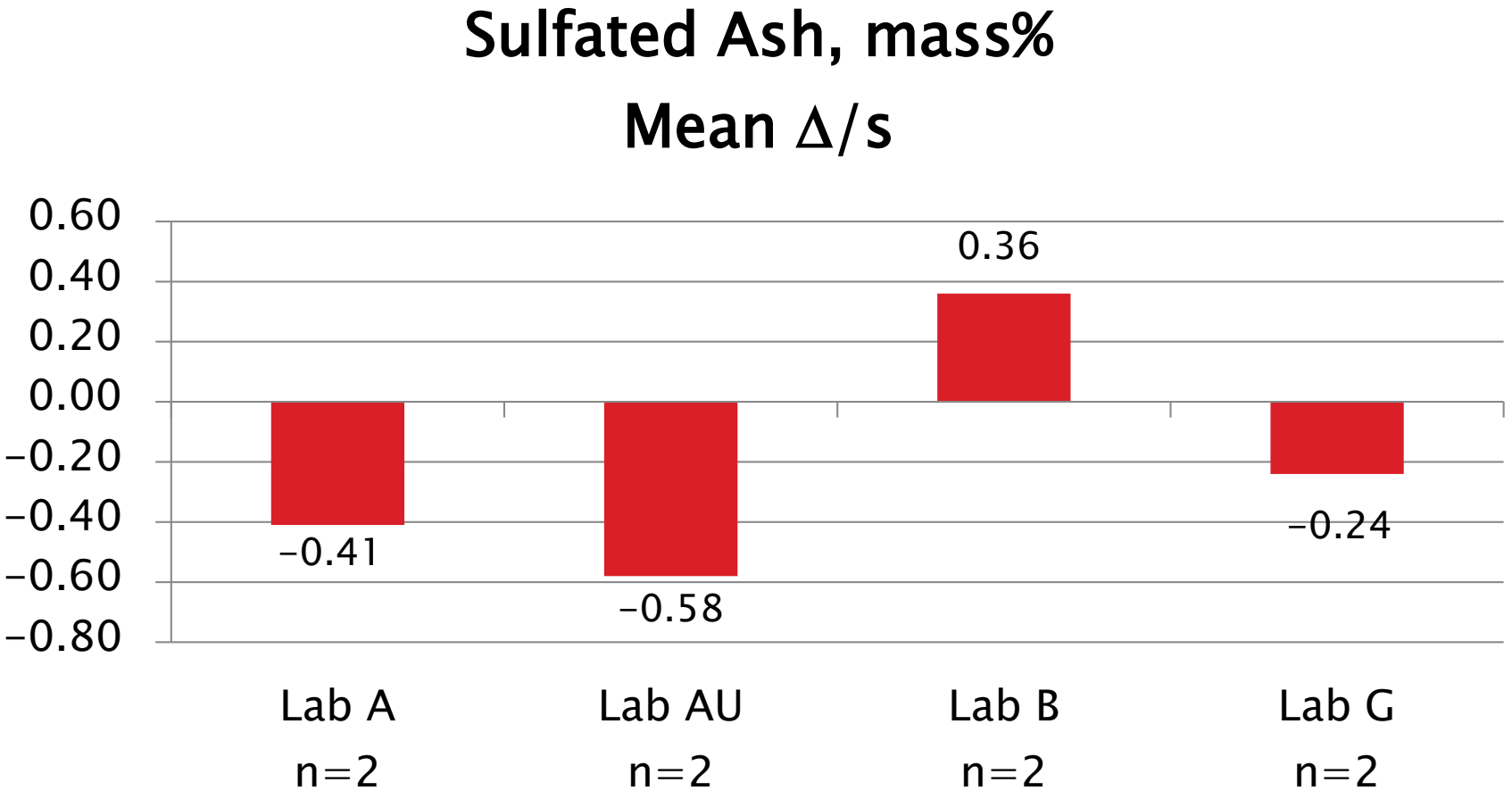


D874: Sulfated Ash

Current Period Severity Estimates by Lab
Sulfated Ash, mass%

	n	Mean Δ/s
Lab A	2	-0.41
Lab AU	2	-0.58
Lab B	2	0.36
Lab G	2	-0.24

D874: Sulfated Ash



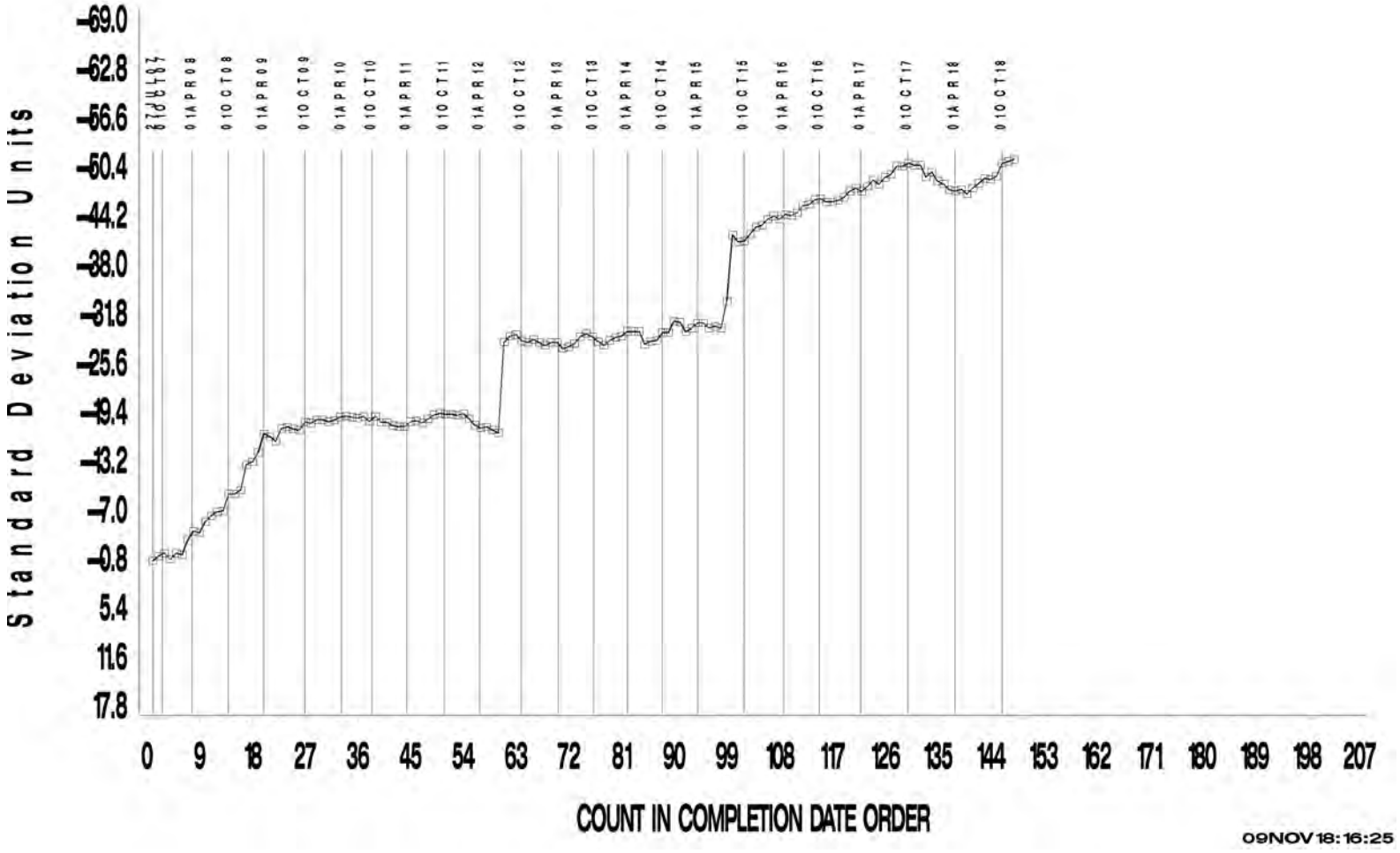
D874: Sulfated Ash

- Precision (Pooled s) is comparable to prior periods
  - More precise than target precision
- Performance (Mean Δ/s) is -0.22 s mild

D874 INDUSTRY OPERATIONALLY VALID DATA

TEST SAMPLE PERCENT SULFATED ASH

CUSUM Severity Analysis

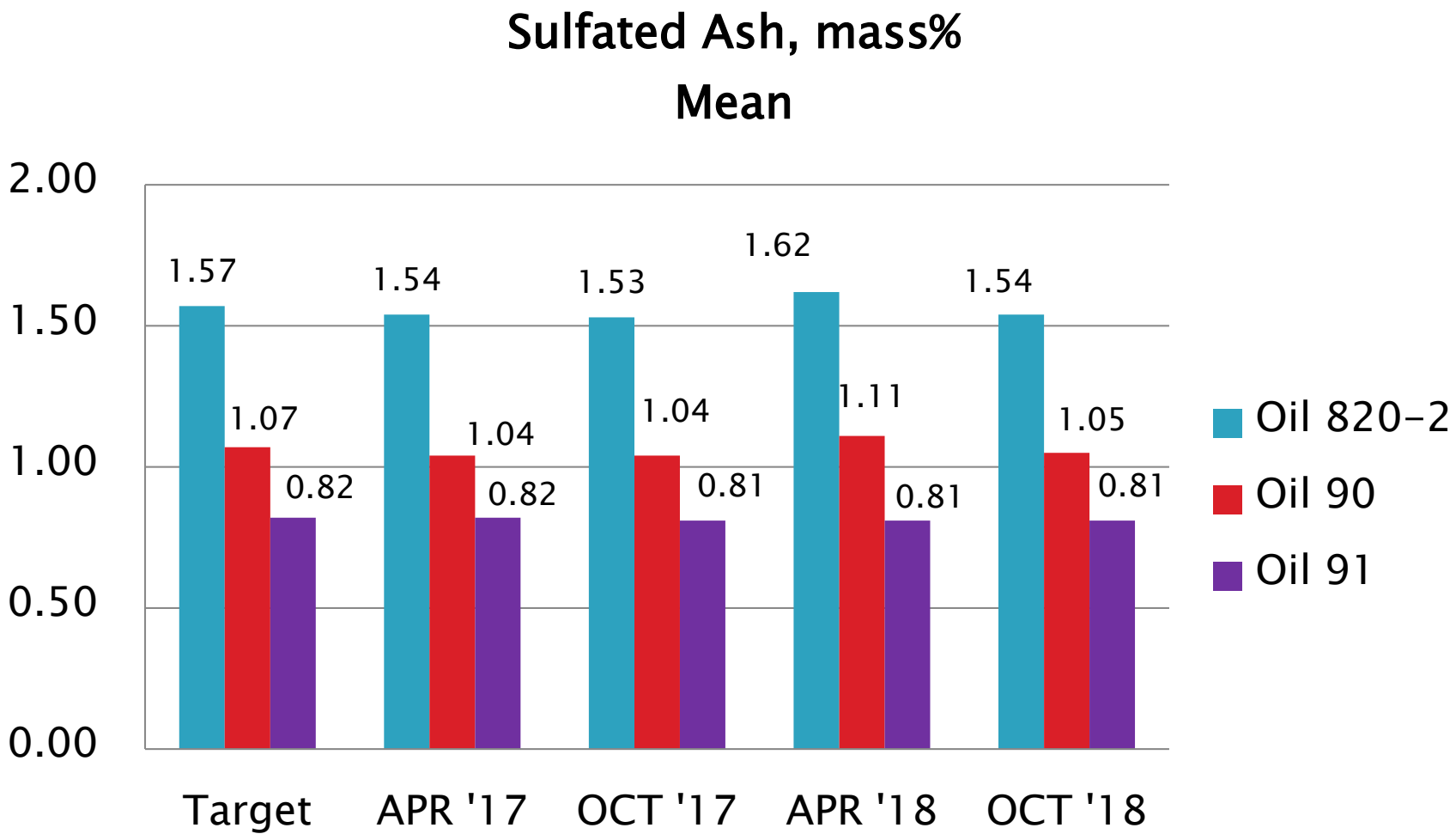


D874: Sulfated Ash

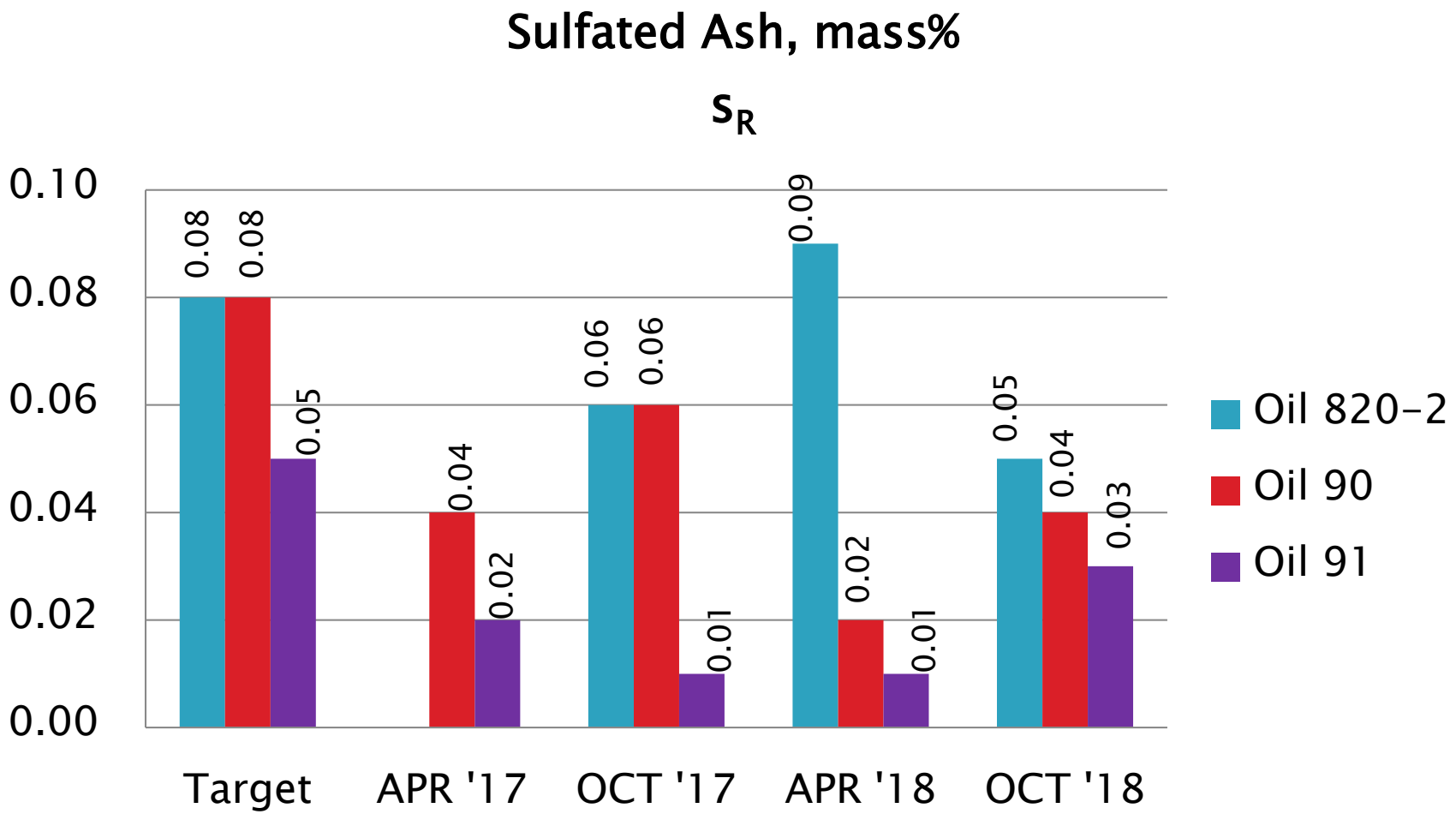
Performance by Oil
Sulfated Ash, mass%

	Targets			4/1/17 – 9/30/17				10/1/17 – 3/31/18				4/1/18 – 9/30/18			
Oil Code	n	Mean	s_R	n	Mean	s_R	Mean Δ/s	n	Mean	s_R	Mean Δ/s	n	Mean	s_R	Mean Δ/s
820-2	27	1.57	0.08	3	1.53	0.06	-0.46	3	1.62	0.09	0.67	2	1.54	0.05	-0.31
90	27	1.07	0.08	3	1.04	0.06	-0.33	3	1.11	0.02	0.46	2	1.05	0.04	-0.25
91	27	0.82	0.05	2	0.81	0.01	-0.20	2	0.81	0.01	-0.20	4	0.81	0.03	-0.15

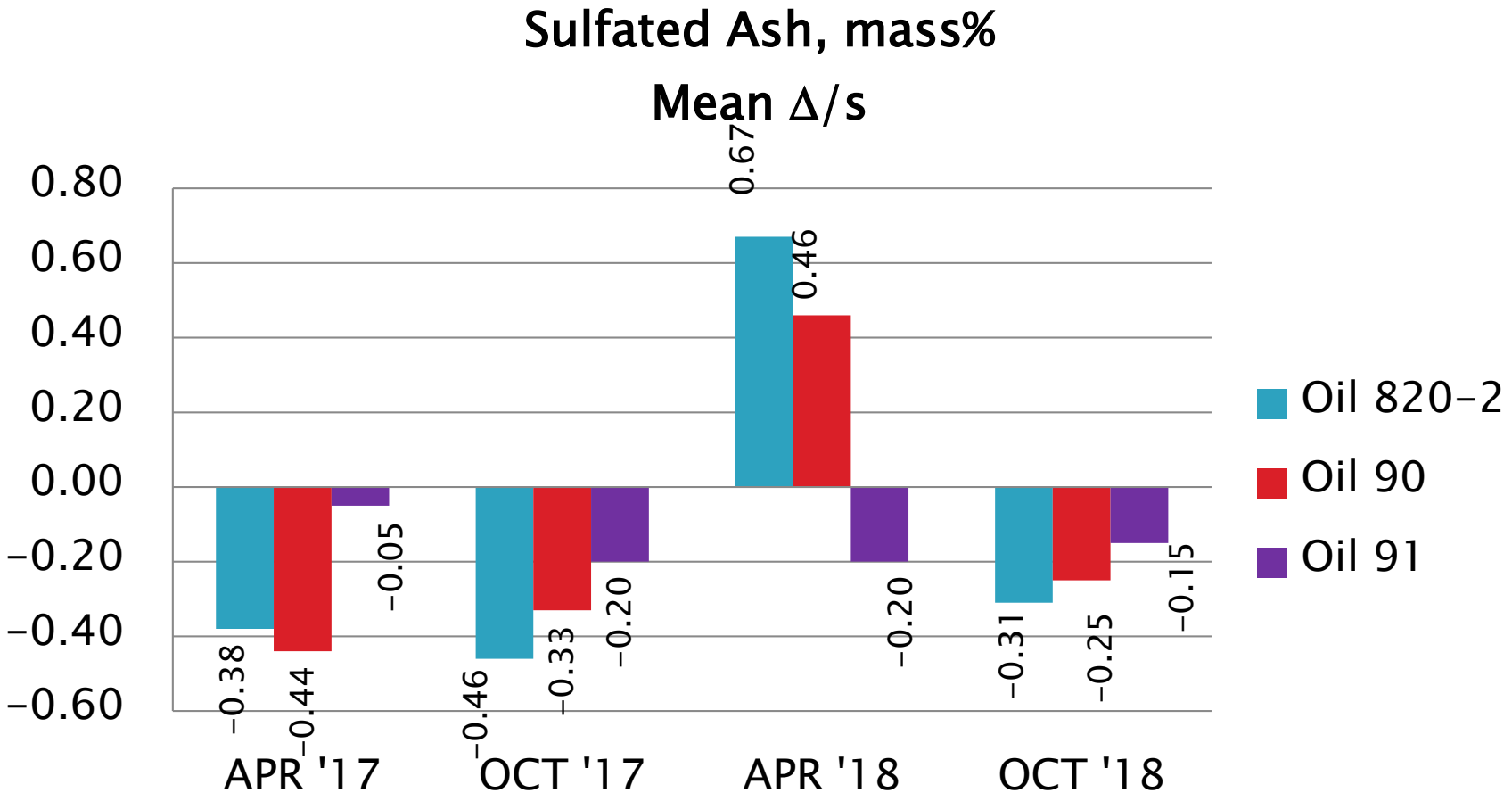
D874: Sulfated Ash



D874: Sulfated Ash



D874: Sulfated Ash



Return to Executive Summary

D7528: Oxidation by ROBO

Test Status	Validity Code	No. Tests
Acceptable Calibration Test	AC	116
Failed Calibration Test	OC	10
Operationally Invalidated by Lab	LC, XC	11
Operationally Invalidated After Initially Reported as Valid	RC	1
Rig Shakedown Runs	NN, ON XN, MC	22
Total		**160**

Number of Labs Reporting Data: 7
Fail Rate of Operationally Valid Tests: 8%

D7528: Oxidation by ROBO

Operationally Invalid Calibration Tests

- 1 test MRV temperature off-spec (XC)
- 1 test MRV Yield Stress off-spec (RC)
- 4 tests NO_2 flow off-spec (XC)
- 1 test sample leak (XC)
- 1 test vacuum failure (XC)
- 1 test heater or heater control failure (XC)
- 1 test thermocouple failure (XC)
- 2 tests power failure

Other Tests

- 18 required rig shakedown runs on five new rigs (not all successful) (NN, ON, XN, MC)
- 4 requested rig shakedown runs to troubleshoot established rigs (NN, MC)

D7528: Oxidation by ROBO

Statistically Unacceptable Tests (OC)	No. Of Tests
Natural Log (MRV Viscosity) Mild	7
Natural Log (MRV Viscosity) Severe	3

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

- One ROBO technical memo was issued this report period:
  - Report Packet Revision Notice ROBO-20180323, issued April 24, 2018, effective May 25, 2018
- Calibration requirement updates are now issued as LTMS document updates

D7528: Oxidation by ROBO

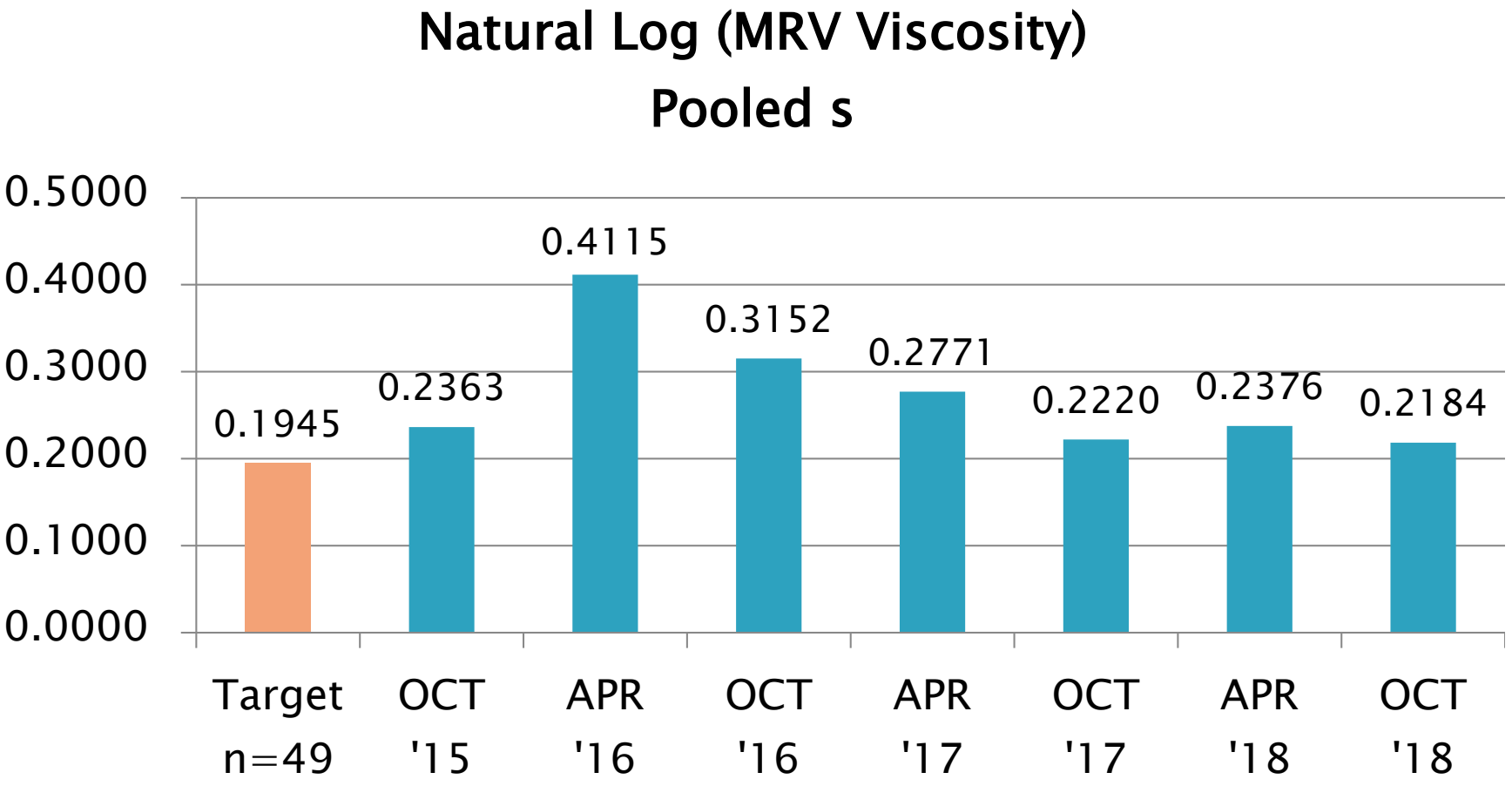
Period Precision and Severity Estimates

Natural Log (MRV Viscosity)	n	df	Pooled s	Mean Δ/s
Current Targets	49	46	0.1945	-----
10/1/15 through 3/31/16*	92	89	0.4115	-0.10
10/1/15 through 3/31/16*	91	88	0.3661	-0.20
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
4/1/18 through 9/30/18*	125	121	0.1958	-0.53

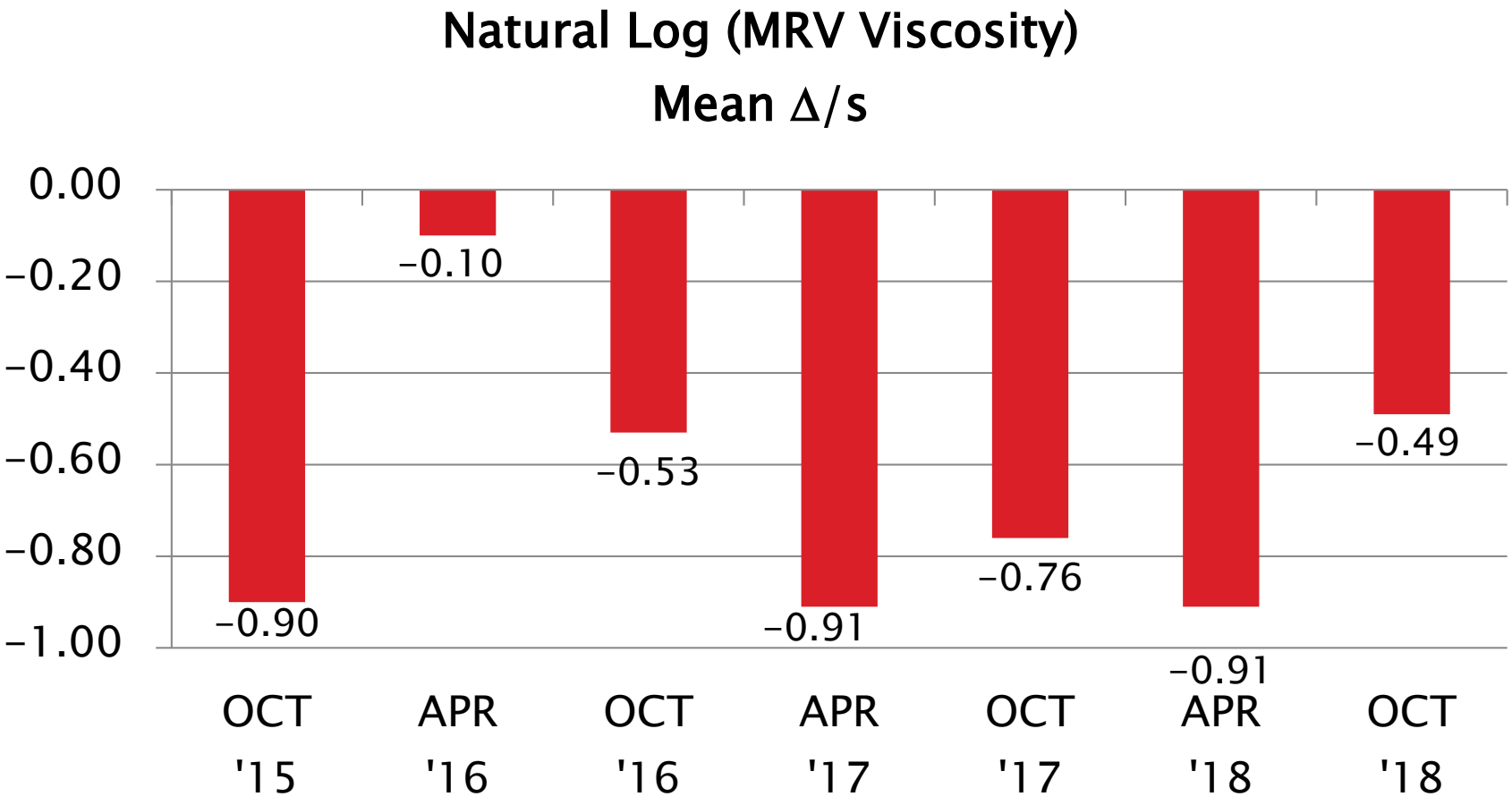
*Period statistics with one extreme result included and excluded

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

D7528: Oxidation by ROBO



D7528: Oxidation by ROBO

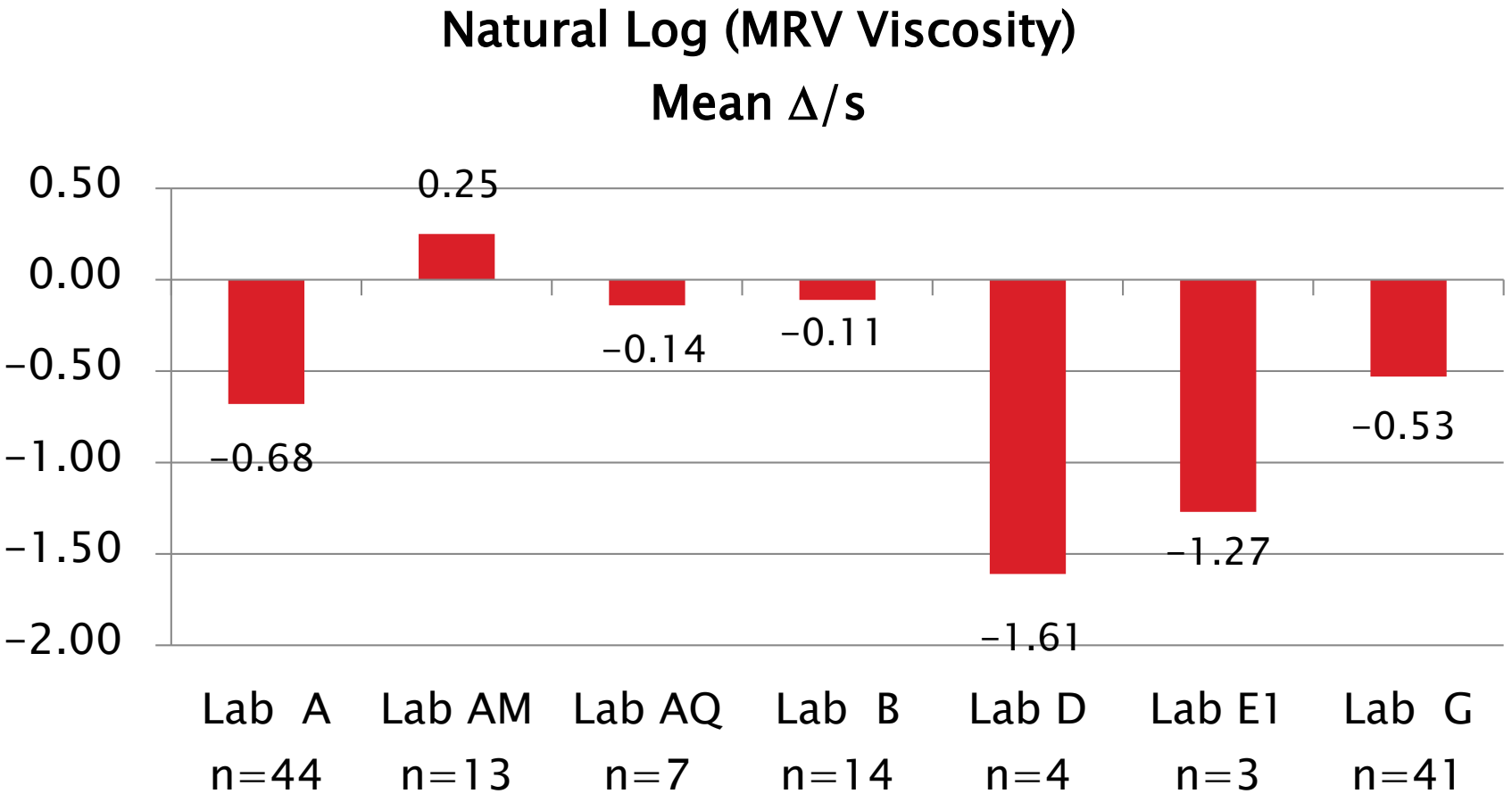


D7528: Oxidation by ROBO

Current Period Severity Estimates by Lab
Natural Log (MRV Viscosity)

	n	Mean Δ/s
Lab A	44	-0.68
Lab AM	13	0.25
Lab AQ	7	-0.14
Lab B	14	-0.11
Lab D	4	-1.61
LAB E1	3	-1.27
Lab G	41	-0.53

D7528: Oxidation by ROBO



D7528: Oxidation by ROBO

- One test reported this period as operationally valid failed 5.0 s severe (Rig B2). Overall period statistics are shown with this result included and excluded.

- As of this report, rig G6 reports 21 calibration attempts and 8 shakedown runs since the last successful calibration expired on 20170805. Of the 21 calibration runs, 5 are AC, 5 OC (3 mild, 2 severe), 10 XC or LC and 1 MC (not acceptable for calibration). The 5 AC tests failed to calibrate under the two-test calibration requirements. Only one of these tests was completed during this report period, an OC fail of 2.3 s severe, which does not significantly affect the period statistics. (The rig very recently passed a two-test calibration sequence, calibrating the rig.)

D7528: Oxidation by ROBO

- Precision (Pooled s) is more precise than last period
  - Continues to be less precise than target precision (but comparable to target with one extreme severe result excluded)
- Performance (Mean Δ/s) is -0.49 s mild
  - Overall performance is -0.59 s mild with one extreme severe result excluded

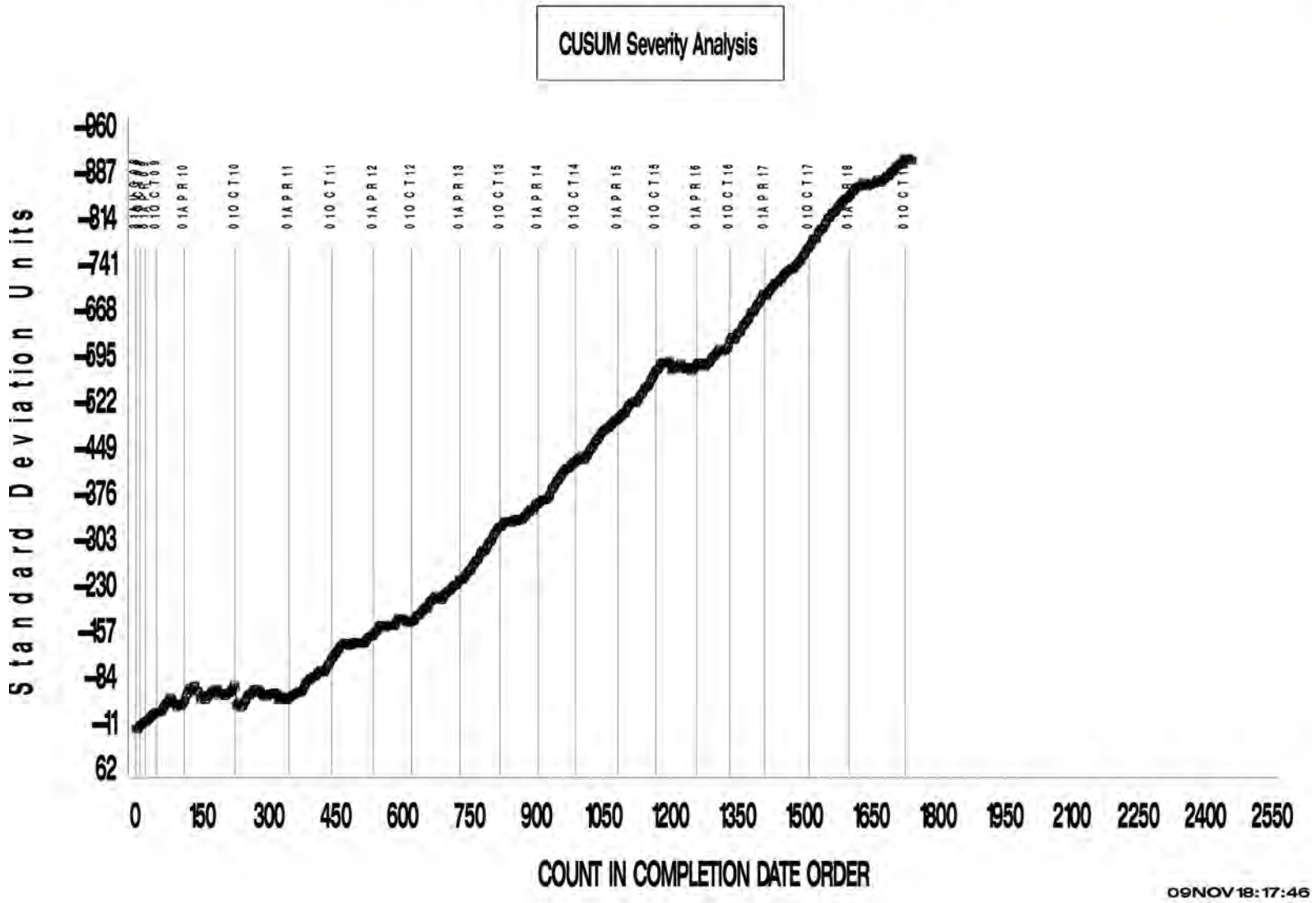
D7528: Oxidation by ROBO

- Oil 434-1 is depleted at the TMC, reblend 434-2 had been introduced last period with preliminary targets set by round robin. 434-2 targets were updated 20180728 with additional calibration test results and by surveillance panel consensus.
  - Any 434-1 in current lab inventories is still being assigned.
  - 434-2 targets were set with consideration of preserving (or not canceling out) the mild trend observed on oil 434-1, and the 434-2 performance reflects that ongoing mild trend.

- CUSUM Severity Plot shows an overall mild trend since the 01APR11 timeline (following a 2011 ROBO workshop) with a brief leveling coincident with the October 2015 ROBO workshop held in San Antonio, TX, but the mild trend returns following the April 2016 timeline.

ROBO TEST INDUSTRY OPERATIONALLY VALID DATA

AGED OIL MRV APPARENT VISCOSITY



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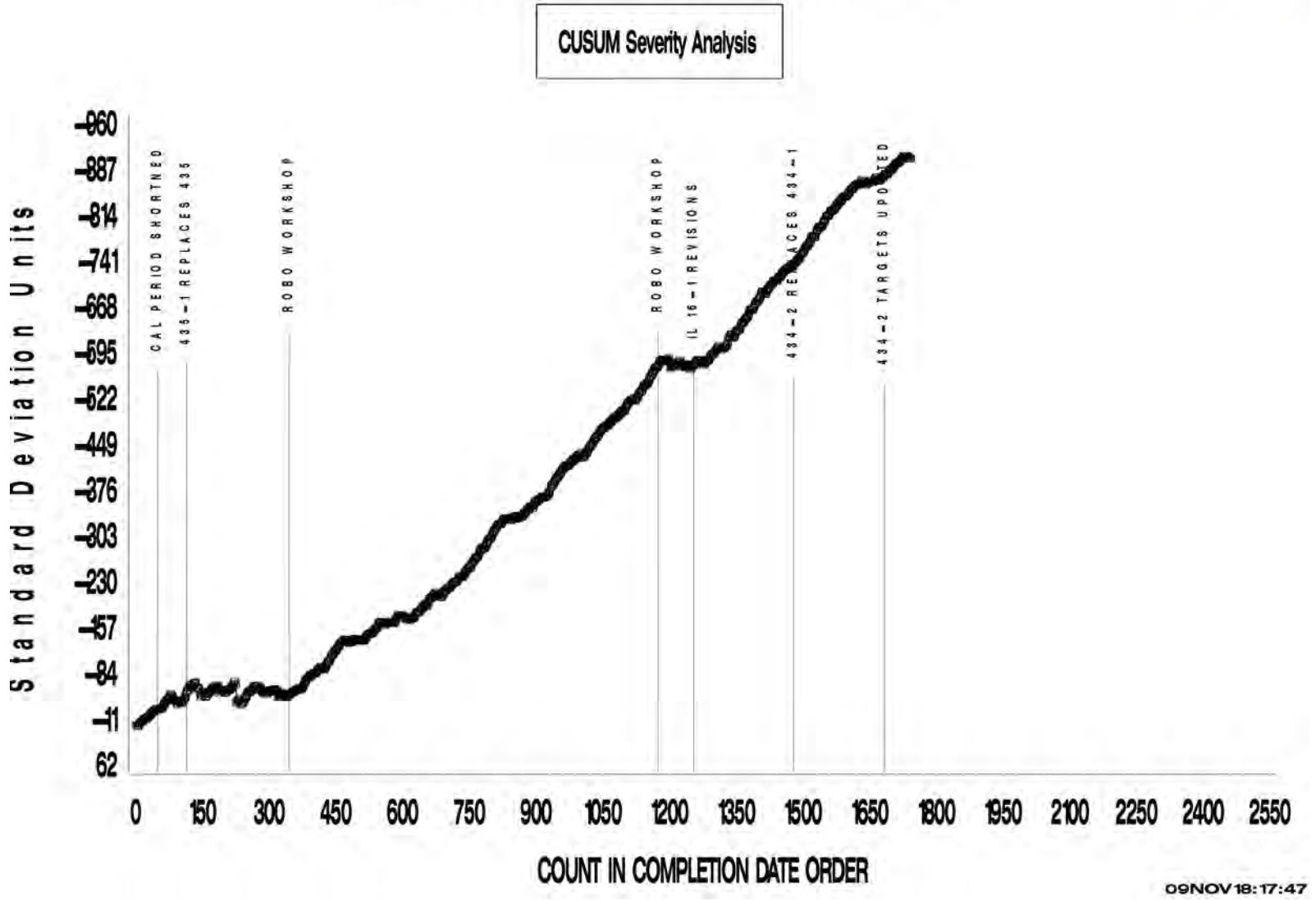
ROBO TEST INDUSTRY OPERATIONALLY VALID DATA

AGED OIL MRV APPARENT VISCOSITY

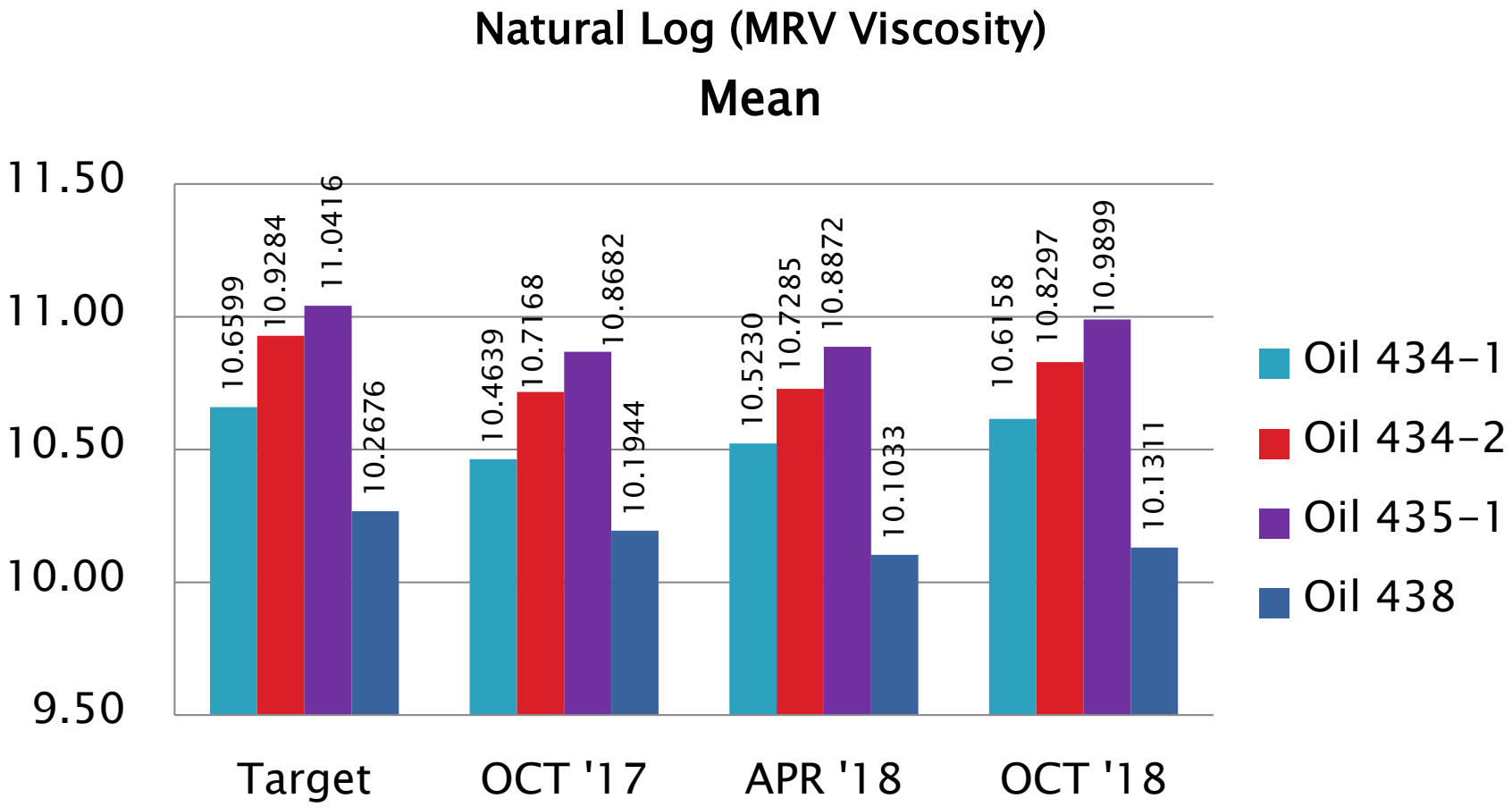


D7528: Oxidation by ROBO

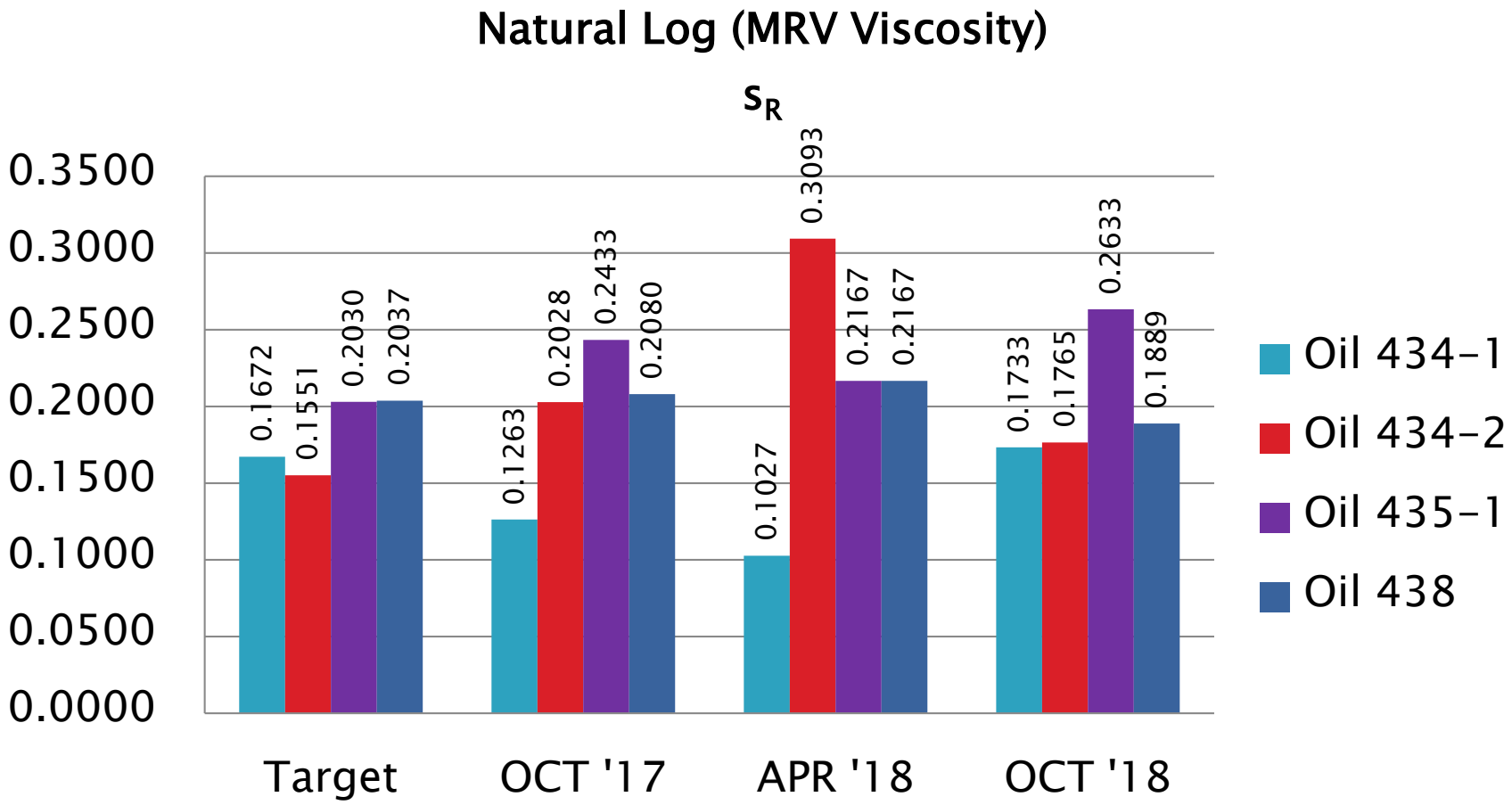
Performance by Oil
Natural Log (MRV Viscosity)

	Targets			4/1/17 - 9/30/17				10/1/17 - 3/31/18				4/1/18 - 9/30/18			
Oil Code	n	Mean	s_R	n	Mean	s_R	Mean Δ/s	n	Mean	s_R	Mean Δ/s	n	Mean	s_R	Mean Δ/s
434-1	13	10.6599	0.1672	8	10.4639	0.1263	-1.17	8	10.5230	0.1027	-0.82	4	10.6158	0.1733	-0.26
434-2	36	10.9284	0.1551	9	10.7168	0.2028	-1.34	23	10.7285	0.3093	-1.27	37	10.8297	0.1765	-0.66
435-1	22	11.0416	0.2030	50	10.8682	0.2433	-0.85	40	10.8872	0.2167	-0.76	50	10.9899	0.2633	-0.25
438	14	10.2676	0.2037	32	10.1944	0.2080	-0.36	19	10.1033	0.2167	-0.81	35	10.1311	0.1889	-0.67

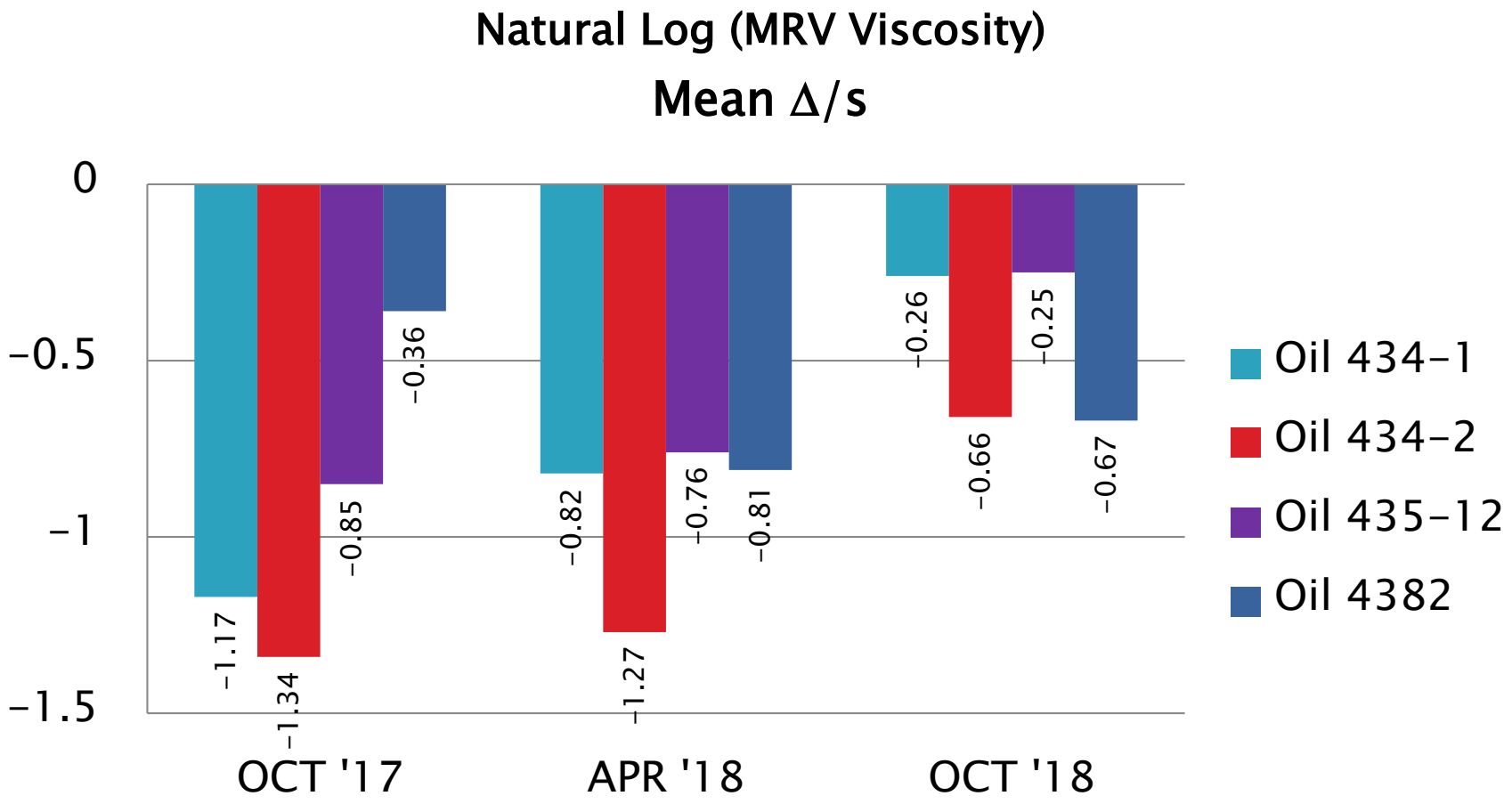
D7528: Oxidation by ROBO



D7528: Oxidation by ROBO



D7528: Oxidation by ROBO



Return to Executive Summary

Reference Oil Inventory

- As of 9/30/2018

Reference Oil Inventory

D5800, D6417, GI

Oil	Year Rec'd By TMC	Tests	TMC Inventory, gallons	Gallons Shipped last 12 months
VOLC12	2013	D5800	37.4	3.5
VOLD12	2013	D5800	40.2	3.1
VOLE12	2013	D5800	38.3	3.9
VOLD14	2014	D5800QC	33.5	76.3
VOLD18*	2018	D5800QC (proposed)	1090.2	1.8
52	1995	D6417	58.9	0.0
55	1995	D6417	66.0	0.0
58	1998	D6417, GI	115.5	0.2

*VOLD18 is currently being evaluated to replace oil VOLD14

Reference Oil Inventory

GI

Oil	Year Rec'd By TMC	Tests	TMC Inventory, gallons	Gallons Shipped last 12 months
62	1996	GI	0.4	0.2
GIA17*	2017	GI (proposed)	9.8	0.1
GIB17*	2017	GI (proposed)	9.9	0.1
1009**	2002	GI	34.1	0.1

*GIA17 & GIB17 are currently being evaluated to replace oil 62

**Multi-test oil; estimated aliquot reserved for bench testing.

Reference Oil Inventory

TEOST, MTEOS & ROBO

Oil	Year Rec'd By TMC	Tests	TMC Inventory, gallons	Gallons Shipped last 12 months
432	1998	MTEOS	107.3	0.6
434	2003	MTEOS	1.8	0.6
75	2010	TEOST	1.3	0.7
75-1*	2016	TEOST (proposed)	9.3	0.0
435-2**	2010	TEOST	2.9	0.3
434-2	2014	ROBO	16.4	5.1
435-1	2008	ROBO	416.2	23.5
438***	2003	ROBO	0.6	3.0

*75-1 is currently being evaluated to replace oil 75

**Multi-test oil; estimated aliquot reserved for bench testing.

***438 resupply from IIIG inventory is no longer available!

Reference Oil Inventory

D6082 & D874

Oil	Year Rec'd By TMC	Tests	TMC Inventory, gallons	Gallons Shipped last 12 months
1007	1998	D6082	8 samples	12 samples
FOAMA18*	2018	~~D6082~~ (no application)	101.5	2.5
FOAMB18*	2018	D6082	99.5	2.5
66	2002	D6082	83.1	0.7
820-2	2001	D874	10.0	0.1
90*	2005	D874/D874QC	19.5	0.6
91	2006	D874	3.9	0.1

*FOAMB18 selected over FOAMA18 to replace nearly depleted oil 1007
**Oil 90 is also used as a D874 QC Check Oil

Additional Information

Additional Information

- Available on the TMC's Website:
  - 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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