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

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

October 2017

B0.07 Bench Testing
Executive Summary

- D6417 (Volatility by GC)
- Precision (Pooled s) is comparable to prior period
  - Comparable to target precision
- Performance (Mean Δ/s) is on target (-0.01 s)
  - Significant improvement over prior period (0.77 s).
- CUSUM plot shows overall on-target performance this period, compared to quite severe performance last period.
- Oil 52 performance affected by single (failing) mild result of -3.1 s (Lab G).

B0.07 Bench Testing
Executive Summary

- D5800 (Volatility by Noack)
- One result was reported as operationally valid at 13 standard deviations severe (rig J2). The TMC did inquire to confirm that the result is considered operationally valid by lab J. Overall statistics are shown with this extreme result included and excluded.
- Precision (Pooled s), at 0.84 mass % (extreme result of 13 s severe excluded), is less precise than the target LTMS pooled precision of 0.73 mass %.
- Performance (Mean Δ/s) is 0.47 s severe (extreme result of 13 s severe excluded), using the current LTMS target precision (0.73 mass % across oils). Prior reported periods use the target pooled s.d. in place at the time.
- Fail rate of operationally valid tests (AC & OC) has dropped to 5% for the most recent two report periods using LTMS, compared to 26% under the Shewhart severity only system.
- Historical long-term severe trend continues with TMC calibrations, but now 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)
- One test reported nearly 5 s severe (Lab I Rig 3, oil 62), overall statistics are shown with this result included and excluded for comparison of influence.
  - This rig had problems passing calibration last period, lab ran a number of shakedowns before passing calibration this period, but followed that with the very severe fail, and with no cause identified. Rig followed with another passing calibration after the close of this period report.
- Fail rate of operationally valid tests is 10% this period, compared to 26% last period, and only 6% before that.
- Overall severity is -0.25 s mild
- Precision (Pooled s), even with extreme result excluded, is less precise than prior period
  - More precise than target precision
- Reference oil 62 inventory is down to 0.7 gallons remaining (with 0.4 gallon shipped prior 12 months).

B0.07 Bench Testing Executive Summary

- D6335 (TEOST-33C)

- Precision (Pooled s) is comparable to prior period
  - Less precise than target precision
  - Severe oil 75 performance continues to be imprecise
- Performance (Mean Δ/s) is on target (or slightly mild with three OC tests on same rig excluded)
- All tests this period report using Rod Batch M

B0.07 Bench Testing Executive Summary

- D7097 (MHT-4 TEOST)
- Precision (Pooled s) is more precise than last period
  - More precise than target precision (for the first time in at least 7 report periods).
    - Precision of both oils is better than target.
    - Possibly because use of new end cap flask seals has improved test precision?
- Performance (Mean Δ/s) is 0.14 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=54) or 16DA (n=29).
  - First calibration tests using catalyst batch 16DA reported this period.

B0.07 Bench Testing
Executive Summary

- D7097 (MHT-4 TEOST) continued

- CUSUM severity plot shows some overall leveling the past three periods (excluding some questionable results)
  - However, lab performance differences persist

- Initial severity bias of new catalyst batch 16DA on severe performing oil 432 is more severe (0.64 s) than we had typically seen with batch 15AA (though batch 14AA had similar severe periods), and will be monitored. Mild performing oil 434 is biased somewhat mild (-0.35 s), more so than the last three periods on 15AA.

B0.07 Bench Testing Executive Summary

- D6082 (High Temperature Foam)
- Foam Tendency Precision (Pooled s) is greatly improved compared to the prior two report periods
  - Also much more precise than target precision
- Performance (Mean Δ/s) is 0.17 s severe
  - Follows the most mild period since at least October 2013
    - Attributable (last period) mostly to Lab B (two instruments, six tests, all between -1.3 and -1.9 s mild)
    - This period, Lab B is only -0.18 s mild (n=4).
- The most accurate AND precise period since at least 2014.
- No non-zero occurrences of Foam Stability (on operationally valid tests)
- All severe oil discrimination runs demonstrated acceptable discrimination.

B0.07 Bench Testing
Executive Summary

- D874 (Sulfated Ash)
- Precision (Pooled s) is identical to the prior period
  - More precise than target precision
- Performance (Mean Δ/s) is -0.41 s mild

B0.07 Bench Testing Executive Summary

- D7528 (ROBO)
- Precision (Pooled s) is more precise than all prior periods since at least October 2104.
  - But, continues to be less precise than target precision
- Performance (Mean Δ/s) is -0.76 s mild with all labs mild to some degree and all four oils performing overall mild
- Lab G, with, by far, the highest n size of any lab this period has a few issues of note:
  - Only three tests exceed 3 s (severe or mild) this period: (-3.8, 3.4, -3.5), but all are from Lab G, and each failing result is on a different rig.
  - Rig G6 has 4 failing OC runs this period (three mild and one severe; two consecutive fails), alternating with passing (AC) runs.
  - Rig G2 has 3 failing OC runs (all mild, two consecutive), alternating with passing (AC) runs.
  - These two rigs (G2 and G6) account for 7 of the 15 OC tests reported this period.

B0.07 Bench Testing
Executive Summary

- D7528 (ROBO) continued
- Oil 434-1 is nearly depleted, Reblend 434-2 has been introduced with preliminary targets set by round robin.
  - 434-2 is running -1.34 s mild on nine tests, however targets were set with consideration of preserving (or not canceling out) the mild trend 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	7
D5800	9	19
D5133 (GI)	6	9
D6335 (TEOST)	5	8
D7097 (MTEOS)	8	37
D6082	5	6
D874	4	--
D7528 (ROBO)	5	16

*As of 9/30/2017

D02.B0.07
TMC Monitored Tests

- April 1, 2017 –
  October 30, 2017

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D6417: Estimation of Engine Oil Volatility by Capillary GC

Test Status	Validity Code	No. Tests
Acceptable Calibration Test	AC	14
Failed Calibration Test	OC	1
Operationally Invalidated by Lab	LC, XC	0
Operationally Invalidated After Initially Reported as Valid	RC	0
Total		**15**

Number of Labs Reporting Data: 6
Fail Rate of Operationally Valid Tests: 7%

D6417: Estimation of Engine Oil Volatility by Capillary GC

Statistically Unacceptable Tests (OC)	No. Of Tests
Volatility Loss Mild	1
Volatility Loss Severe	0

- There were no technical memos issued this period for D6417.

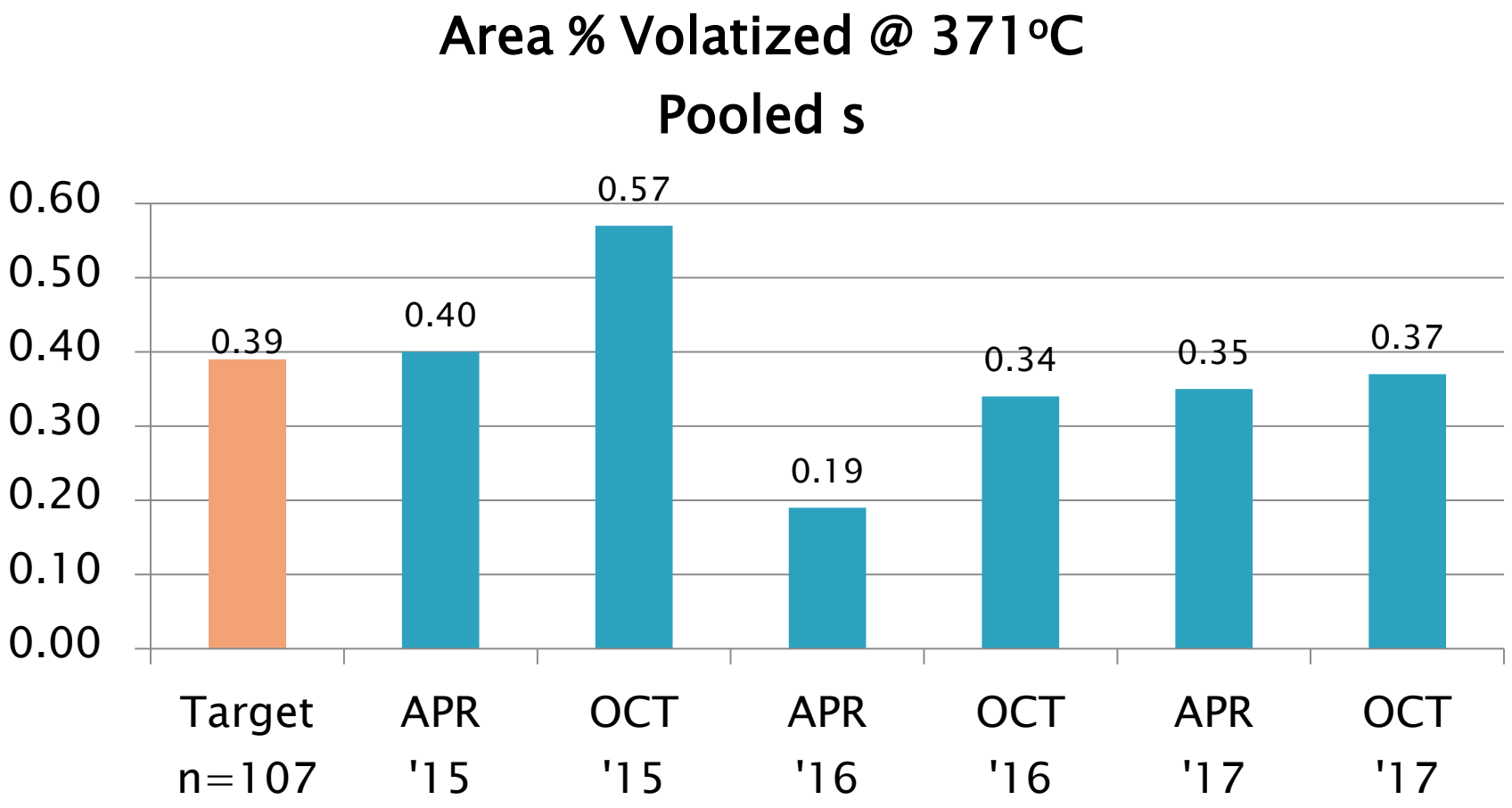
D6417: Estimation of Engine Oil Volatility by Capillary GC

Period Precision and Severity Estimates

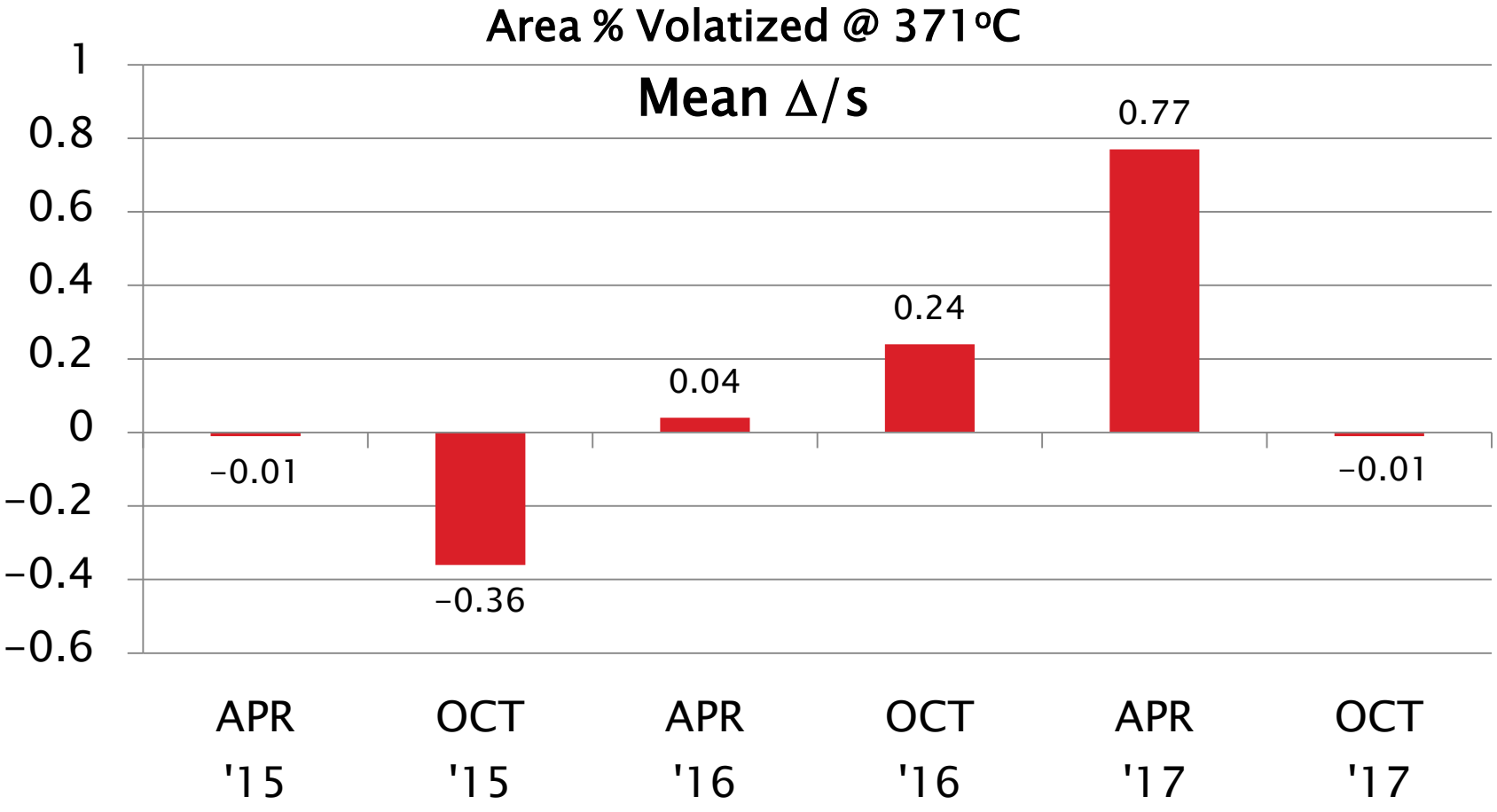
Area % Volatized @ 371°C	n	df	Pooled s	Mean Δ/s
Initial Selected Oils from RR	54	51	0.39	-----
10/1/14 through 3/31/15	14	11	0.40	-0.01
4/1/15 through 9/30/15* 4/1/15 through 9/30/15*	16 15	13 12	0.57 0.42	-0.36 -0.04
10/1/15 through 3/31/16	13	10	0.19	0.04
4/1/16 through 9/30/16	11	8	0.34	0.24
10/1/16 through 3/31/17	13	10	0.35	0.77
4/1/17 through 9/30/17	15	12	0.37	-0.01

*Extreme OC result included and excluded

D6417 Precision Estimates



D6417 Severity Estimates



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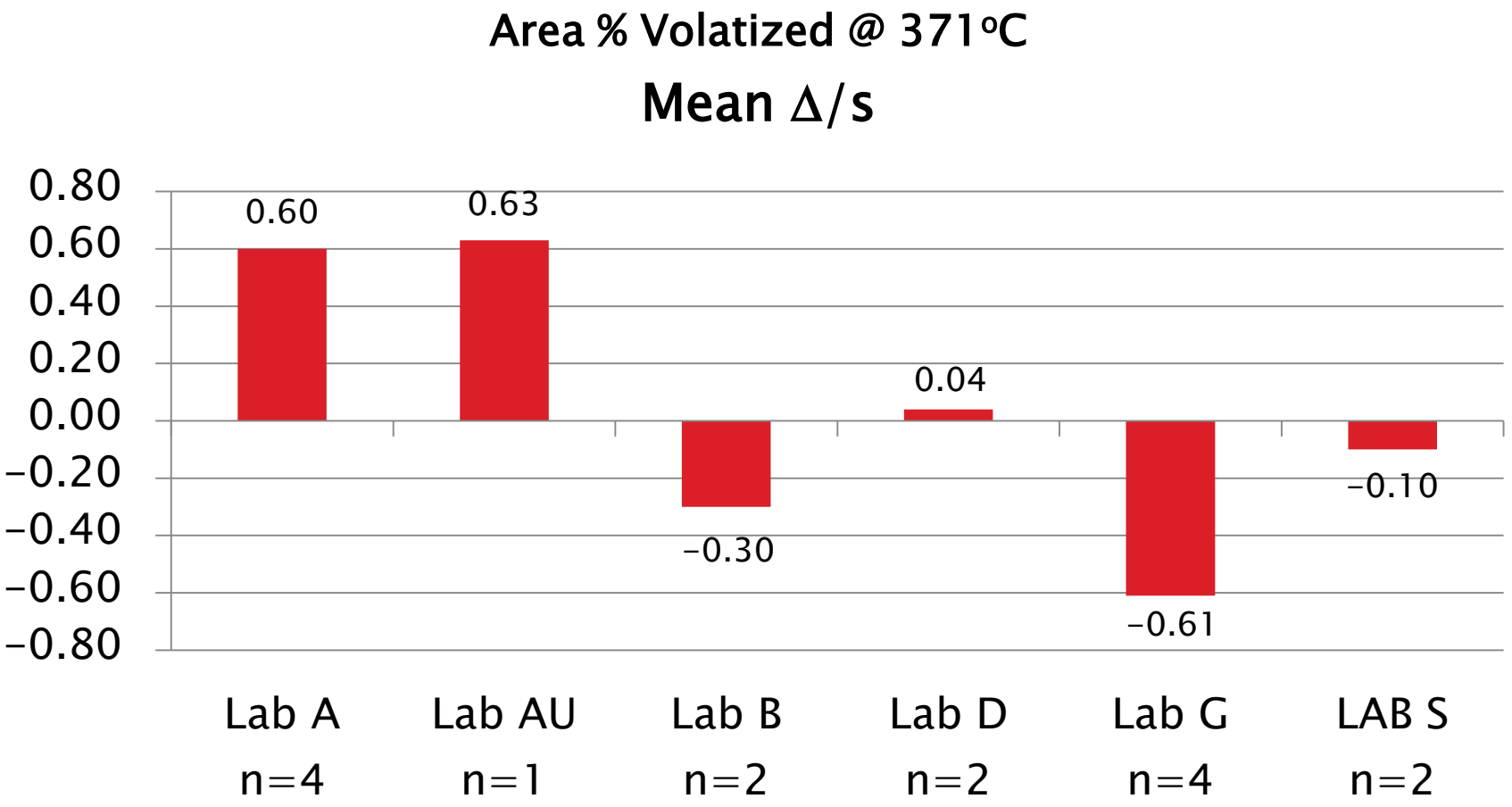
D6417: Estimation of Engine Oil Volatility by Capillary GC

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

	n	Mean Δ/s
Lab A	4	0.60
Lab AU	1	0.63
Lab B	2	-0.30
Lab D	2	0.04
Lab G	4	-0.61
Lab S	2	-0.10

D6417 Lab Severity Estimates



D6417: Estimation of Engine Oil Volatility by Capillary GC

- Precision (Pooled s) is comparable to prior period
  - Comparable to target precision
- Performance (Mean Δ/s) is on target (-0.01 s)
  - Significant improvement over prior period (0.77 s).
- CUSUM plot shows overall on-target performance this period, compared to quite severe performance last period.
- Oil 52 performance affected by single (failing) mild result of -3.1 s (Lab G).

D6417 VOLATILITY BY GC INDUSTRY OPERATIONALLY VALID DATA

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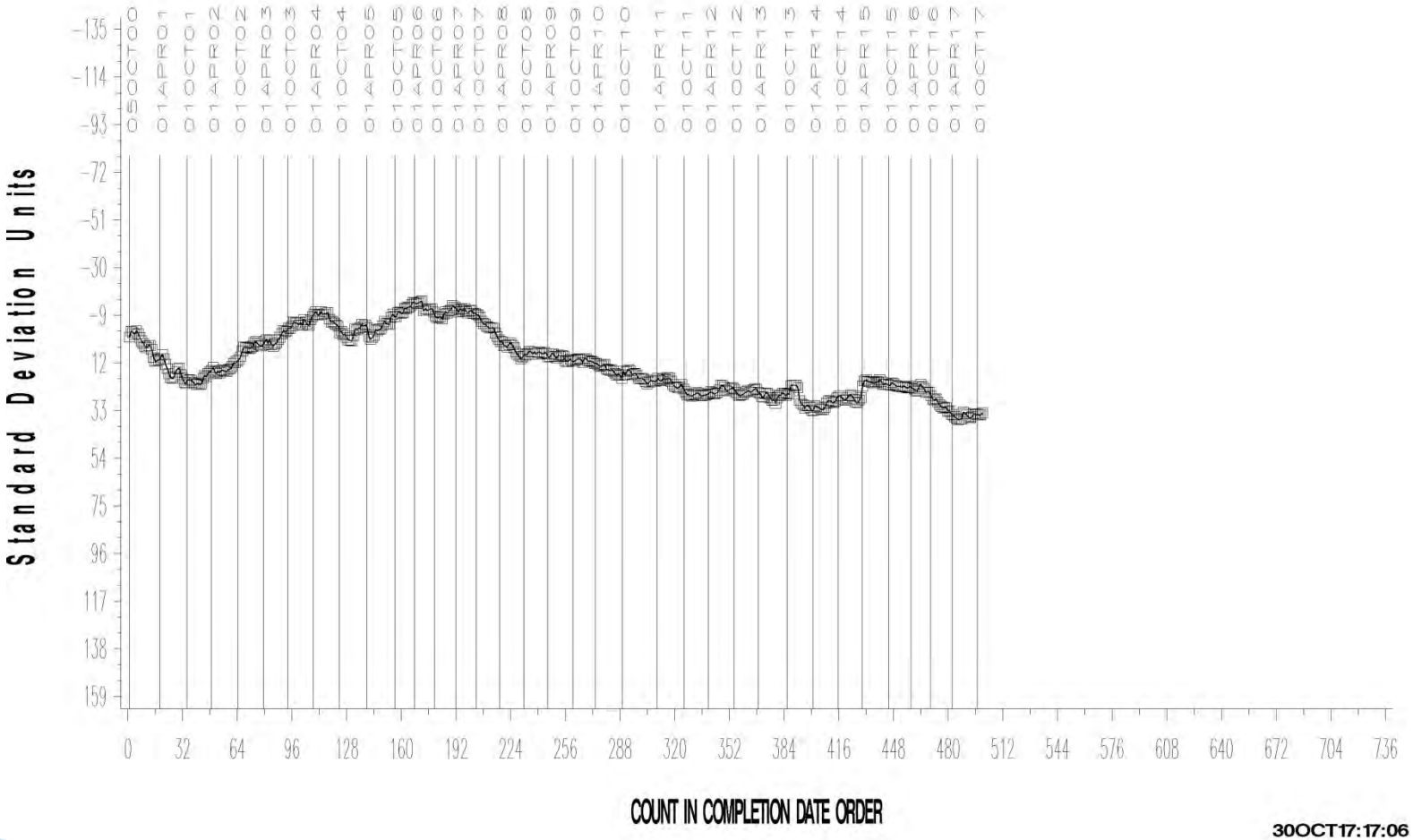
SAMPLE AREA % VOLATIZED

CUSUM Severity Analysis



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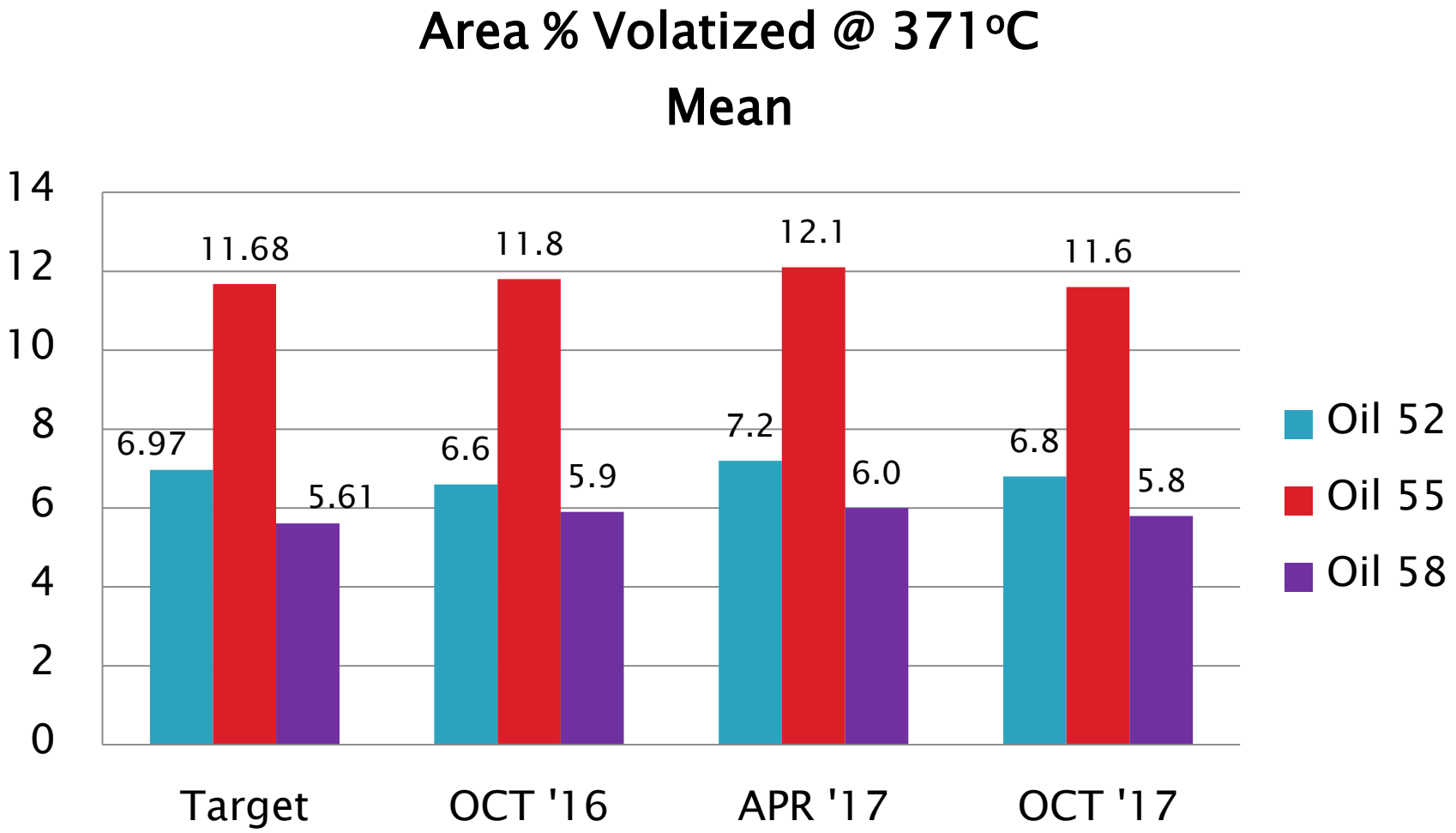
D6417: Estimation of Engine Oil Volatility by Capillary GC

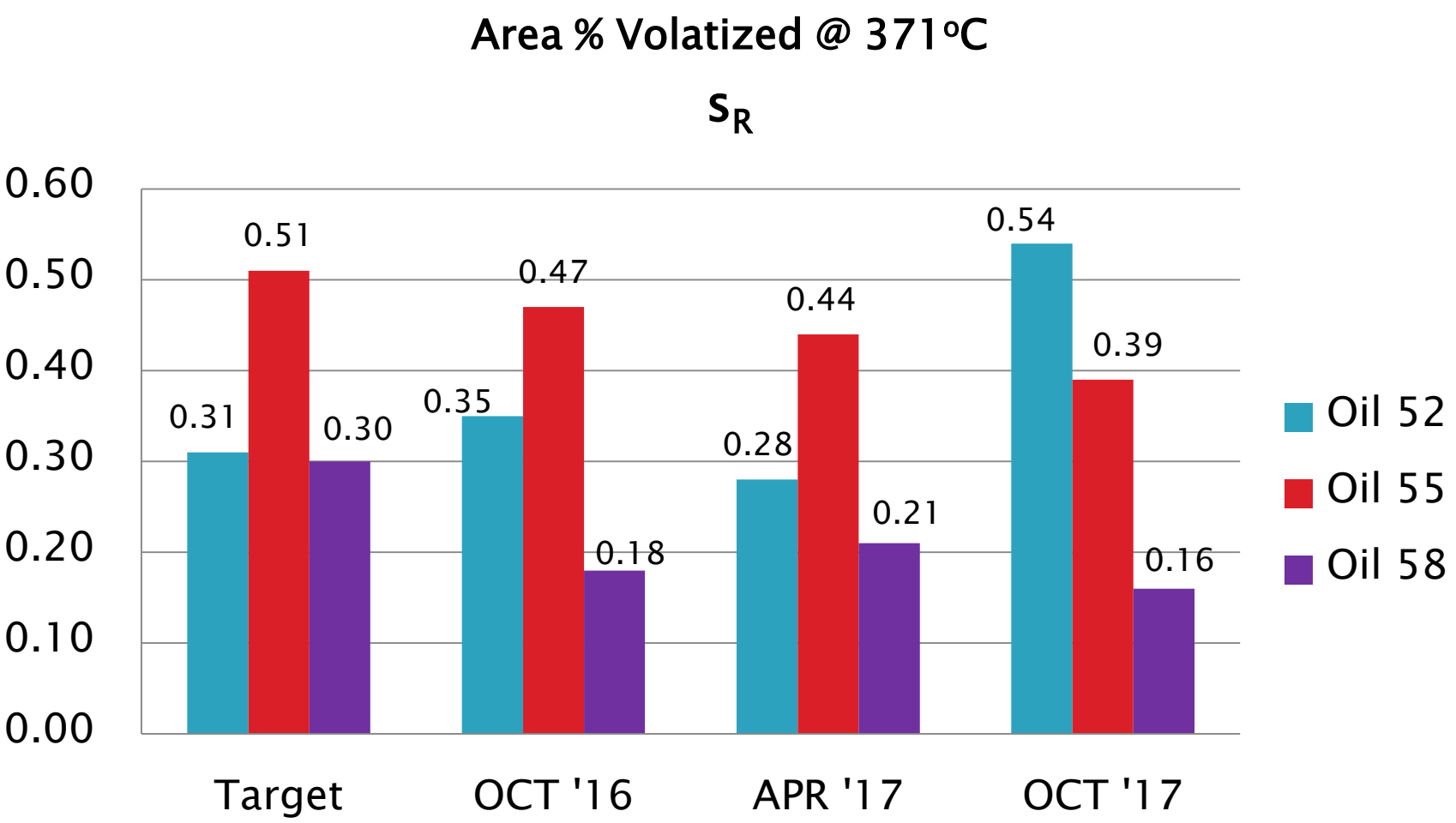
Area % Volatized @ 371°C
Performance by Oil

	Targets			4/1/16 - 9/30/16				10/1/16 - 3/31/17				4/1/17- 9/30/17			
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	2	6.6	0.35	-1.03	6	7.2	0.28	0.63	4	6.8	0.54	-0.63
55	18	11.68	0.51	4	11.8	0.47	0.14	5	12.1	0.44	0.78	5	11.6	0.39	-0.08
58	18	5.61	0.30	5	5.9	0.18	0.83	2	6.0	0.21	1.13	6	5.8	0.16	0.47

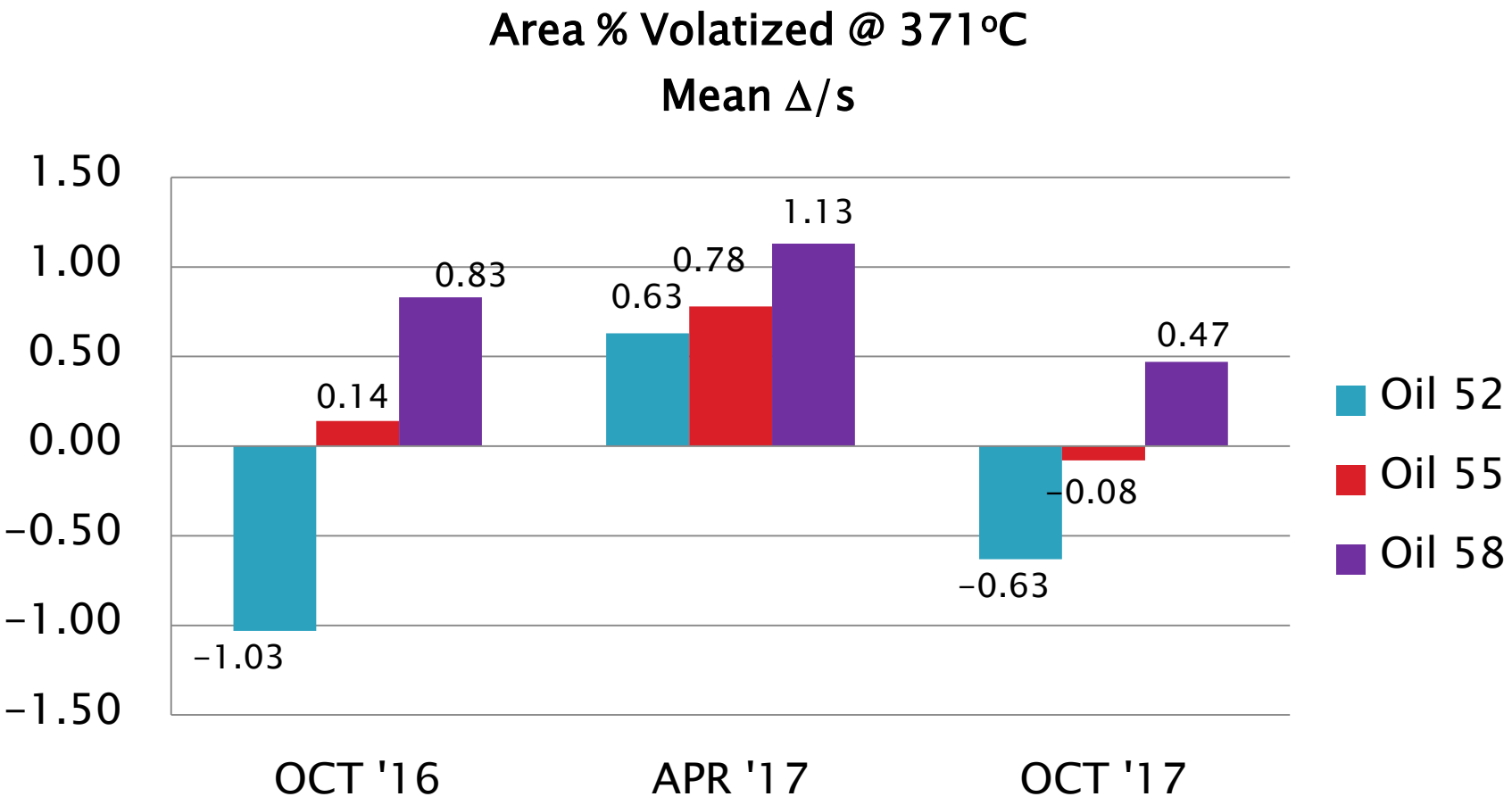
D6417 Performance by Oil



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	139
Failed Calibration Test	OC	8
Operationally Invalidated by Lab	LC, XC	2
Operationally Invalidated After Initially Reported as Valid	RC	0
Non-Blind Instrument Shakedown	NN	3
Total		**152**

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

D5800: Evaporation Loss of Lubricating Oil by Noack Method

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

- One test triggered both Ei L3 severe and Zi L2 severe alarms.
- One test triggered both Ei L3 mild and Zi L2 mild alarms.

- Three OC tests (Zi L2 severe) from two rigs, at one lab; three follow-up shakedown runs are also severe, lab still working on a solution.

- Two operational failing runs reported:
  - Electrical short in heating unit (XC)
  - Unrecoverable weighing error in final sample weight (LC).

D5800: Evaporation Loss of Lubricating Oil by Noack Method

- There were no technical updates issued this report period.
  - However, the new D5800 LTMS calibration requirements issued in TMC memo 16-029 (September 19, 2016, and effective October 19, 2016) have been incorporated into the TMC's LTMS document as Section 40. Future updates will be made through updates to the LTMS document.

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	-----
10/1/14 through 3/31/15	60	57	0.80	0.44
4/1/15 through 9/30/15* 4/1/15 through 9/30/15*	55 54	52 51	0.67 0.61	1.04 0.95
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

*Extreme OC result included and excluded

D5800: Evaporation Loss of Lubricating Oil by Noack Method

Performance Comparison by Procedure & Model

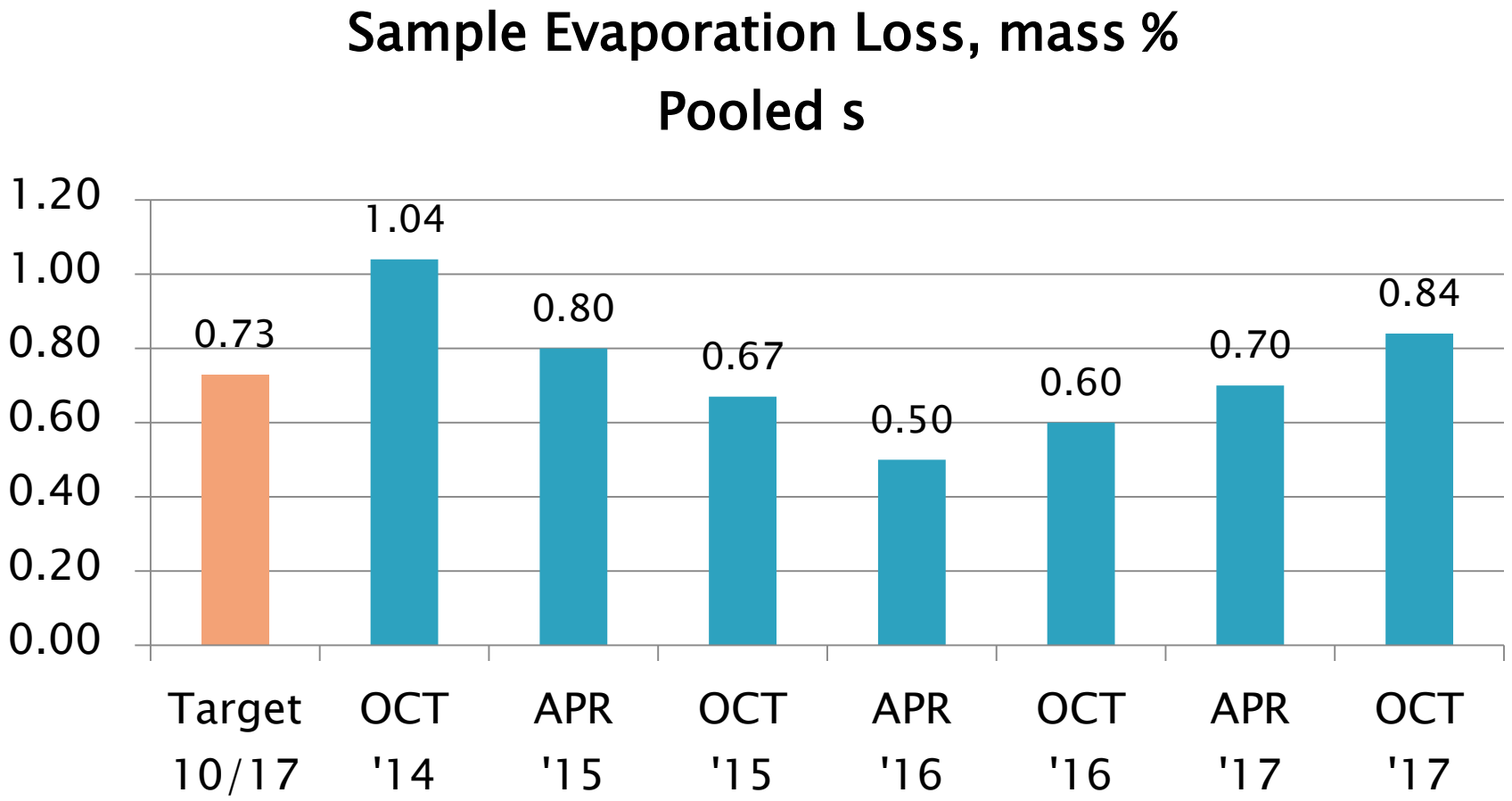
Sample Evaporation Loss, Mass %

	n	df	Pooled s	Mean Δ/s
Procedure B*	125	122	0.69	0.67
Procedure C	21	18	1.06	-0.68

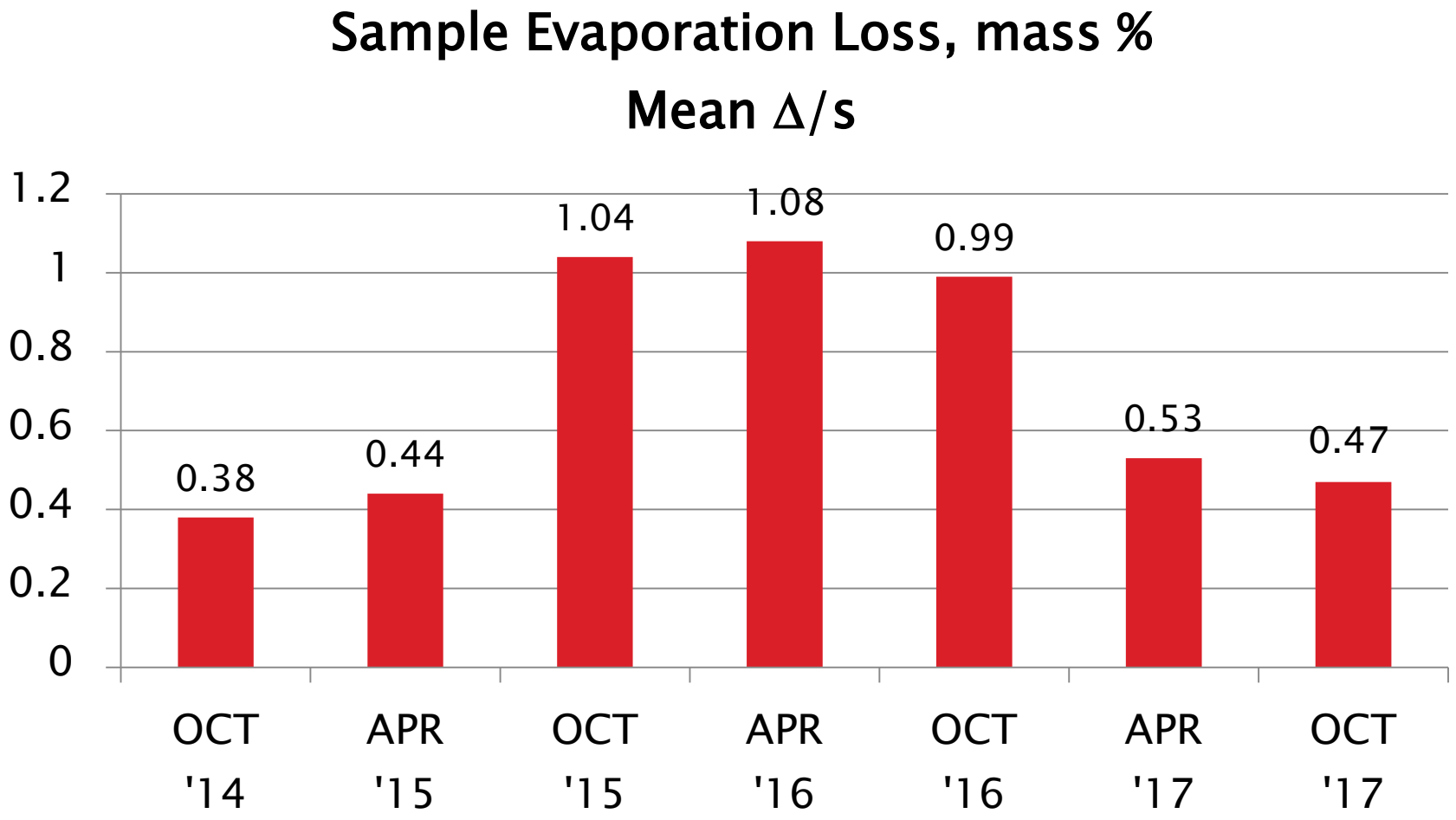
Model	n	df	Pooled s	Mean Δ/s
NCK2	17	14	0.35	0.24
NCK25G*	108	105	0.71	0.74
SVT1	21	18	1.06	-0.68

(*Excludes extreme OC result of 13 s severe)

D5800 Precision Estimates



D5800 Severity Estimates



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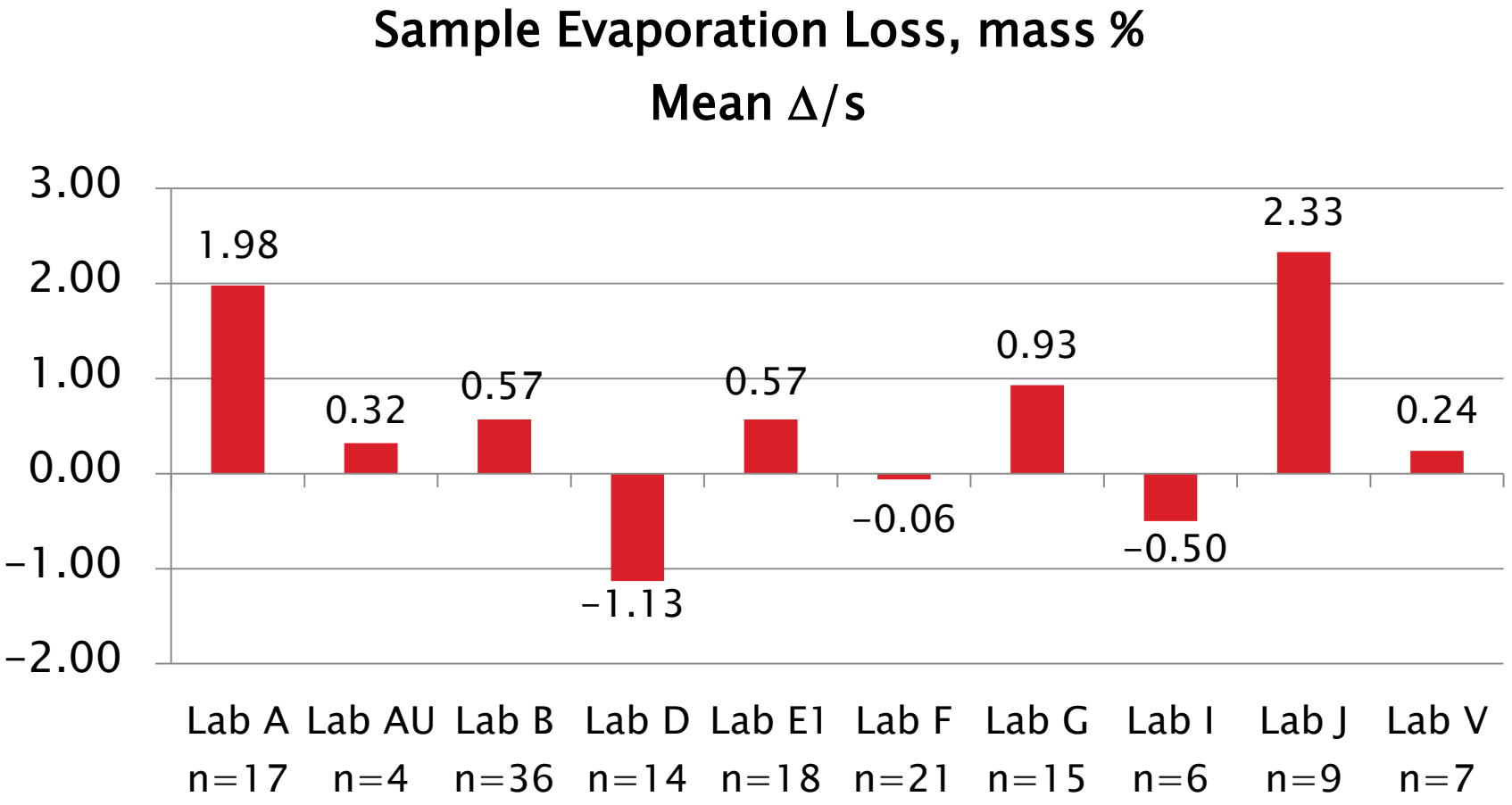
D5800: Evaporation Loss of Lubricating Oil by Noack Method

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

Lab	n	Mean Δ/s	Lab	n	Mean Δ/s
Lab A	17	1.98	Lab F	21	-0.06
Lab AU	4	0.32	LAB G	15	0.93
Lab B	36	0.57	Lab I	6	-0.50
Lab D	14	-1.13	Lab J	9	2.33
Lab E1	18	0.57	Lab V	7	0.24

D5800 Lab Severity Estimates



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D5800: Evaporation Loss of Lubricating Oil by Noack Method

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- Precision (Pooled s), at 0.84 mass % (extreme result of 13 s severe excluded), is less precise than the target LTMS pooled precision of 0.73 mass %.
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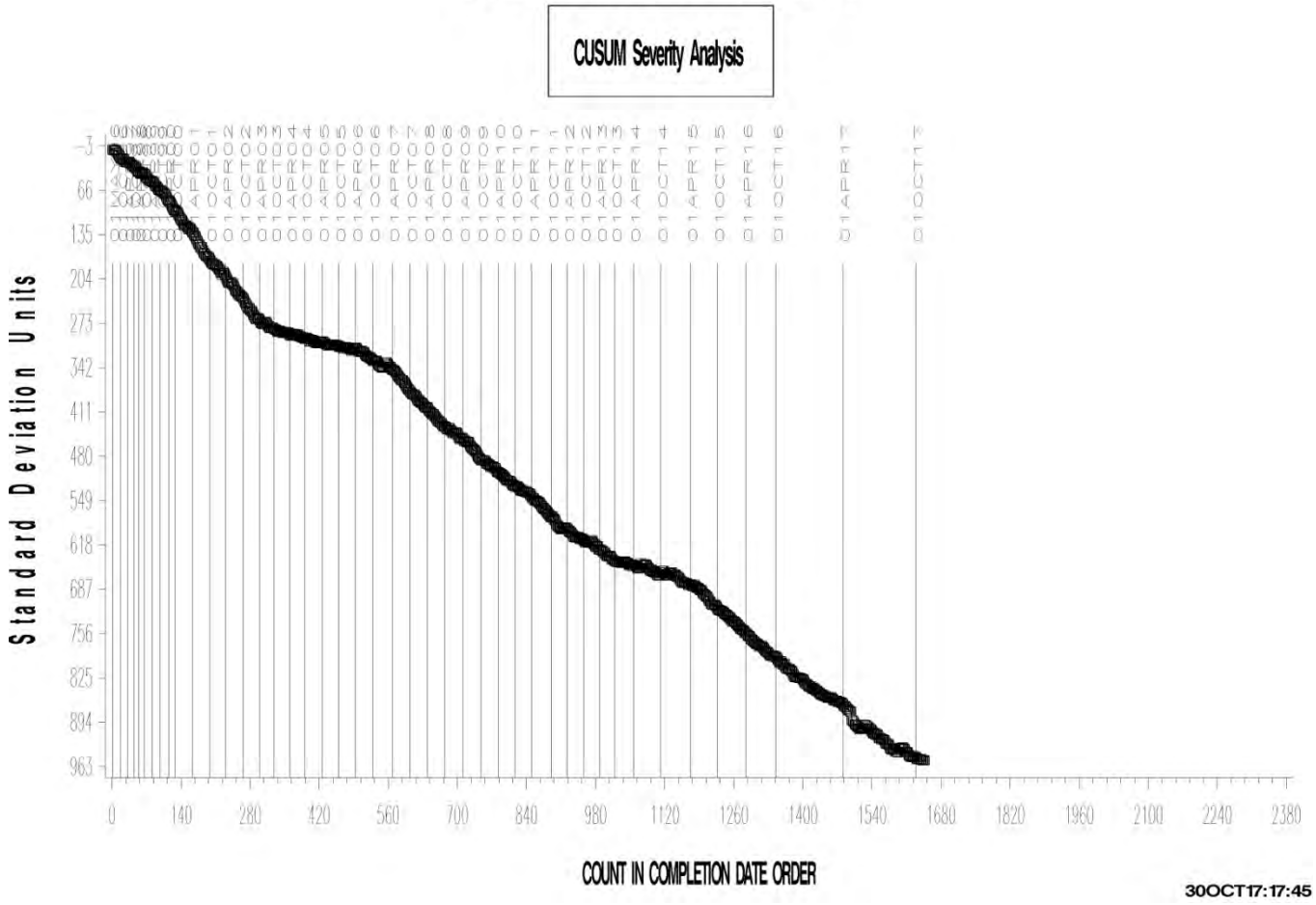
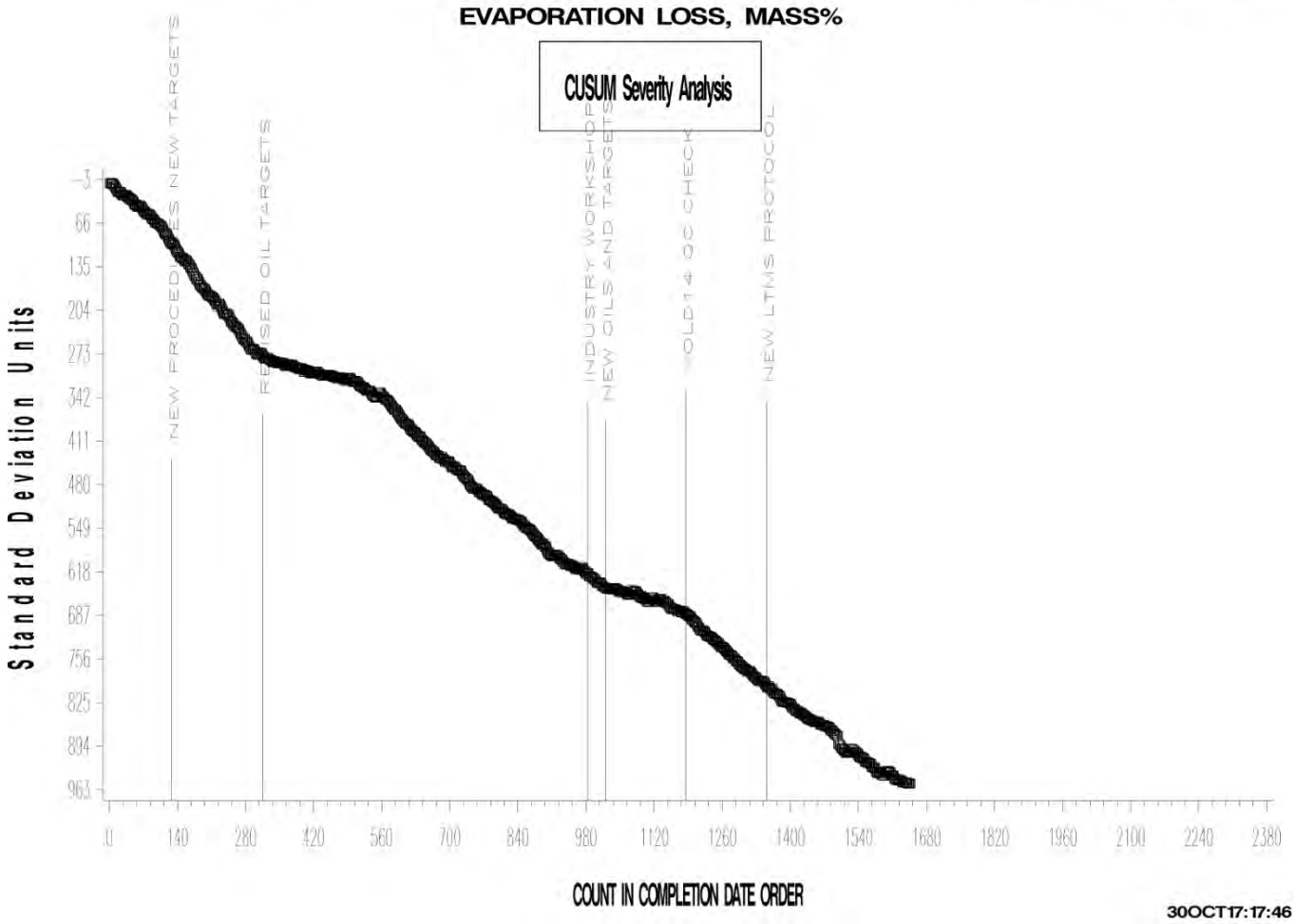
- Fail rate of operationally valid tests (AC & OC) has dropped to 5% for the most recent two report periods using LTMS, compared to 26% under the Shewhart severity only system.
- Historical long-term severe trend continues with TMC calibrations, but now D5800 non-reference results are severity adjusted by instrument, with SA's updated by LTMS calibration evaluation.

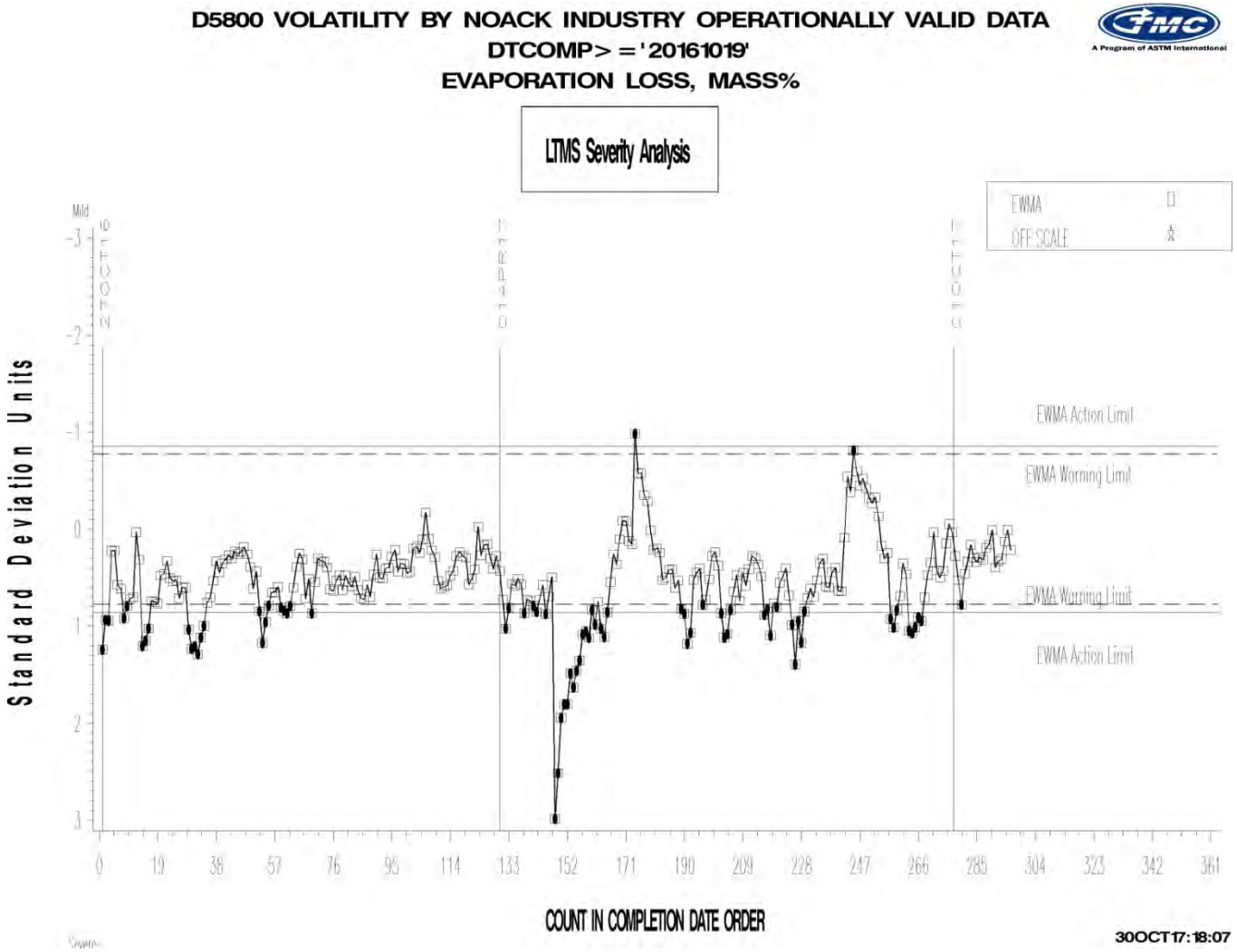
D5800 VOLATILITY BY NOACK INDUSTRY OPERATIONALLY VALID DATA

EVAPORATION LOSS, MASS%



D5800 VOLATILITY BY NOACK INDUSTRY OPERATIONALLY VALID DATA




D5800 VOLATILITY BY NOACK INDUSTRY OPERATIONALLY VALID DATA
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EVAPORATION LOSS, MASS%
LTMS Severity Analysis
EWMA
OFF SCALE
Mild
Standard Deviation Units
EWMA Action Limit
EWMA Warning Limit
EWMA Warning Limit
EWMA Action Limit
COUNT IN COMPLETION DATE ORDER
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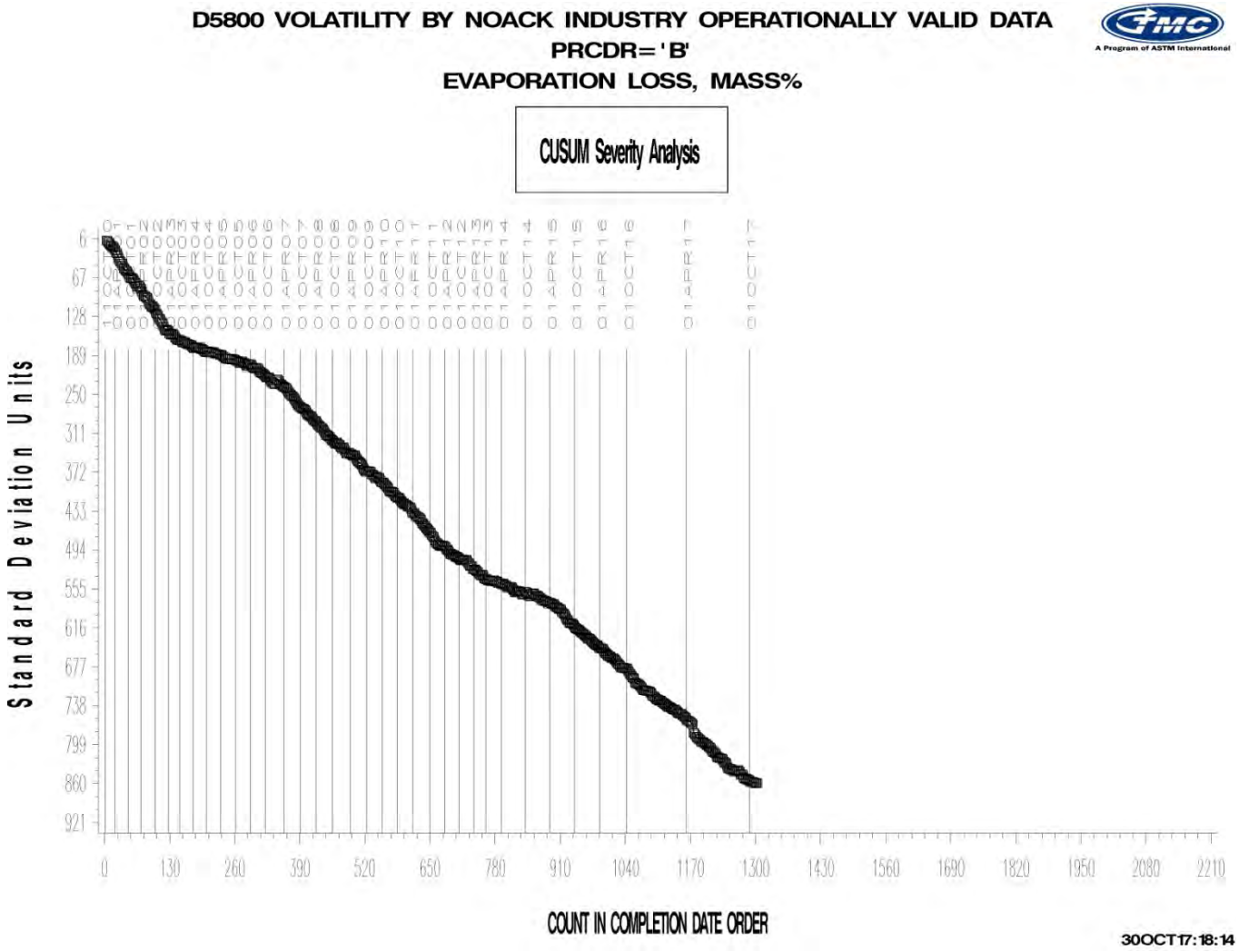
D5800 VOLATILITY BY NOACK INDUSTRY OPERATIONALLY VALID DATA
PRCDR='B'
EVAPORATION LOSS, MASS%
CUSUM Severity Analysis
Standard Deviation Units
6
67
128
189
250
311
372
433
494
555
616
677
738
799
860
921
0
130
260
390
520
650
780
910
1040
1170
1300
1430
1560
1690
1820
1950
2080
2210
COUNT IN COMPLETION DATE ORDER
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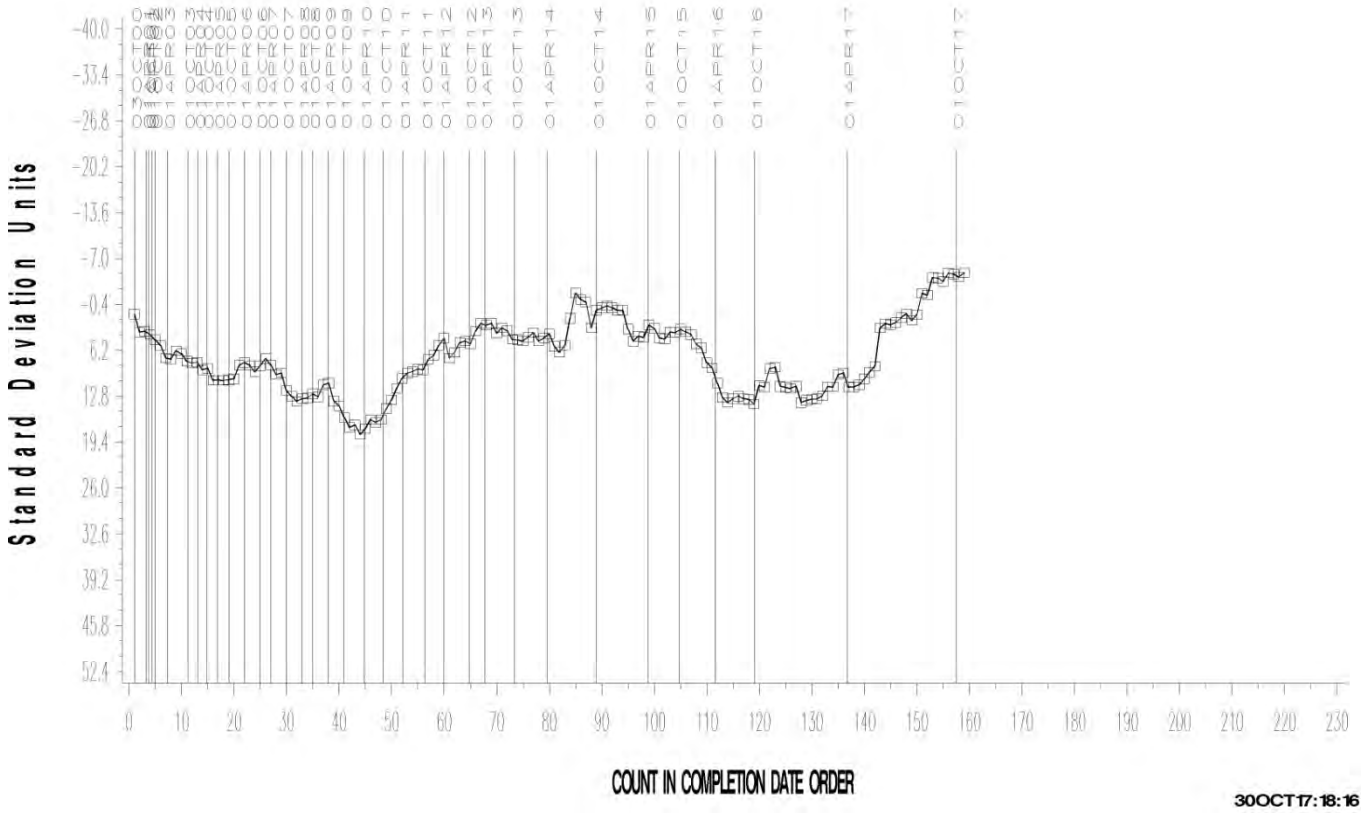
D5800 VOLATILITY BY NOACK INDUSTRY OPERATIONALLY VALID DATA
PRCDR='C'
EVAPORATION LOSS, MASS%

CUSUM Severity Analysis



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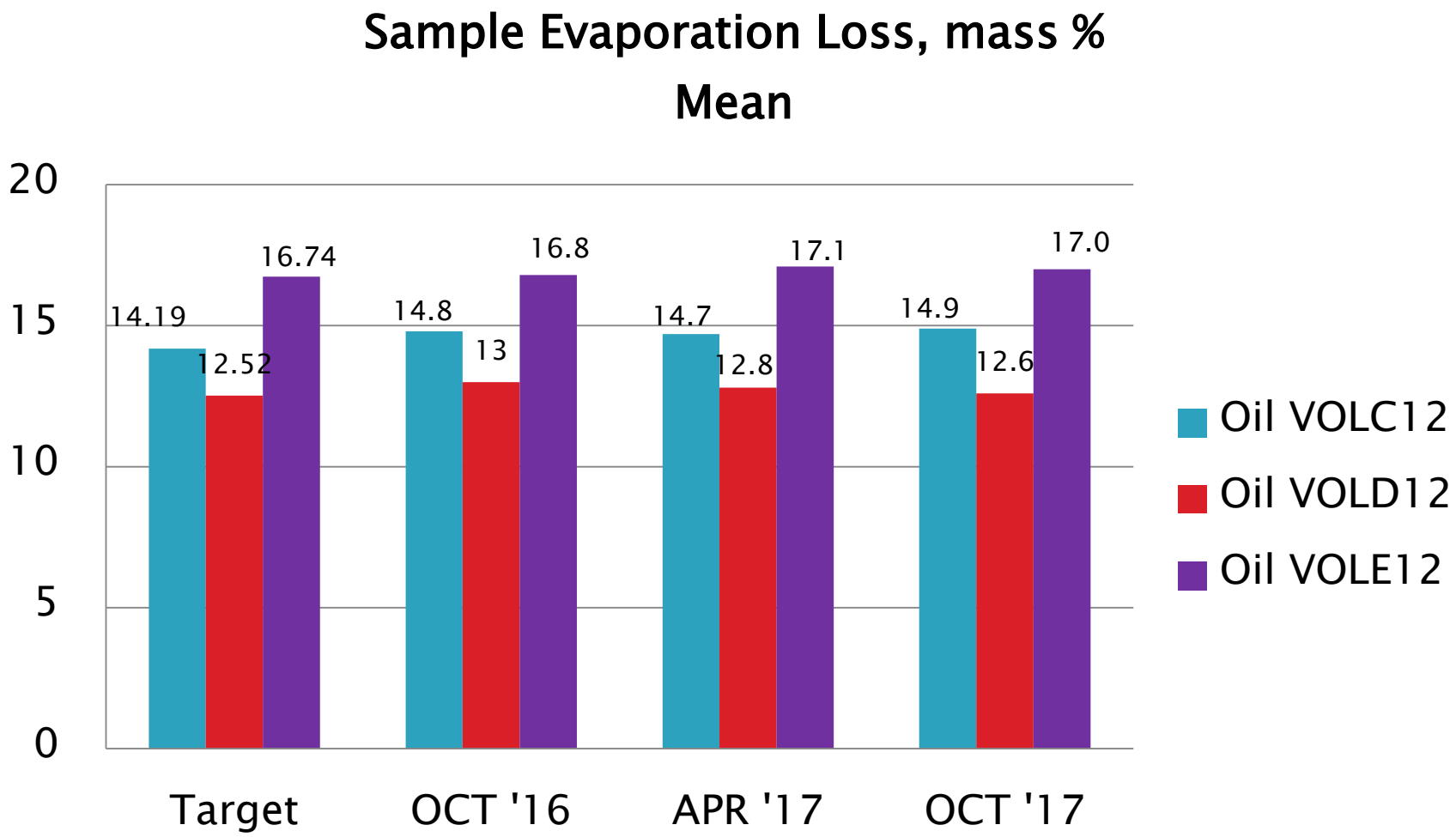
D5800: Evaporation Loss of Lubricating Oil by Noack Method

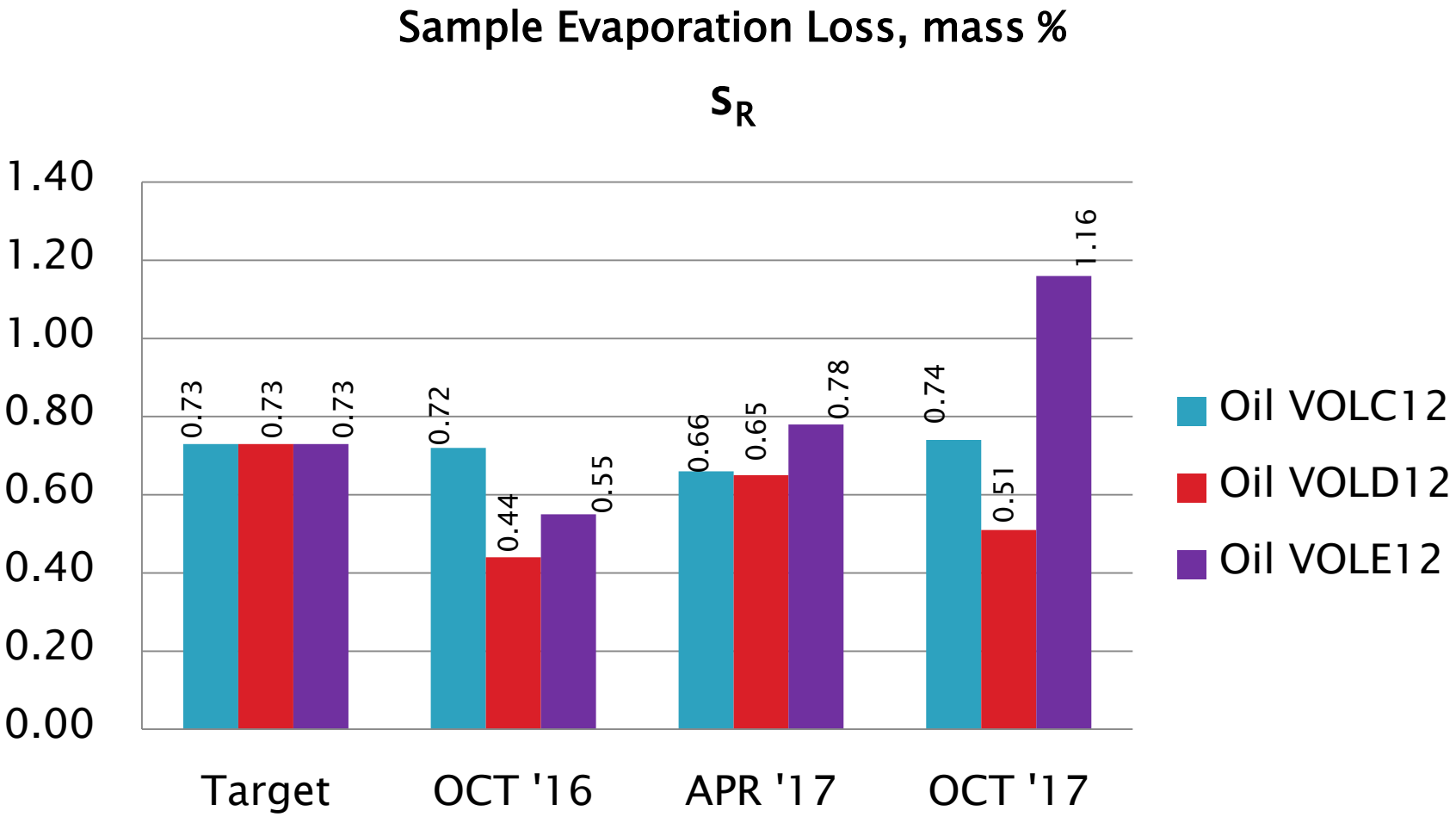
Sample Evaporation Loss, mass %
Performance by Oil

	Targets			4/1/16 – 9/30/16				10/1/156– 3/31/17				4/1/17 – 9/30/17			
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	29	14.8	0.72	1.40	47	14.7	0.66	0.69	46	14.9	0.74	0.92
VOLD12	27	12.52	0.73	22	13.0	0.44	0.89	40	12.8	0.65	0.45	51	12.6	0.51	0.14
VOLE12	27	16.74	0.73	11	16.8	0.55	0.09	49	17.1	0.78	0.46	49	17.0	1.16	0.40

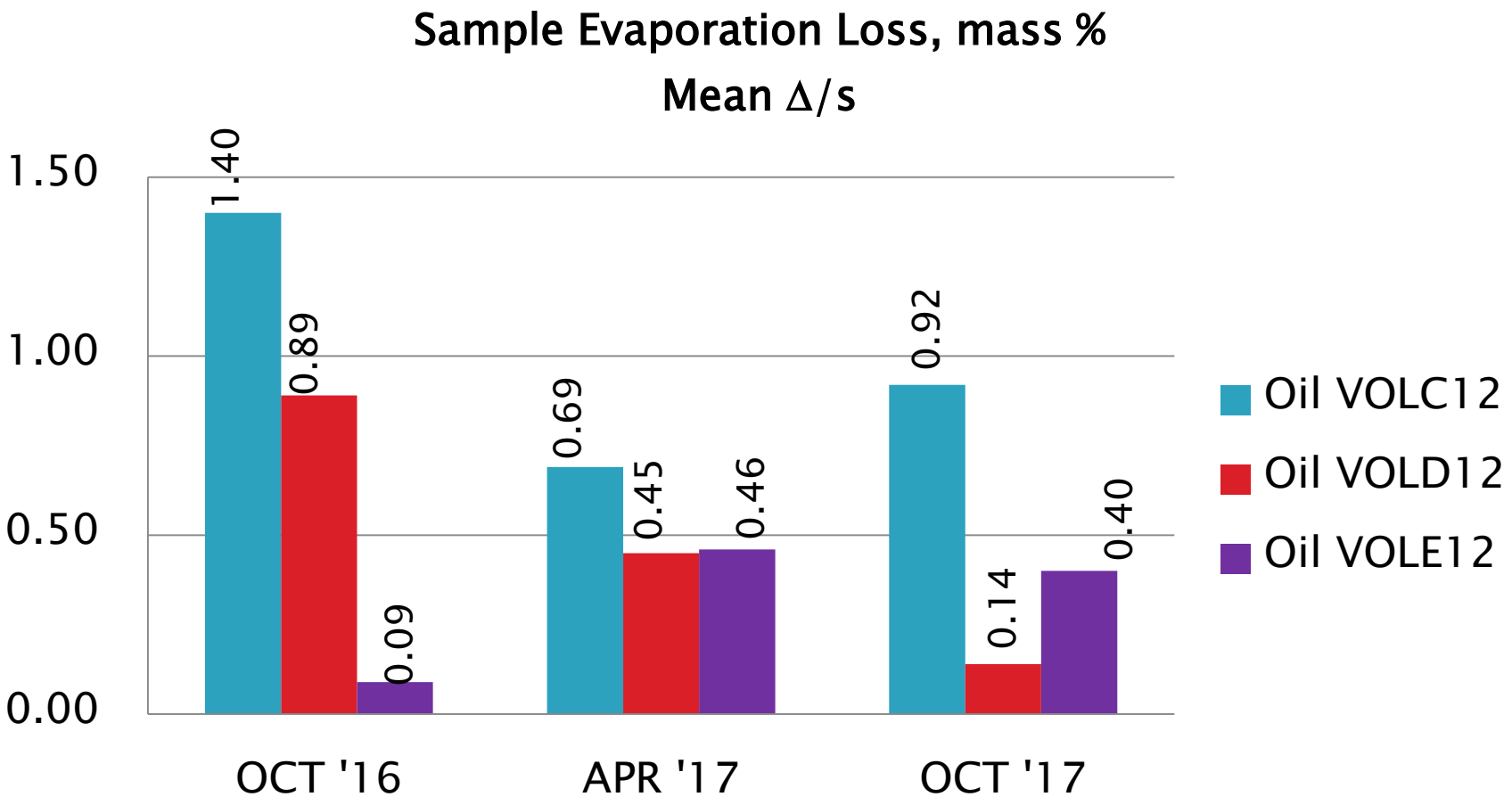
D5800 Performance by Oil



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	27
Failed Calibration Test	OC	3
Operationally Invalidated by Lab	LC, XC	2
Operationally Invalidated After Initially Reported as Valid	RC	0
Non-blind Instrument Shakedowns	NN, XN	37
Total		**69**

Number of Labs Reporting Data: 8 (only 7 calibrated)
Fail Rate of Operationally Valid Tests: 10%

D5133: Gelation Index

Statistically Unacceptable Tests (OC)	No. Of Tests
Gelation Index Mild	2
Gelation Index Severe	1

- Operationally failing runs:
  - Two aborted for data acquisition failure (XC)
  - Two aborted due to power failure (shakedowns)

- Lab/rigs I3, G3, AU1 (new rig) ran numerous shakedowns to confirm performance of all heads before proceeding with TMC calibrations.

- No TMC technical updates issued this period

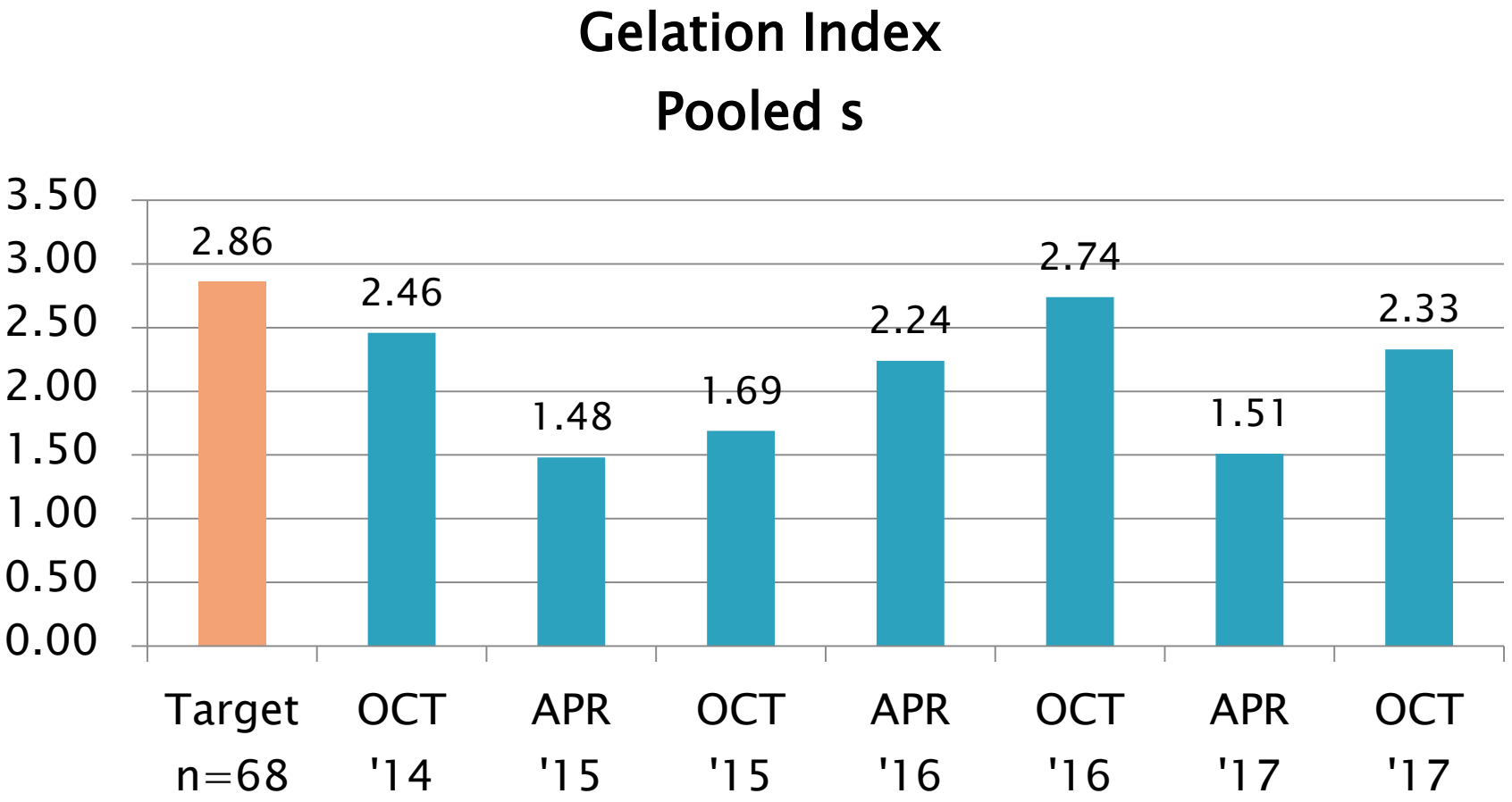
D5133: Gelation Index

Period Precision and Severity Estimates

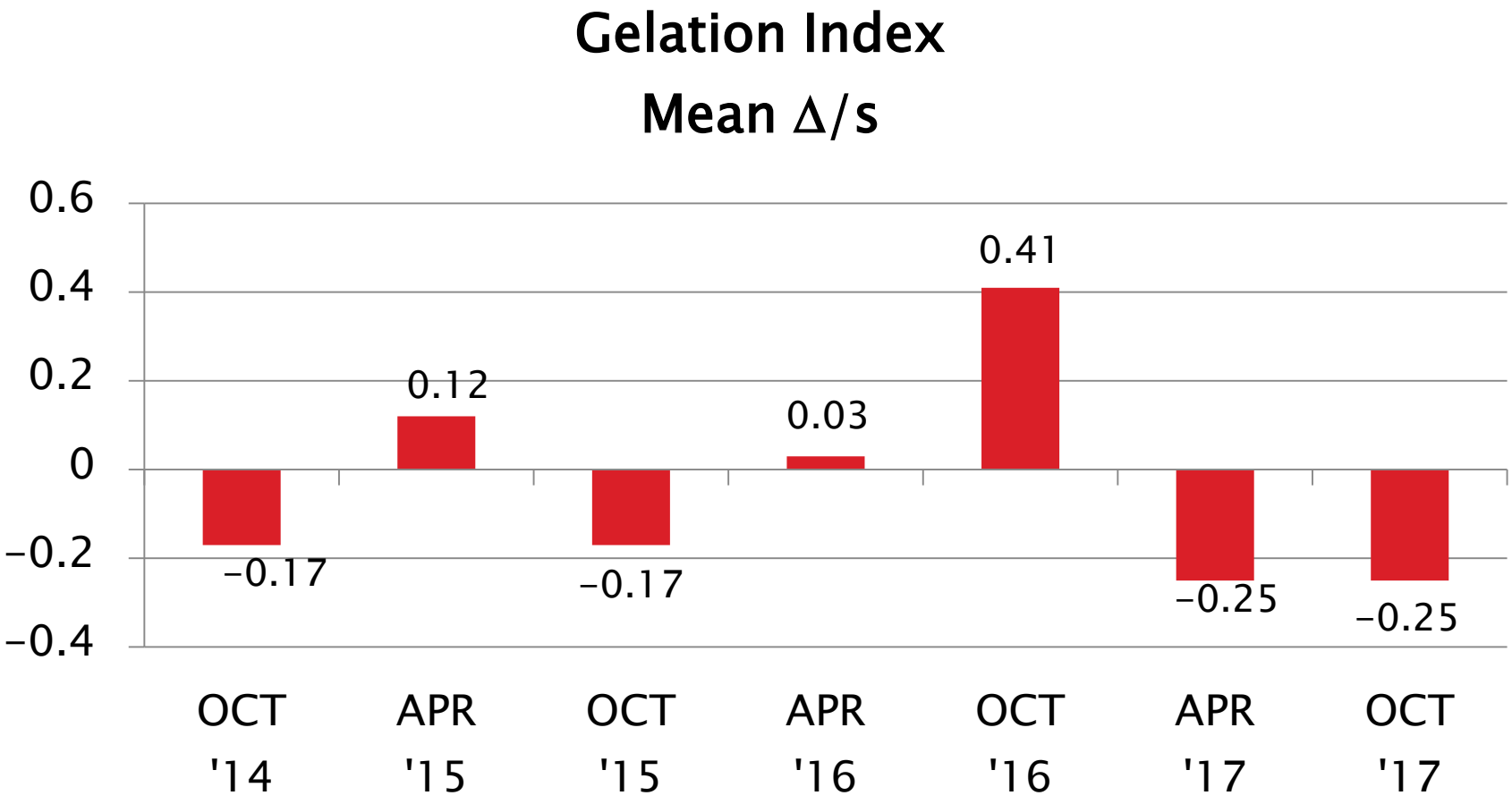
Gelation Index	n	df	Pooled s	Mean Δ/s
Current Targets 7/15/2003	68	65	2.86	-----
10/1/14 through 3/31/15	28	25	1.48	0.12
4/1/15 through 9/30/15	34	31	1.69	-0.17
10/1/15 through 3/31/16	31	28	2.24	0.03
4/1/16 through 9/30/16	31	28	2.74	0.41
10/1/17 through 3/31/17	35	32	1.51	-0.25
4/1/17 through 9/30/17* 4/1/17 through 9/30/17*	30 29	27 26	4.69 2.33	-0.08 -0.25

*Extreme OC result included and excluded

D5133 Precision Estimates



D5133 Severity Estimates



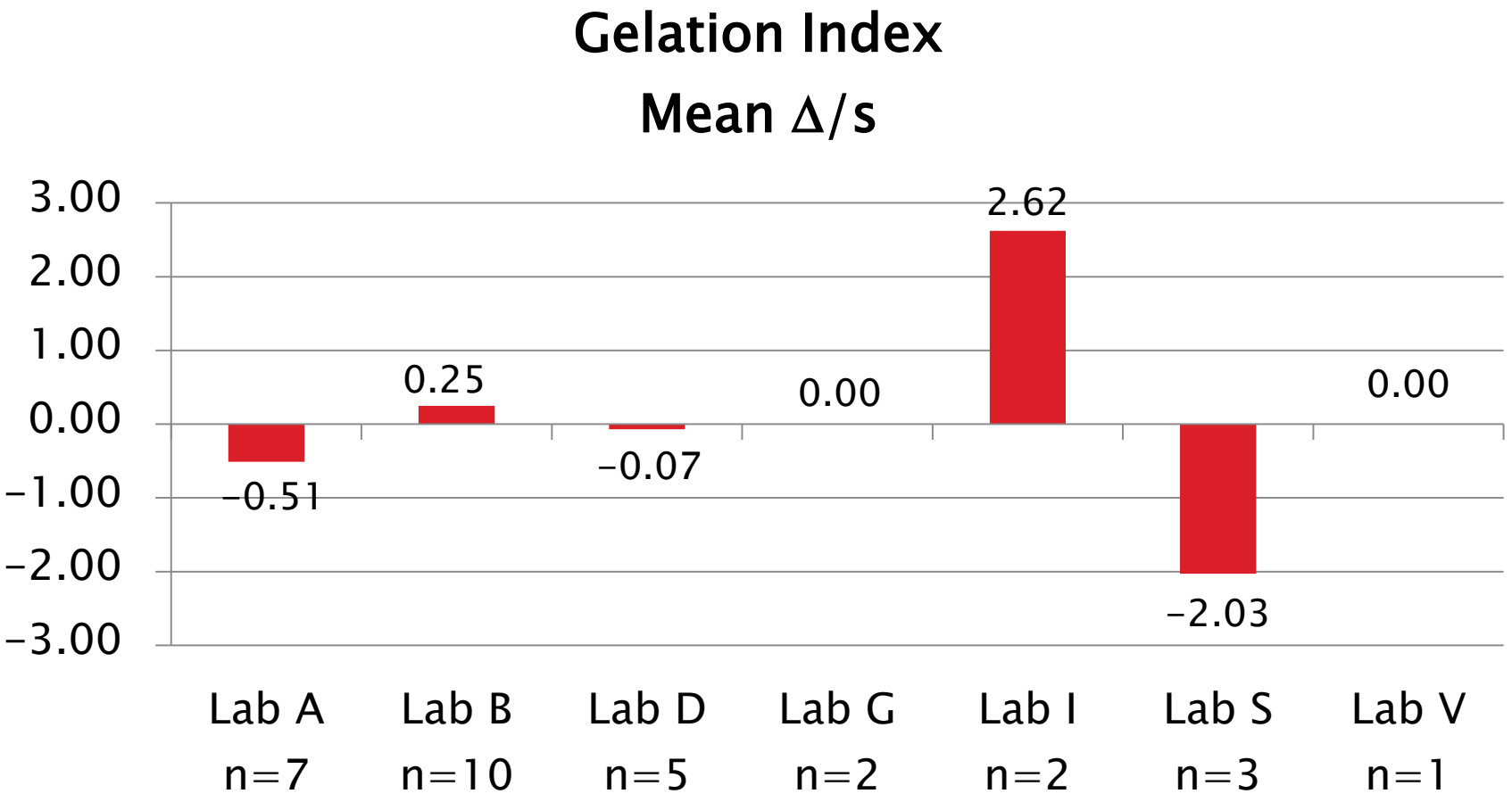
D5133: Gelation Index

Current Period Severity Estimates by Lab

Gelation Index

	n	Mean Δ/s
Lab A	7	-0.51
Lab B	10	0.25
Lab D	5	-0.07
Lab G	2	0.00
Lab I	2	2.62
Lab S	3	-2.03
Lab V	1	0.00

D5133 Lab Severity Estimates



D5133: Gelation Index

- One test reported nearly 5 s severe (Lab I Rig 3, oil 62), overall statistics are shown with this result included and excluded for comparison of influence.
  - This rig had problems passing calibration last period, lab ran a number of shakedowns before passing calibration this period, but followed that with the very severe fail, and with no cause identified. Rig followed with another passing calibration after the close of this period report.
- Fail rate of operationally valid tests is 10% this period, compared to 26% last period, and only 6% before that.
- Overall severity is -0.25 s mild
- Precision (Pooled s), even with extreme result excluded, is less precise than prior period
  - More precise than target precision
- Reference oil 62 inventory is down to 0.7 gallons remaining (with 0.4 gallon shipped prior 12 months).

D5133: Gelation Index

- Precision on oils 58 and 1009 improved considerably this period.
- However, with non-gelling oil 58 performing severe, and low gelling oil 1009 mild, the overall period mean GI performances on those oils do not show adequate discrimination over the report period (similar to last period).
- Oils 62 and 1009 are both quite mild this period at -0.77 s and -0.70 s respectively (even with extreme result excluded on oil 62).
  - Severe oil 62 period mean performance is GI 14.0 compared to the target GI of 17.0.

D5133 GELATION INDEX INDUSTRY OPERATIONALLY VALID DATA

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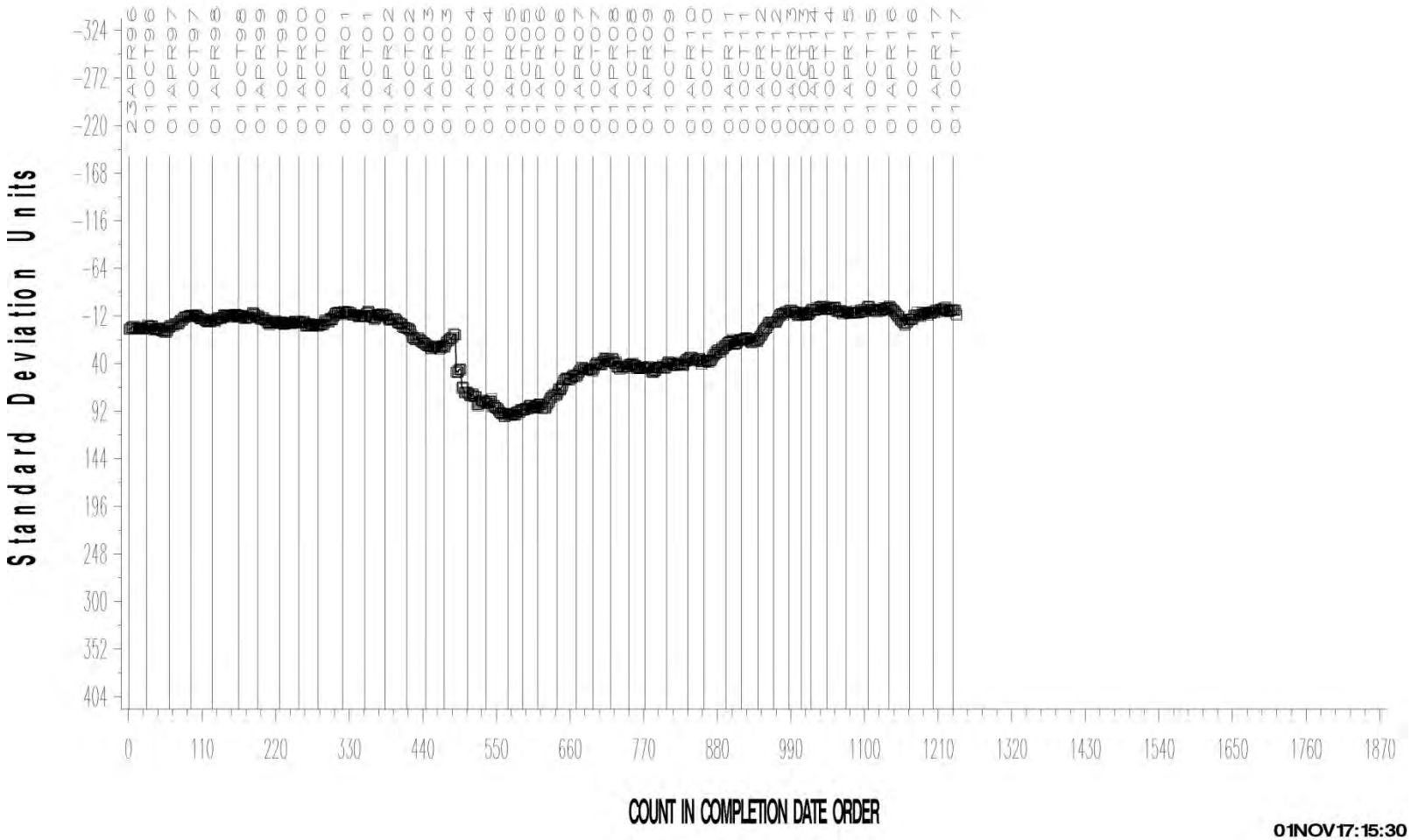
GELATION INDEX

CUSUM Severity Analysis



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D5133 GELATION INDEX INDUSTRY OPERATIONALLY VALID DATA

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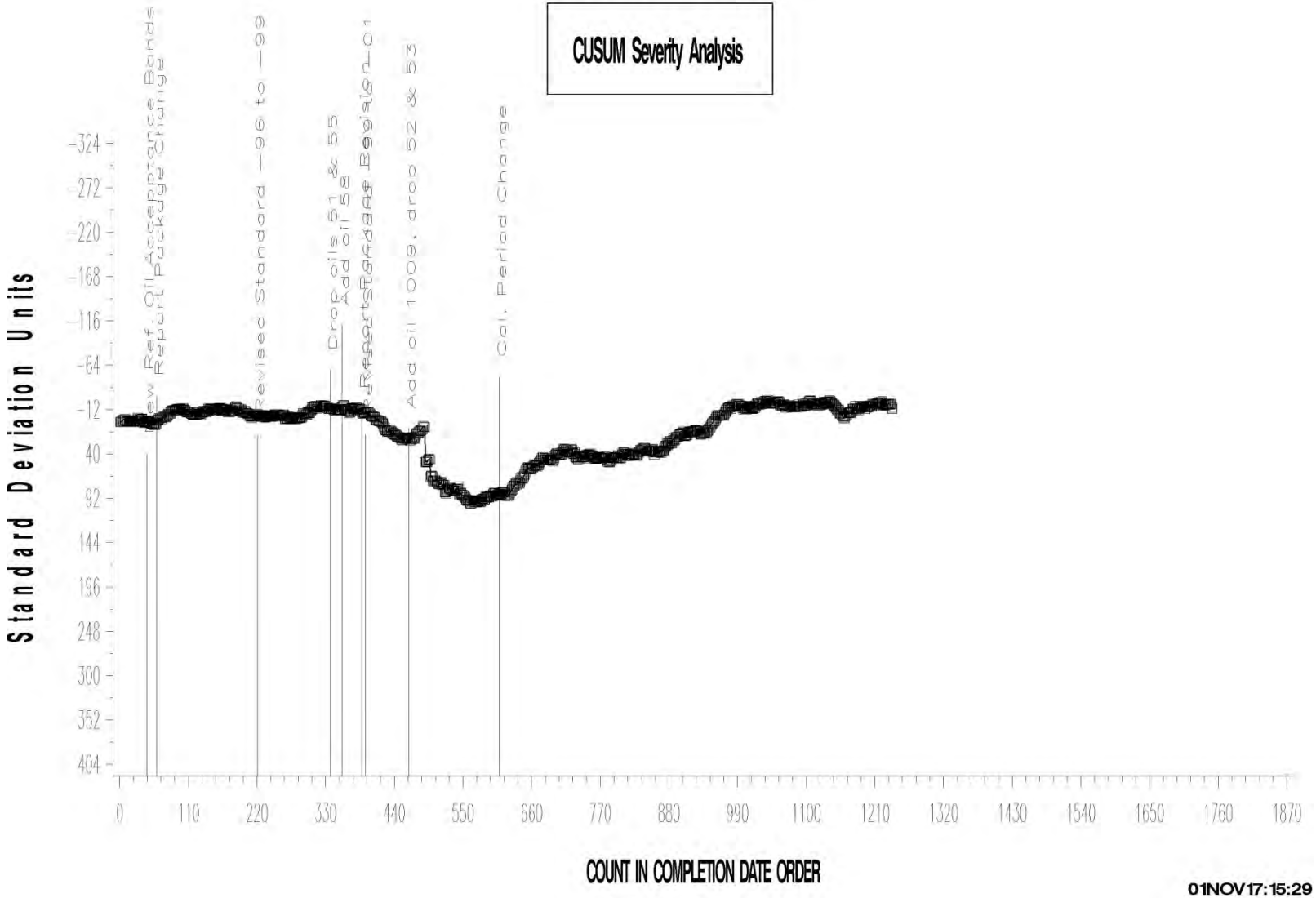
GELATION INDEX

CUSUM Severity Analysis



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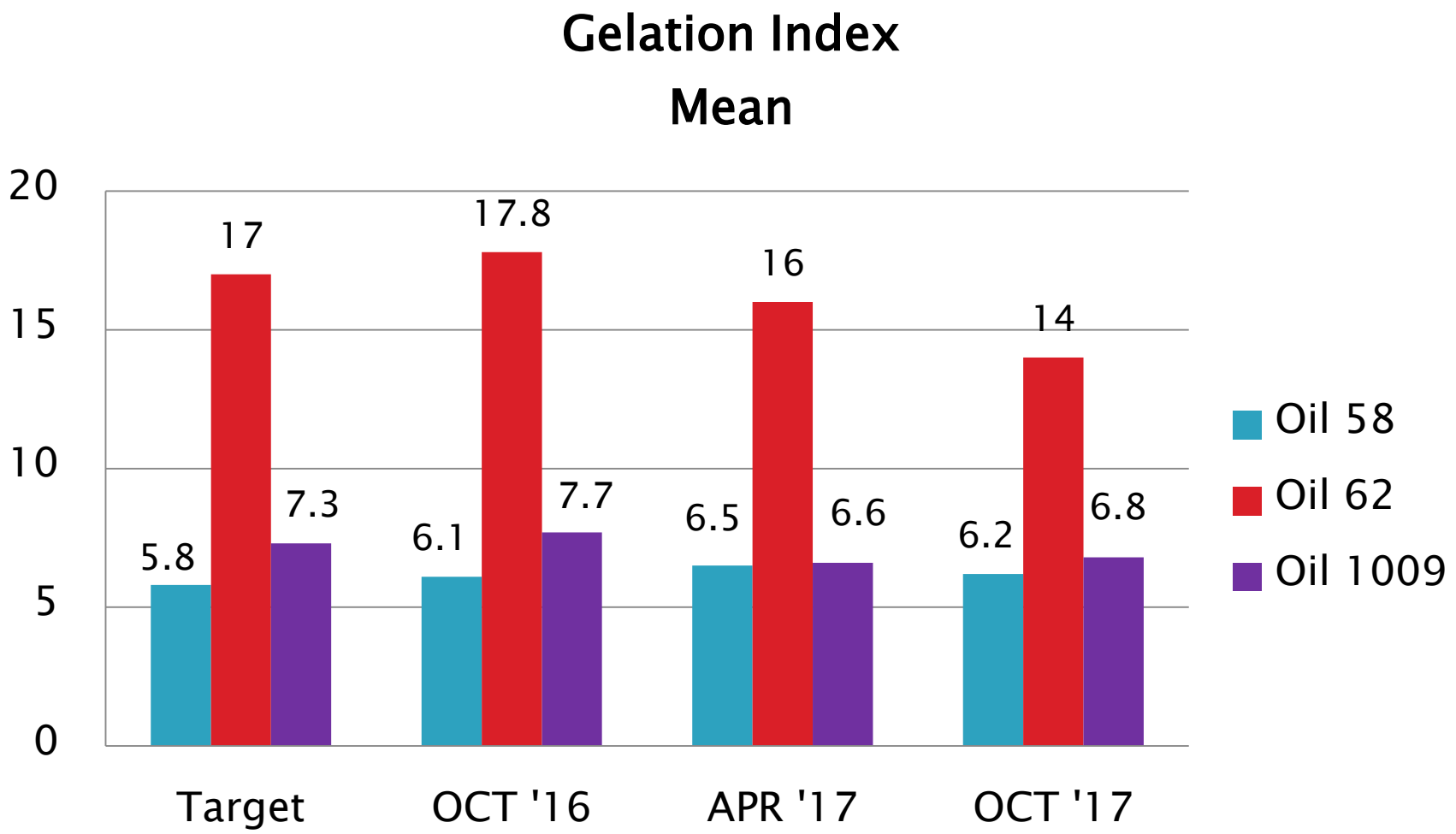
D5133 Performance by Oil

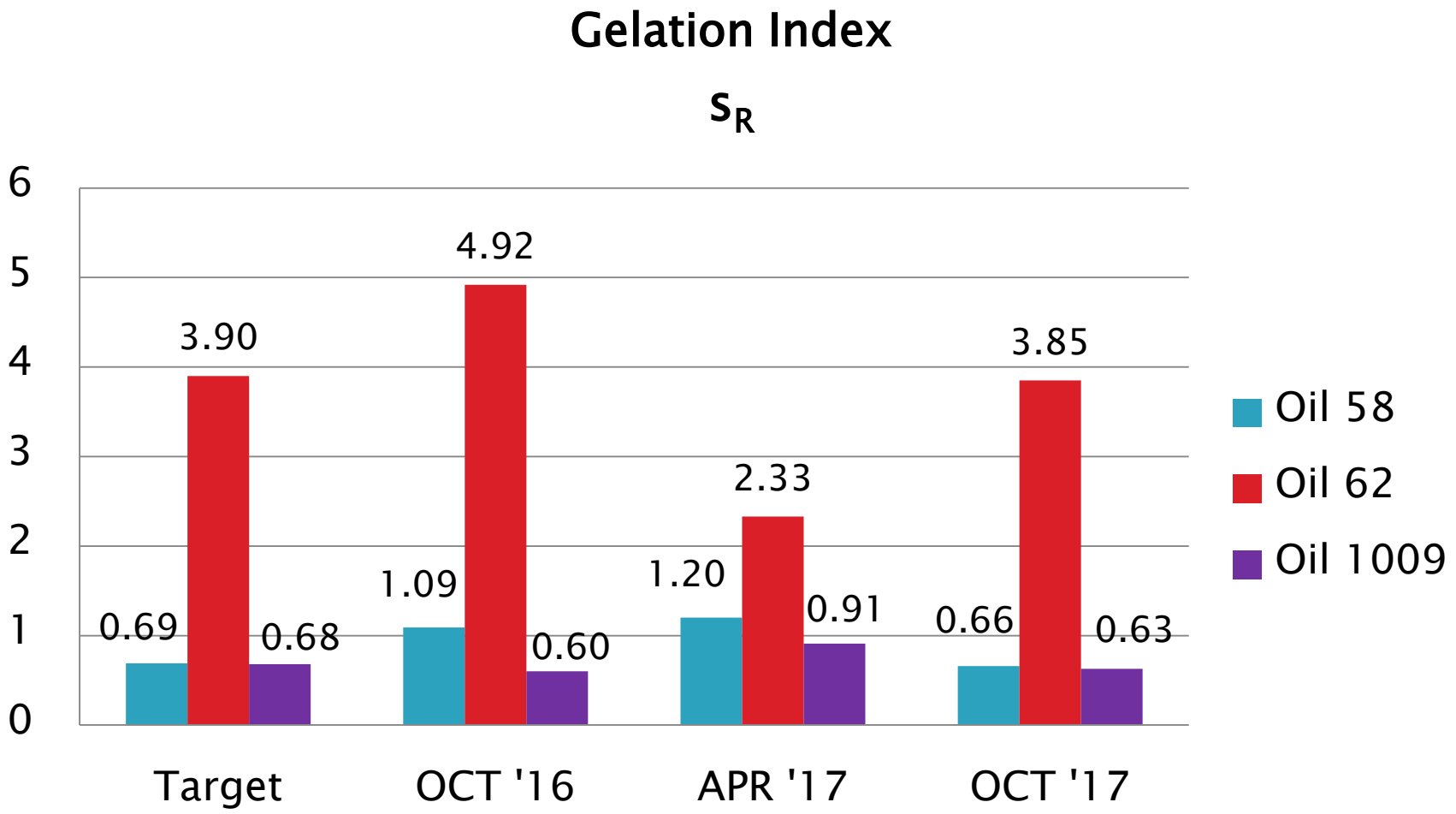
Gelation Index
Performance by Oil

	Targets			4/1/16 – 9/30/16				10/1/16– 3/31/17				4/1/17– 9/30/17			
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	6.1	1.09	0.47	9	6.5	1.20	1.05	11	6.2	0.66	0.55
62	35	17.0	3.90	9	17.8	4.92	0.21	10	16.0	2.33	-0.26	10	14.0	3.85	-0.77
1009	16	7.30	0.68	11	7.7	0.60	0.52	16	6.6	0.91	-0.97	8	6.8	0.63	-0.70

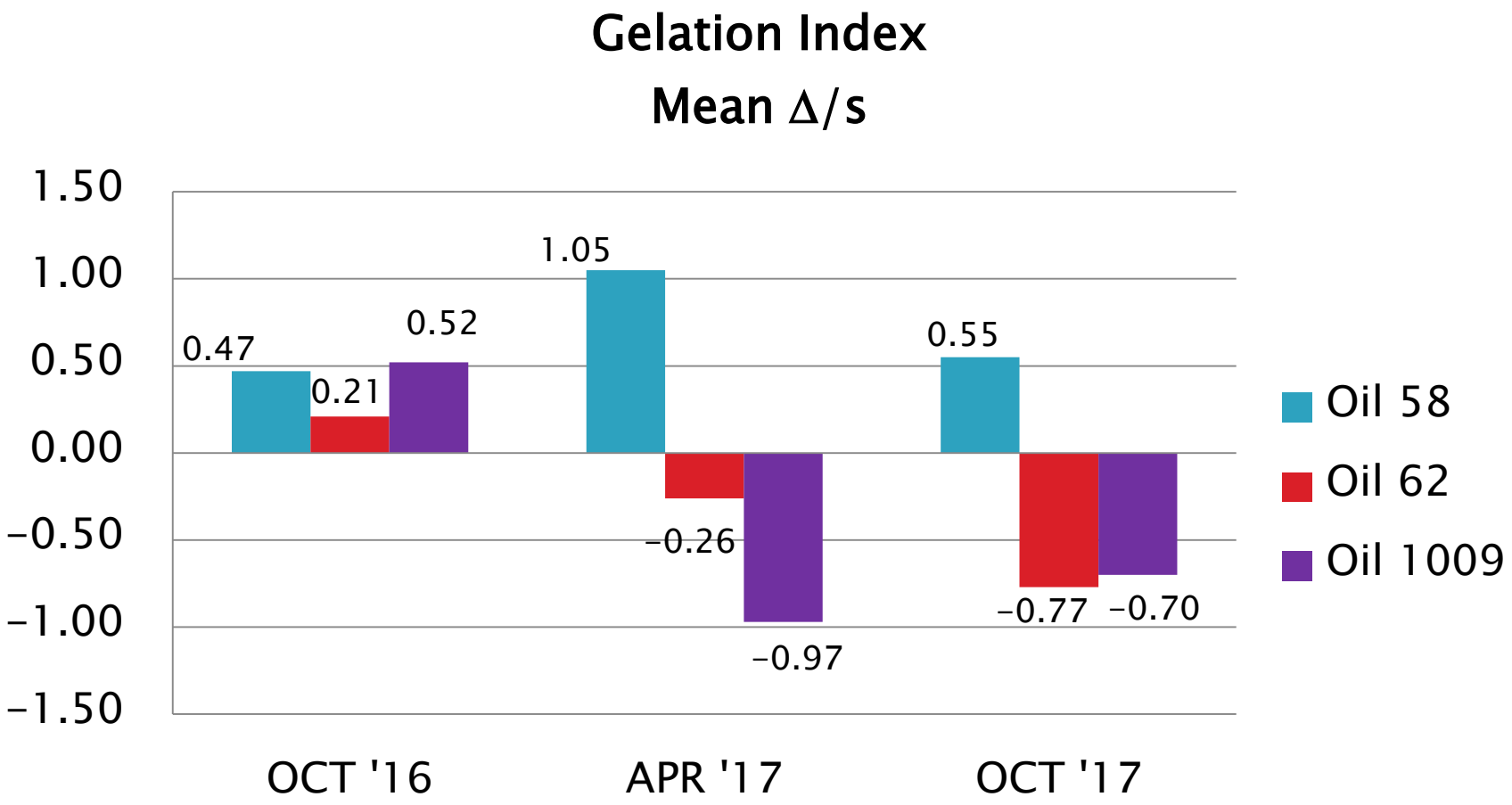
D5133 Performance by Oil



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	22
Failed Calibration Test	OC	3
Operationally Invalidated by Lab	LC, XC	1
Operationally Invalidated After Initially Reported as Valid	RC	3
Donated Runs Oil 75-1 (RR)	AG	5
Total		**34**

Number of Labs Reporting Data: 7
Fail Rate of Operationally Valid Tests: 12%

D6335: Deposits by TEOST-33C

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

- Lab D Rig 2 failed three consecutive calibration attempts severe (all OC) before passing, lab did not invalidate these runs (reason for fails unknown).
  - Rig passed on fourth try with required two-test sequence.
  - Rig passed again on single calibration run later in period.

- Four operationally invalid tests this period:
  - One test found to have air and N_2O flow restrictions (LC)
  - Two tests with heater failures after reporting as operationally valid (RC)
  - One test of required two-test sequence not run consecutively (RC)

- Five donated round robin runs (AG) on proposed replacement reblend of oil 75 (75-1 RR is incomplete and continues into next period).

D6335: Deposits by TEOST-33C

- No TMC technical updates were issued this report period.

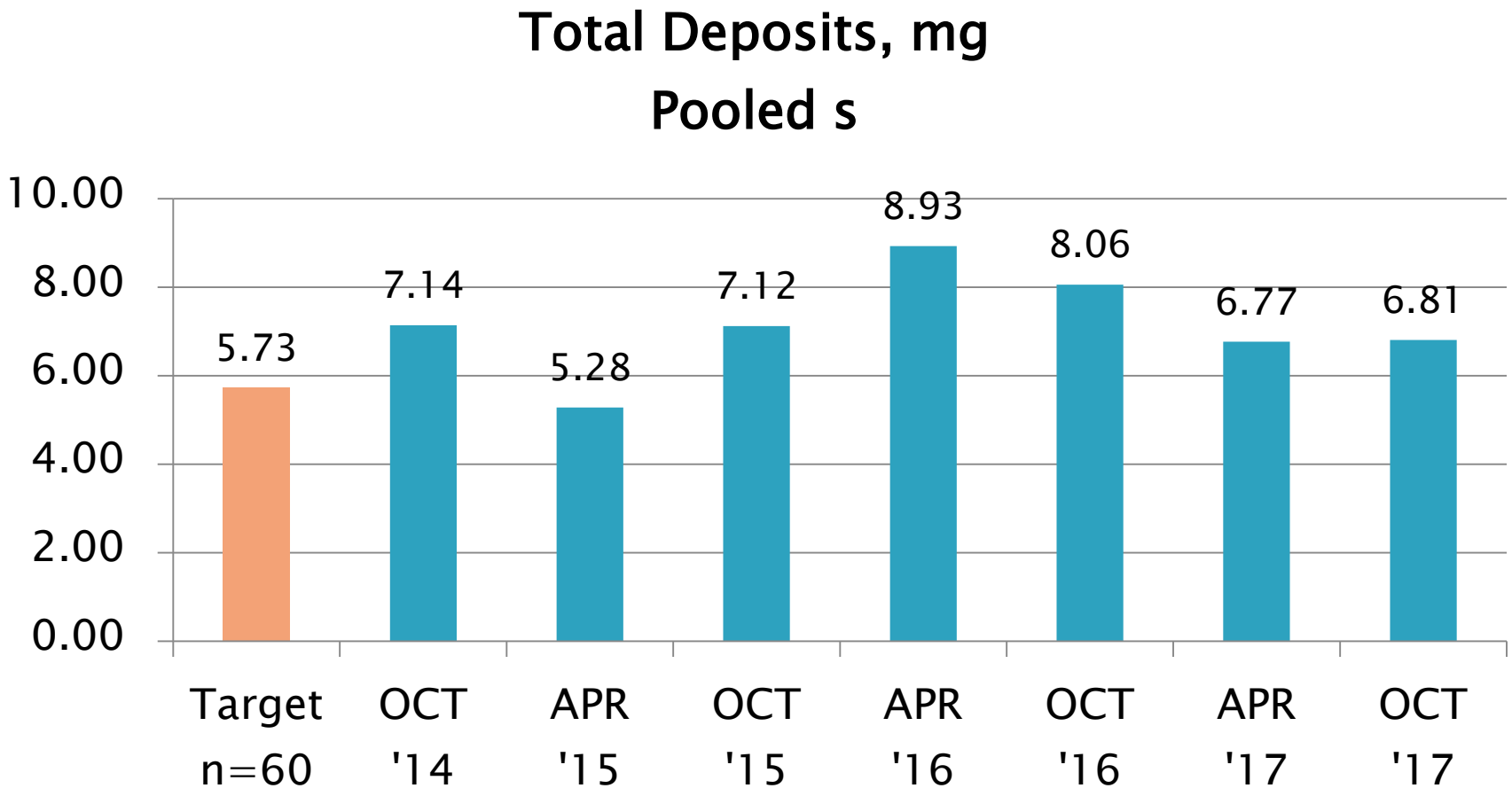
D6335: Deposits by TEOST-33C

Period Precision and Severity Estimates

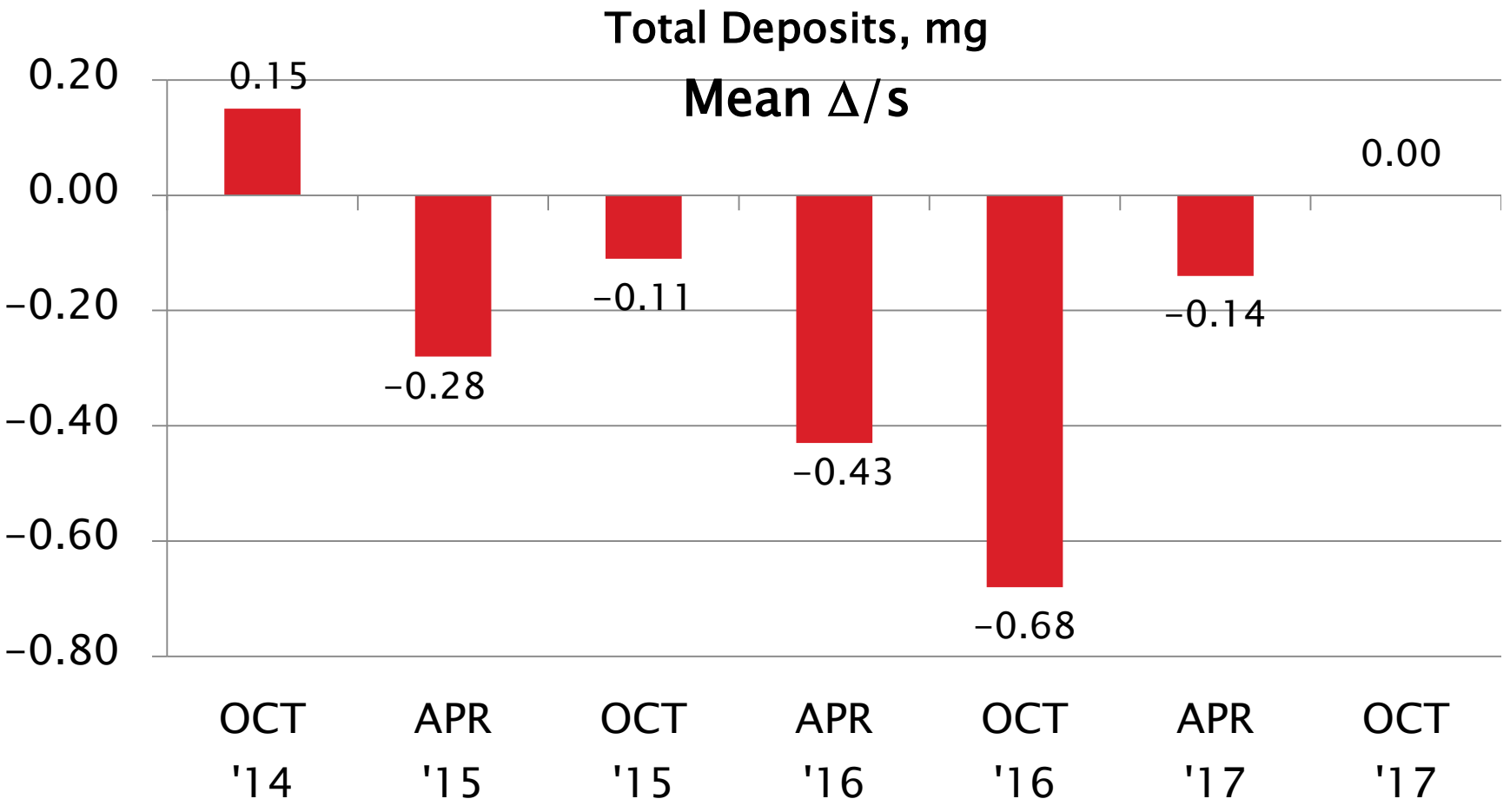
Total Deposits, mg	n	df	Pooled s	Mean Δ/s
Updated Targets 20130415	60	58	5.73	-----
4/1/14 through 9/30/14	15	13	7.14	0.15
10/1/14 through 3/31/15	15	13	5.28	-0.28
4/1/15 through 9/30/15	16	14	7.12	-0.11
10/1/15 through 3/31/16	21	19	8.93	-0.43
4/1/16 through 9/30/16	21	19	8.06	-0.68
10/1/16 through 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

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

D6335 Precision Estimates



D6335 Severity Estimates

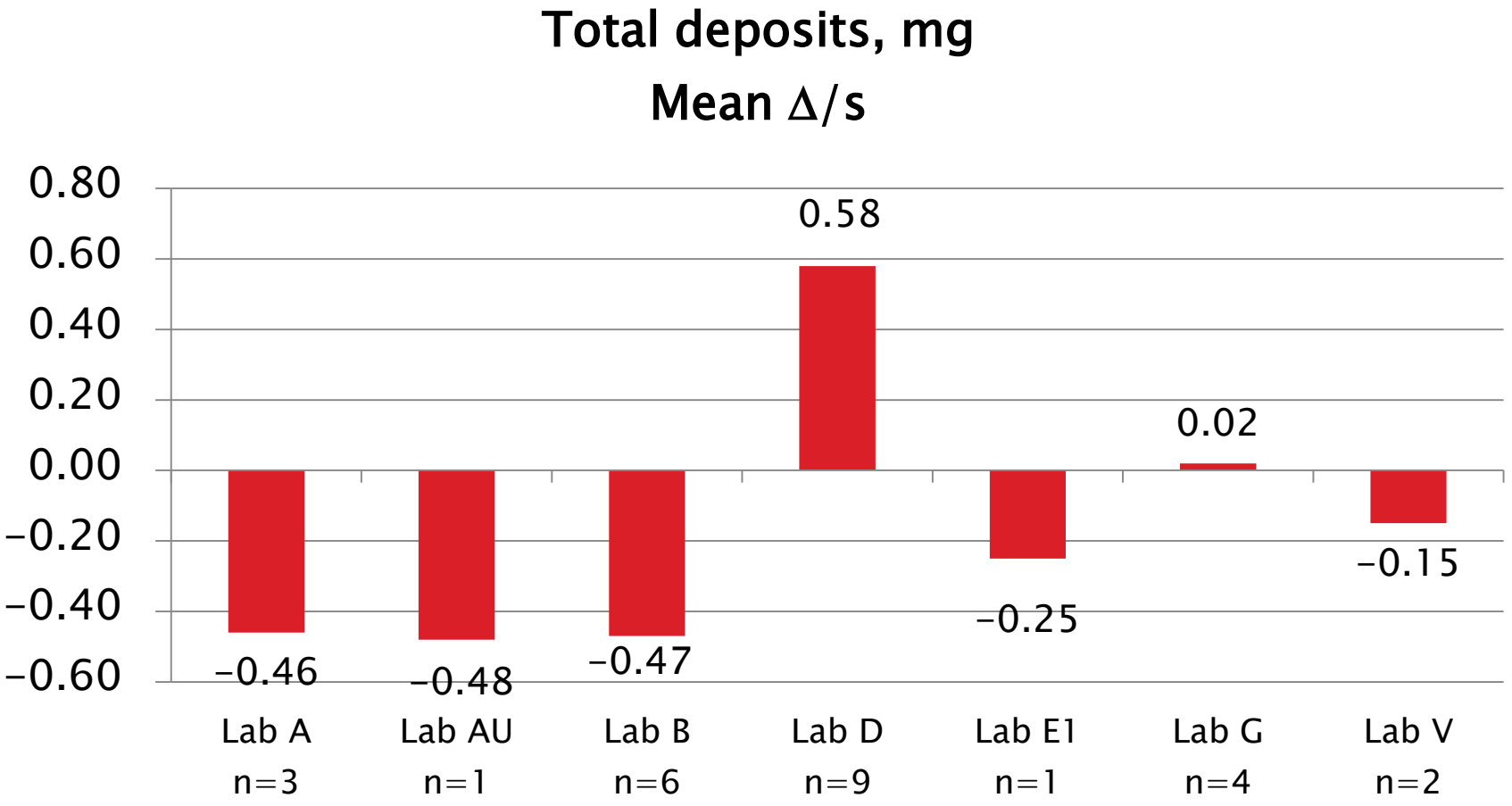


D6335: Deposits by TEOST-33C

Current Period Severity Estimates by Lab
Total Deposits, mg

	n	Mean Δ/s
Lab A	3	-0.46
Lab AU	1	-0.48
Lab B	6	-0.47
Lab D	9	0.58
Lab E1	1	-0.25
Lab G	4	0.02
Lab V	2	-0.15

D6335 Lab Severity Estimates



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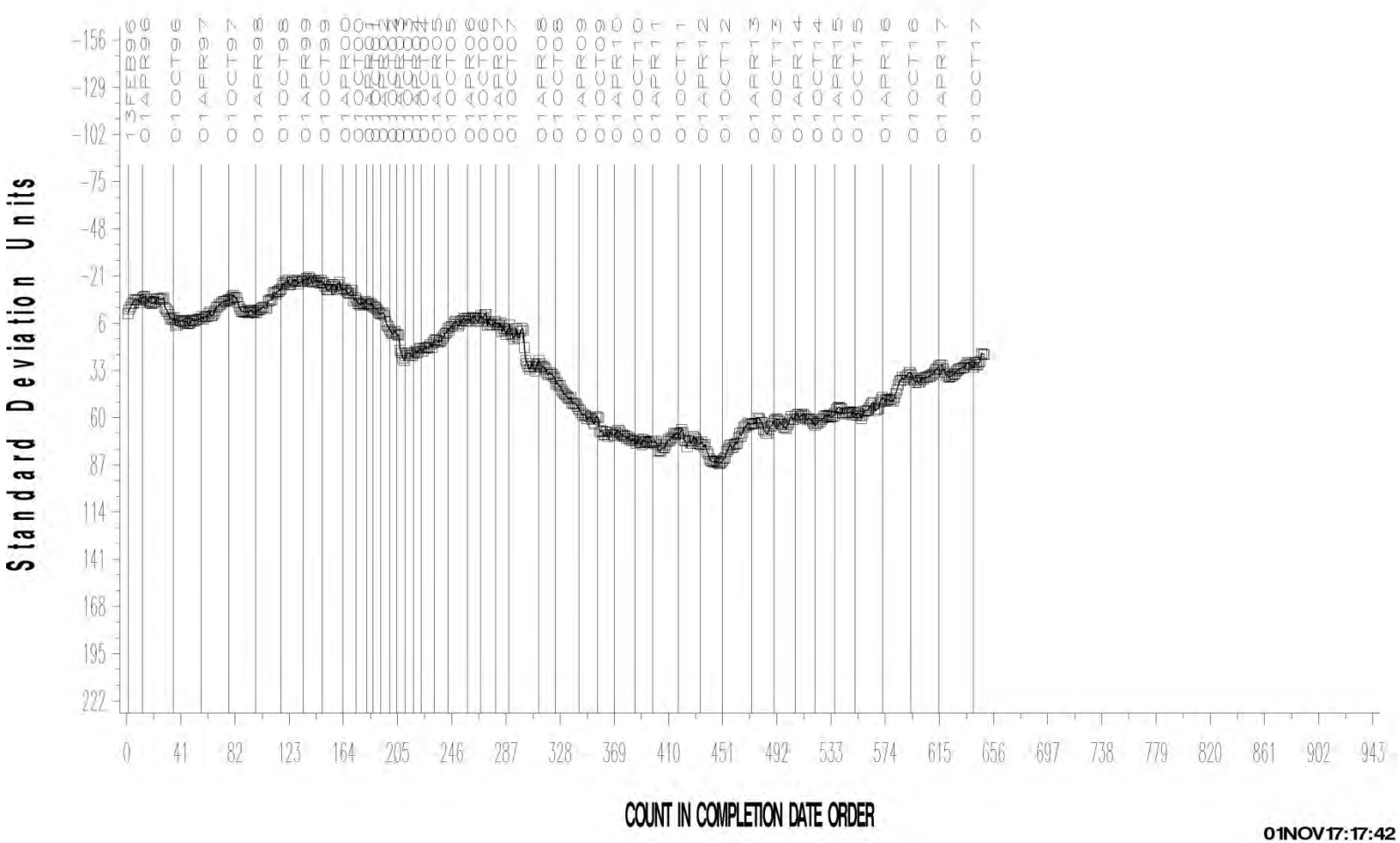
D6335: Deposits by TEOST-33C

- Rig D2 had three consecutive severe fails (the only three OC's for the period) before passing calibration on the fourth try. The lab did not find a cause to declare the failing runs as operationally invalid. Overall statistics are shown with these three results included and excluded.
- Precision (Pooled s) is comparable to prior period
  - Less precise than target precision
  - Severe oil 75 performance continues to be imprecise
- Performance (Mean Δ/s) is on target (or slightly mild with three OC tests on same rig excluded)
- All tests this period report using Rod Batch M

TEOST—33C INDUSTRY OPERATIONALLY VALID DATA

TOTAL DEPOSITS MG

CUSUM Severity Analysis



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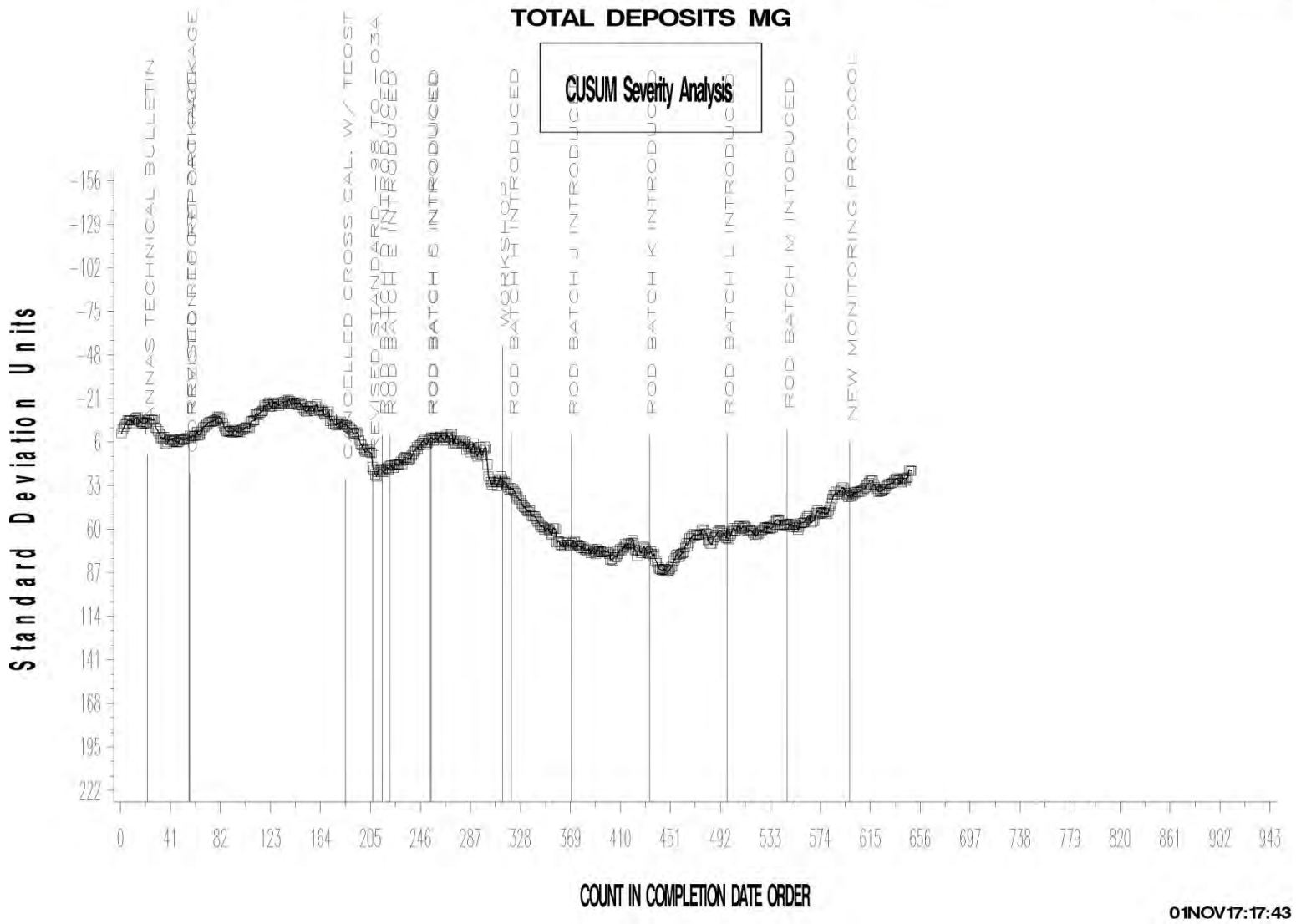
TEOST—33C INDUSTRY OPERATIONALLY VALID DATA



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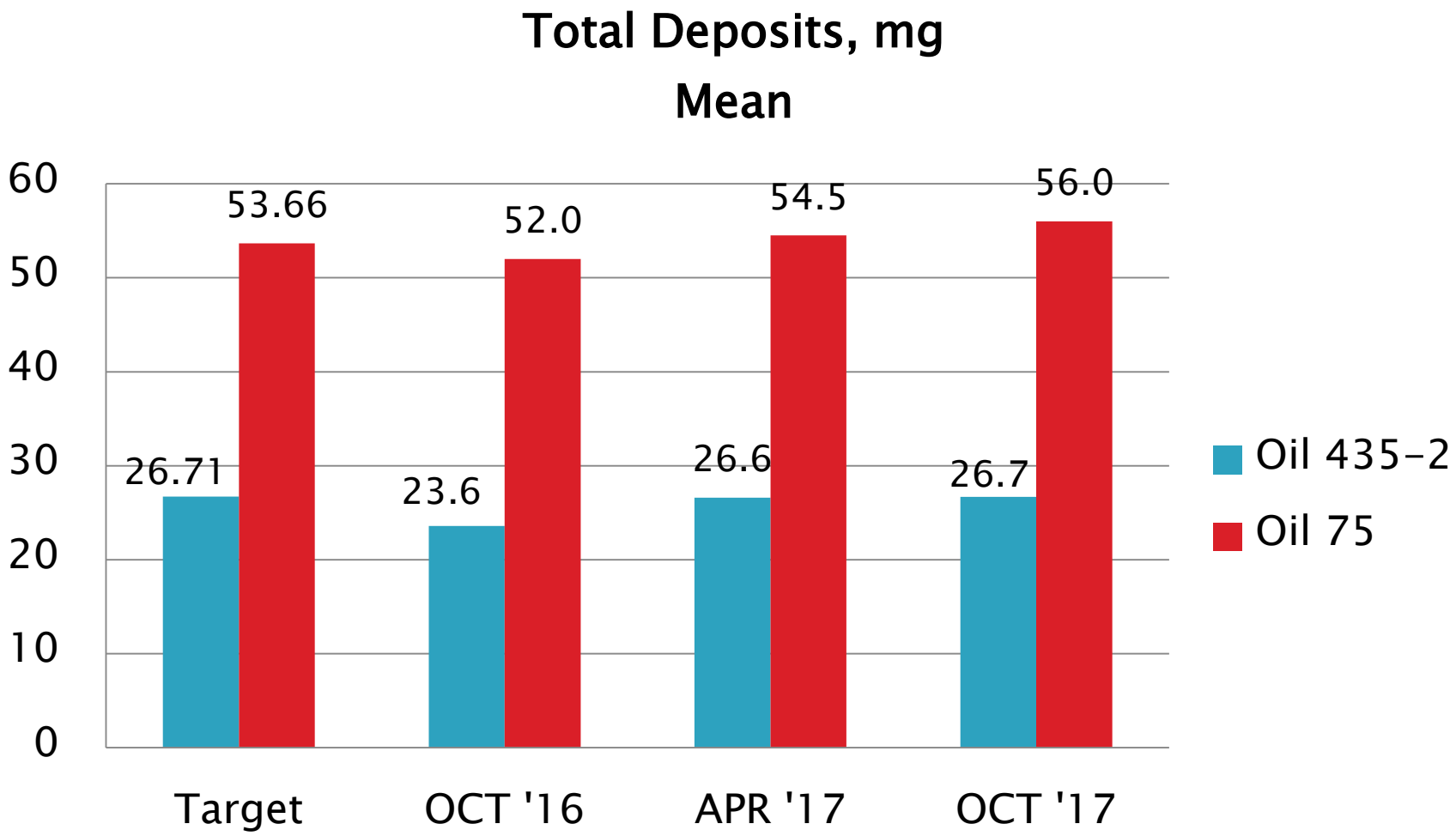
D6335 Performance by Oil

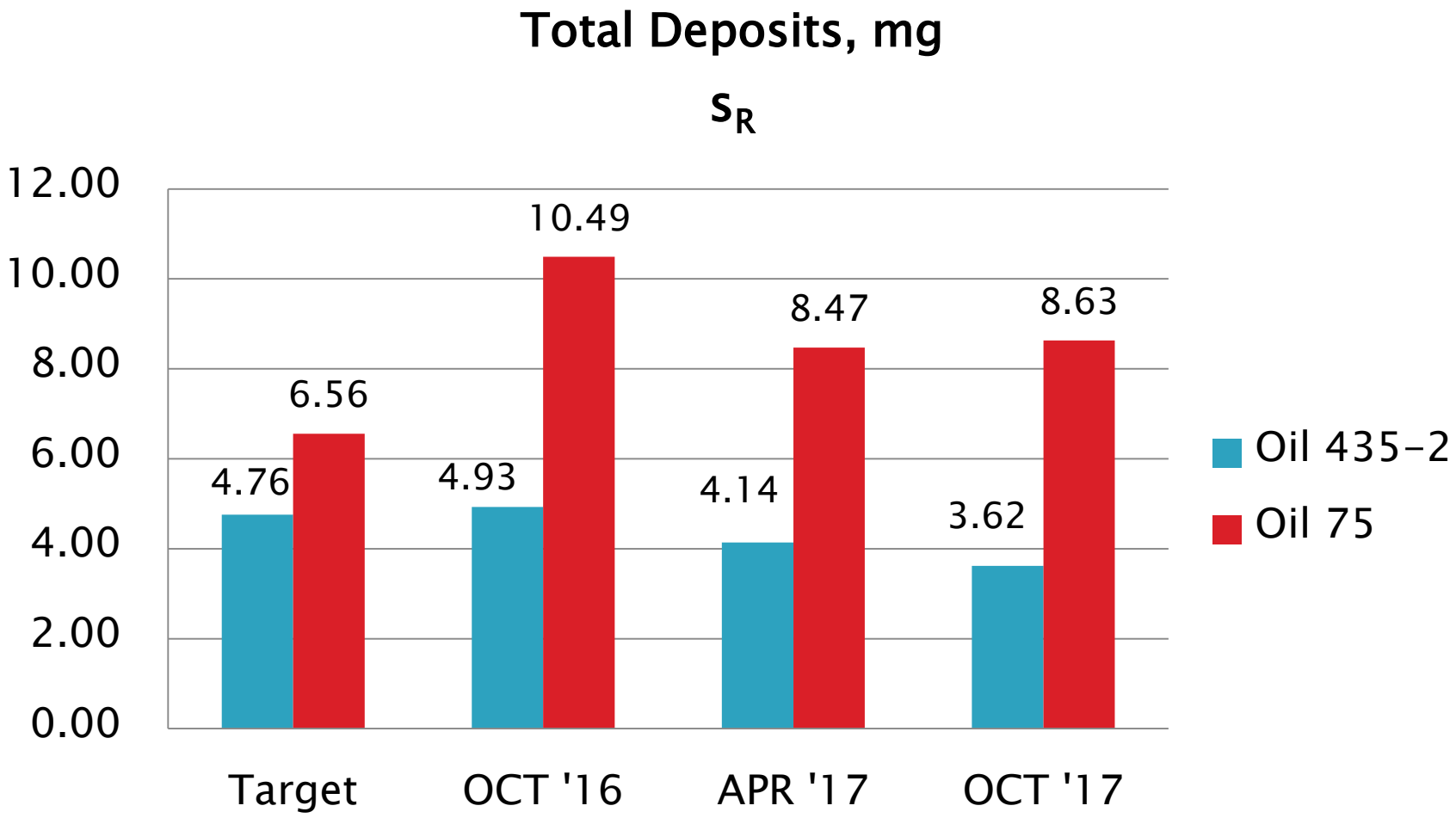
Total Deposits, mg
Performance by Oil

	Targets 20130415			4/1/16– 9/30/16				10/1/16 – 3/31/17				4/1/17– 9/30/17			
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	11	23.6	4.93	-1.07	10	26.6	4.14	-0.45	12	26.7	3.62	-0.42
75	30	53.66	6.56	10	52.0	10.49	-0.25	11	54.5	8.47	0.13	14	56.0	8.63	0.36

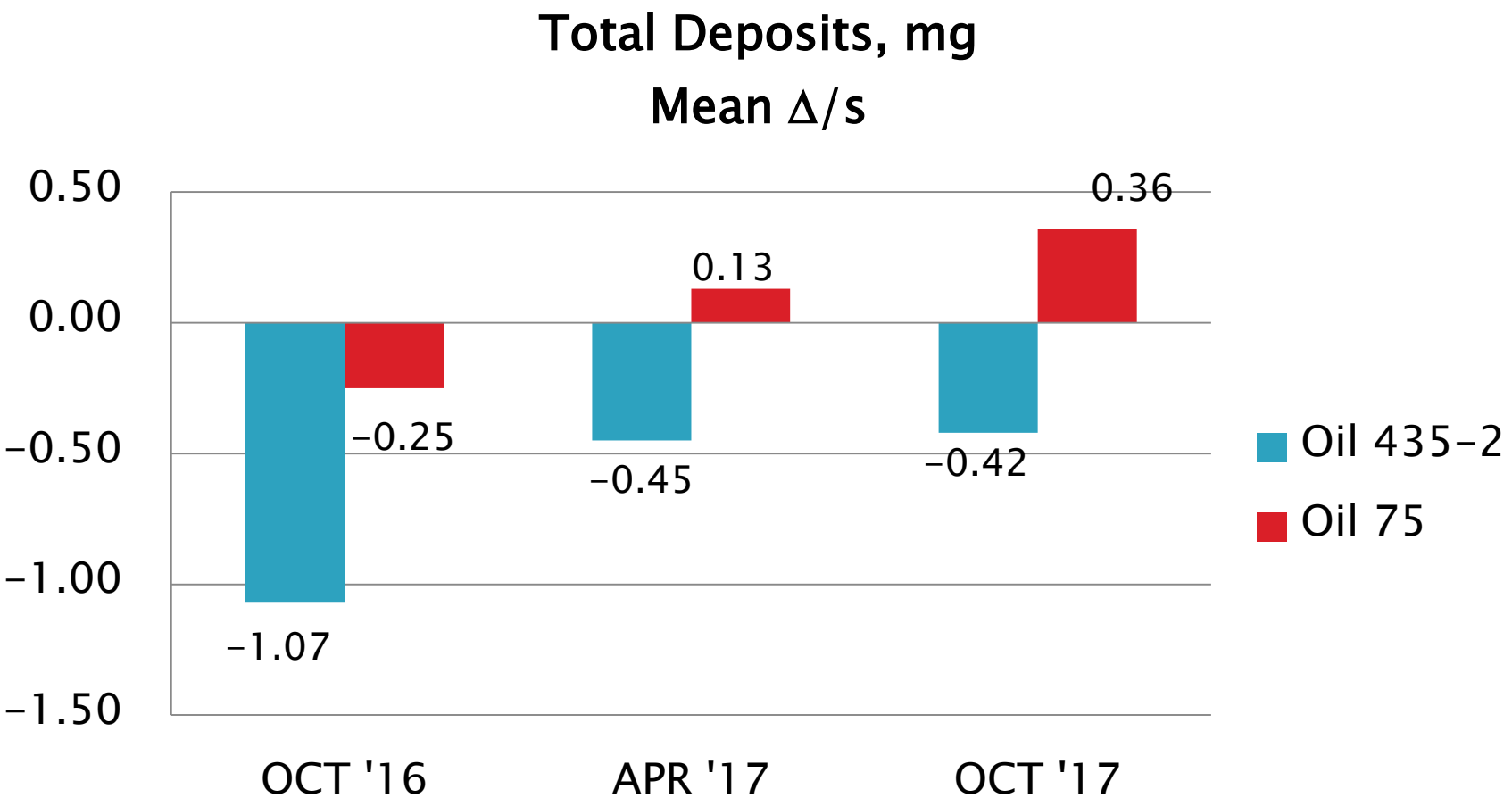
D6335 Performance by Oil



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	80
Failed Calibration Test	OC	3
Operationally Invalidated by Lab	LC, XC	3
Operationally Invalidated After Initially Reported as Valid	RC	0
Instrument Shakedown	NN	2
Donated Catalyst Screener Runs	AG, OG, XG	17
Total		**105**

Number of Labs Reporting Data: 10
Fail Rate of Operationally Valid Tests: 4%

D7097: Deposits by MHT TEOST

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

- Three operationally invalid calibration test reported this period:
  - Thermocouple depth off spec (LC)
  - Thermocouple calibration off spec (XC)
  - Obstructed sample feed tube (XC)

- Two shakedown runs reported to troubleshoot instruments (NN)

- Seventeen donated round robin runs to evaluate new catalyst batch 16DA.

- No TMC technical updates were issued this report period.

D7097: Deposits by MHT TEOST

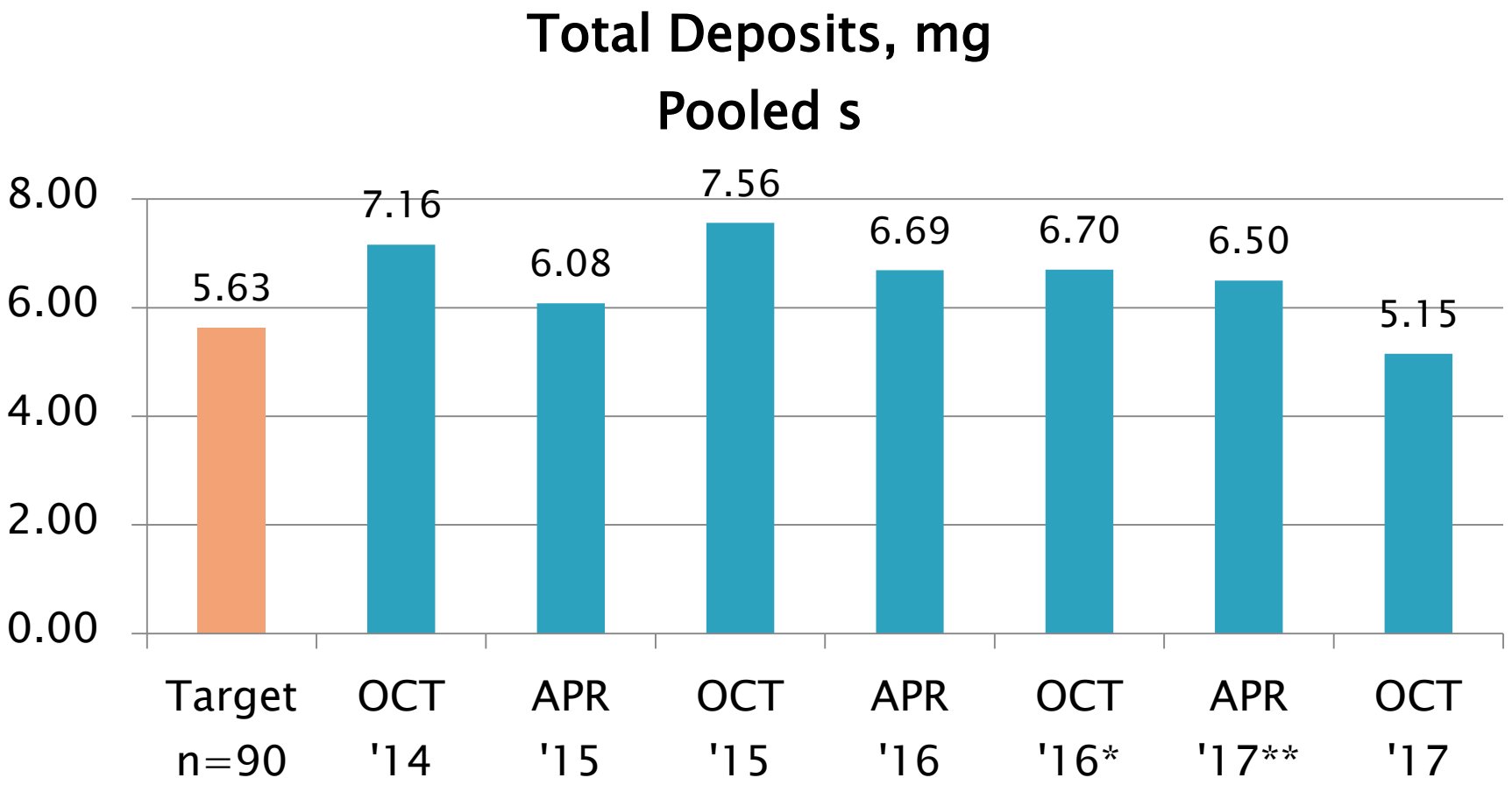
Period Precision and Severity Estimates

Total Deposits, mg	n	df	Pooled s	Mean Δ/s
Current Targets 7/31/2006	90	87	5.63	-----
4/1/15 through 9/30/15	84	82	7.56	0.39
10/1/15 through 3/31/16	84	82	6.69	0.29
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

*Three severe OC tests from instrument P1 included and excluded

**Eight 2TESTCAL tests from instrument J2 included and excluded

D7097 Precision Estimates



*Three severefrom OC tests from instrument P1 excluded
**Eight tests instrument J2 excluded (failed to calibrate)

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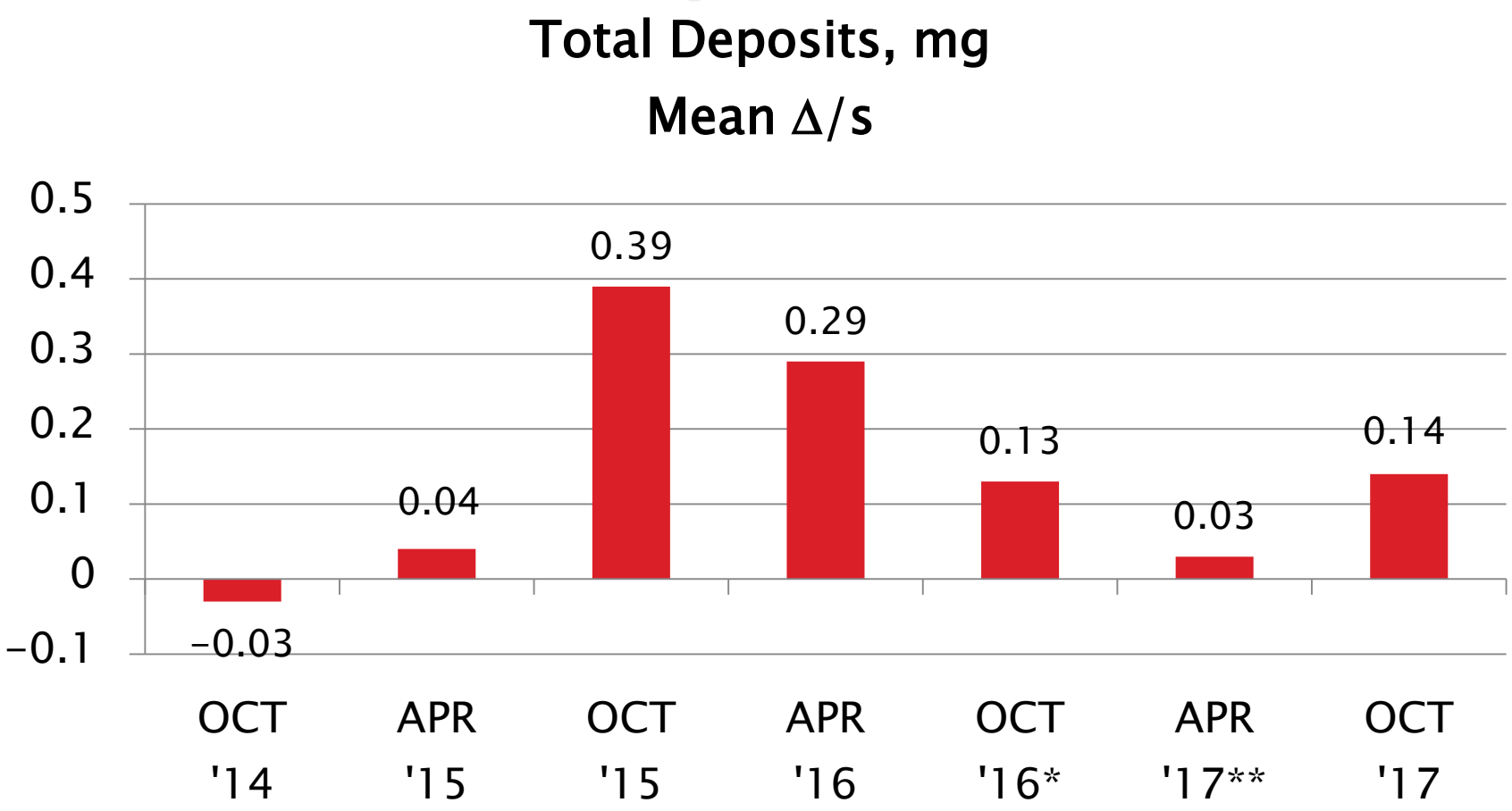
D7097 Severity Estimates



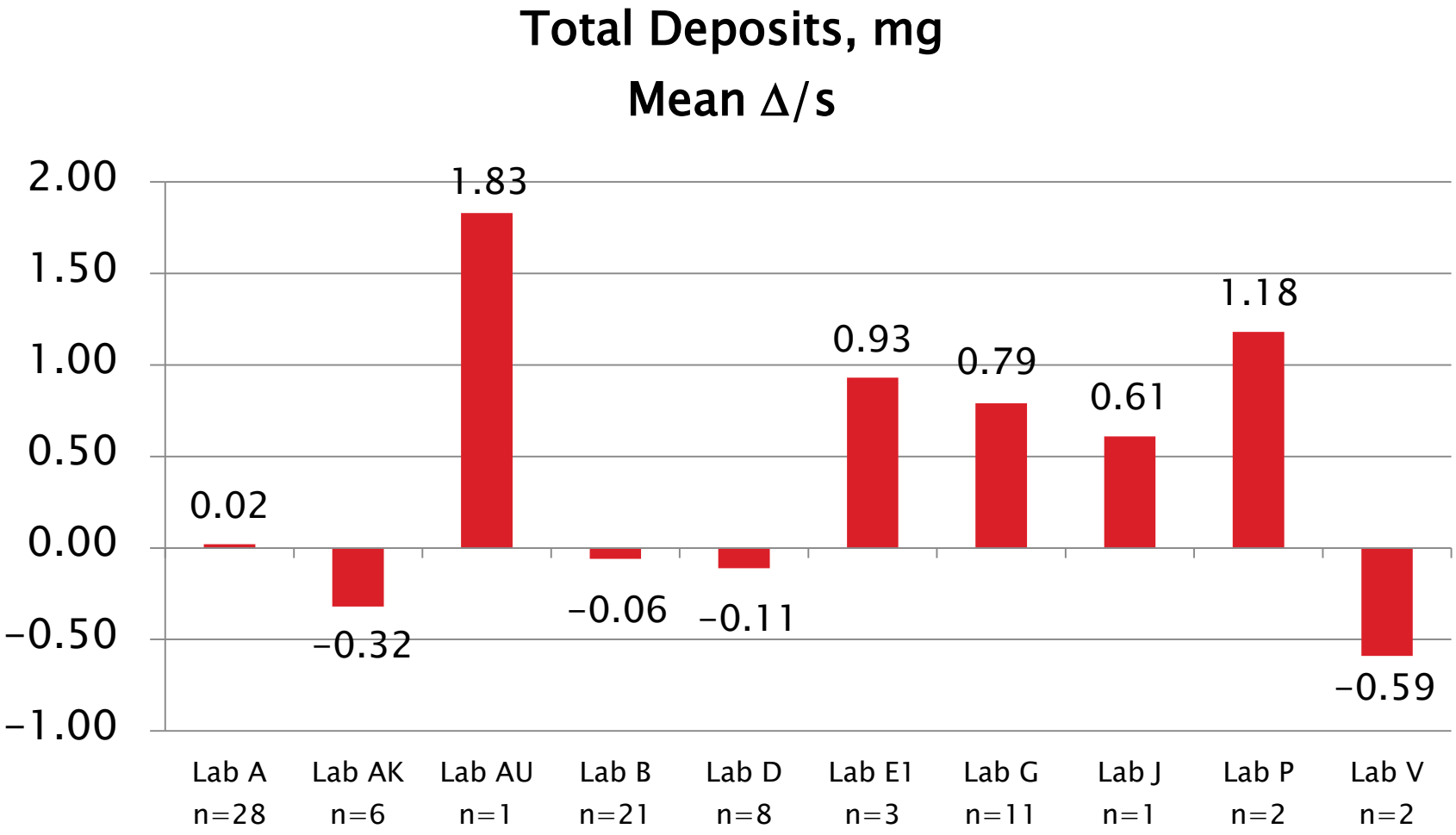
*Three severe OC tests from instrument P1 excluded
**Eight tests from instrument J2 excluded (failed to calibrate)

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	28	0.02	Lab E1	3	0.93
Lab AK	6	-0.32	Lab G	11	0.79
Lab AU	1	1.83	Lab J	1	0.61
Lab B	21	-0.06	Lab P	2	1.18
Lab D	8	-0.11	Lab V	2	-0.59

D7097 Lab Severity Estimates



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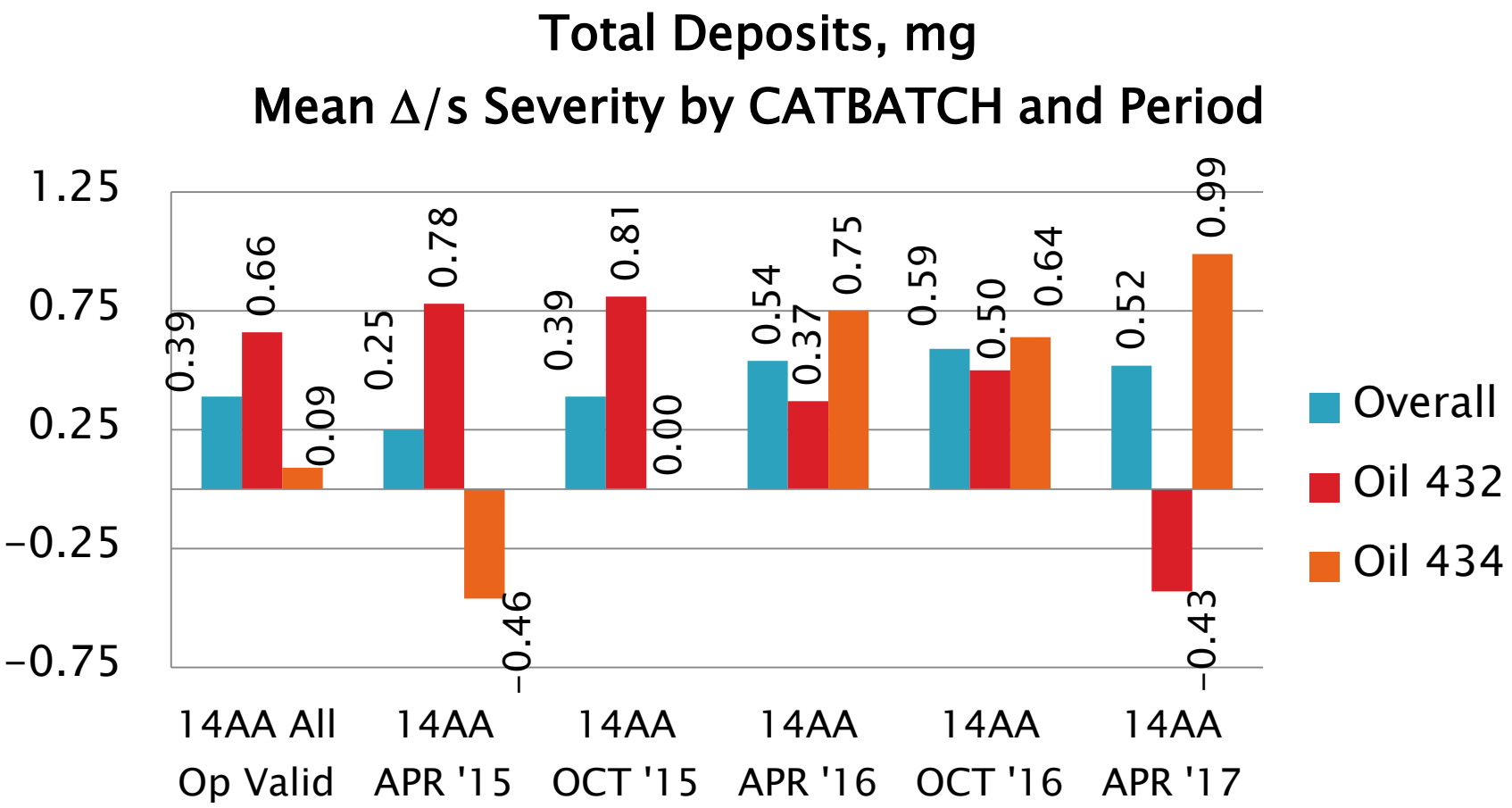
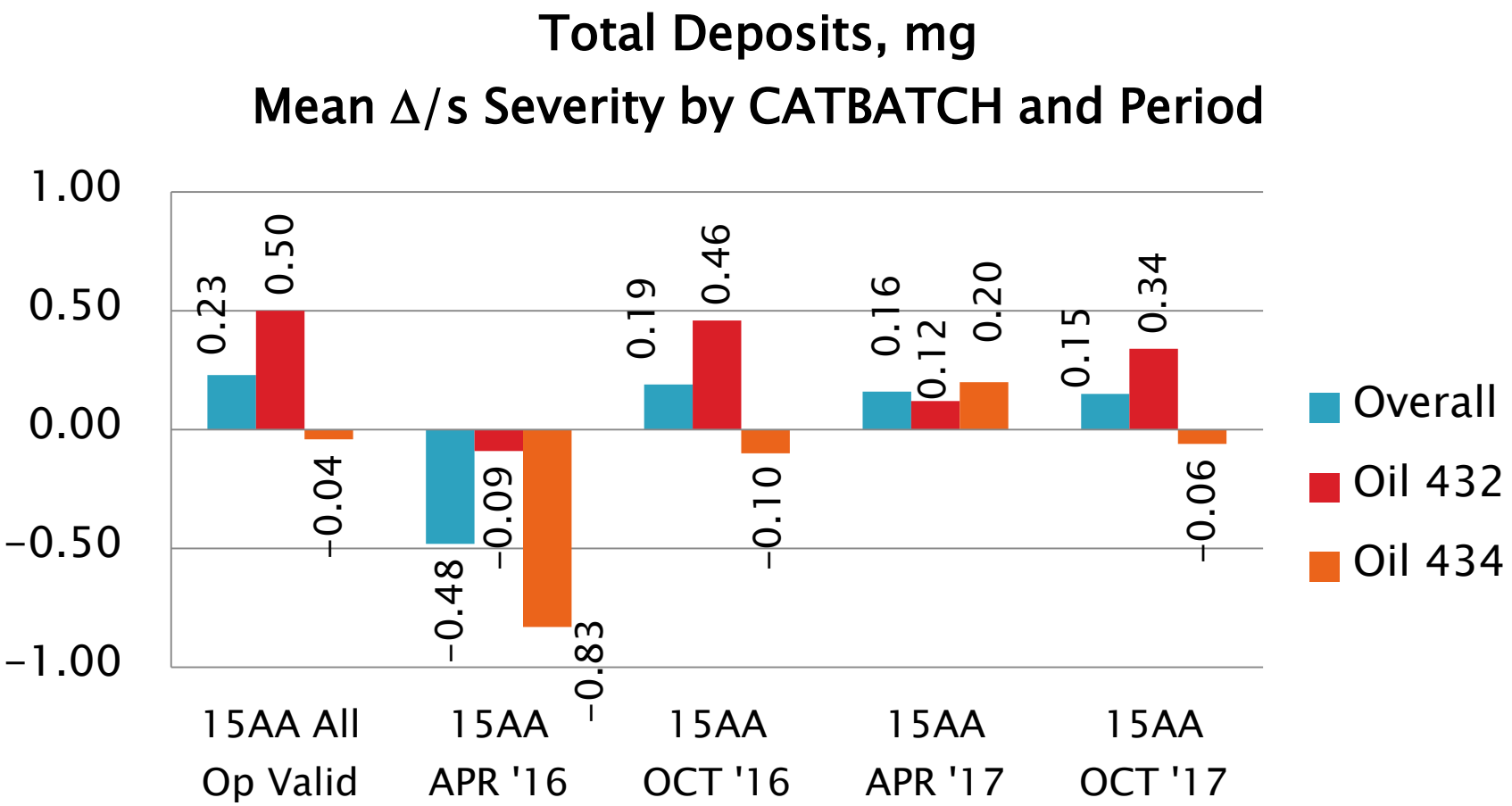
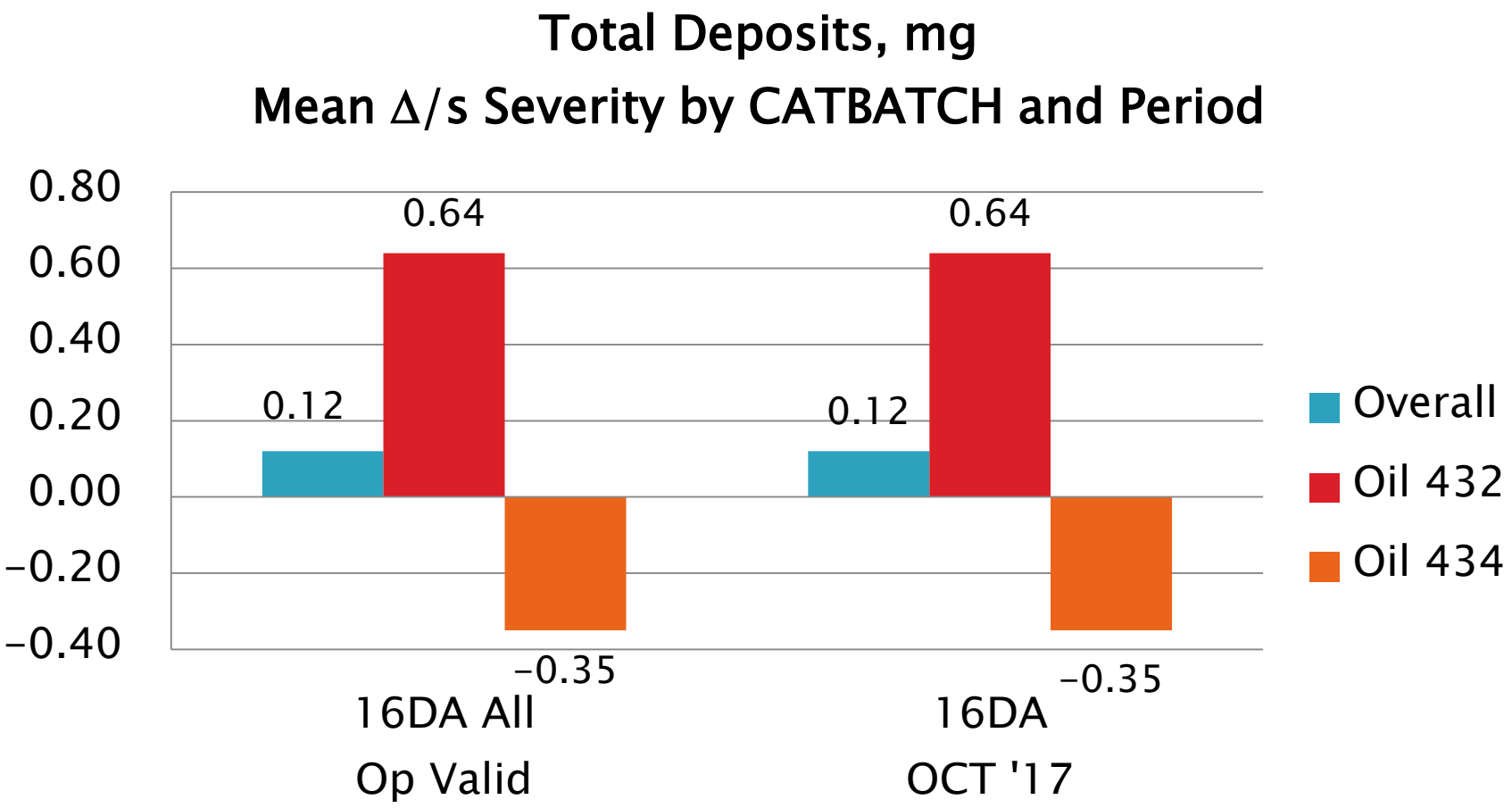
D7097: Deposits by MHT TEOST



D7097: Deposits by MHT TEOST



D7097: Deposits by MHT TEOST



D7097: Deposits by MHT TEOST

- Precision (Pooled s) is more precise than last period
  - More precise than target precision (for the first time in at least 7 report periods).
    - Precision of both oils is better than target.
    - Possibly because use of new end cap flask seals has improved test precision?
- Performance (Mean Δ/s) is 0.14 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=54) or 16DA (n=29).
  - First calibration tests using catalyst batch 16DA reported this period.

D7097: Deposits by MHT TEOST

- CUSUM severity plot shows some overall leveling the past three periods (excluding some questionable results)
  - However, lab performance differences persist

- Initial severity bias of new catalyst batch 16DA on severe performing oil 432 is more severe (0.64 s) than we had typically seen with batch 15AA (though batch 14AA had similar severe periods), and will be monitored. Mild performing oil 434 is biased somewhat mild (-0.35 s), more so than the last three periods on 15AA.

MHT—4 TEOST INDUSTRY OPERATIONALLY VALID DATA

TOTAL DEPOSITS MG

CUSUM Severity Analysis

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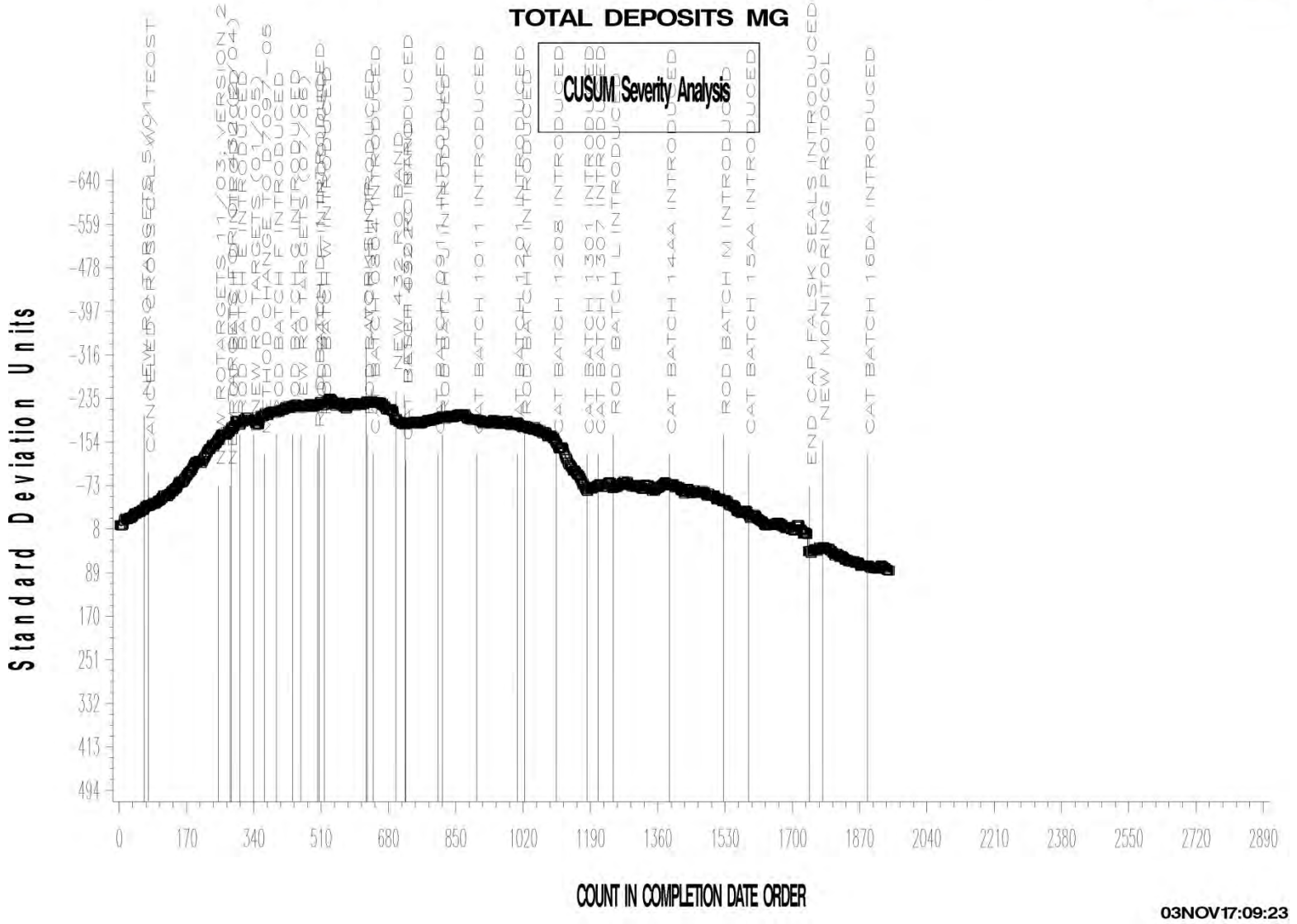
MHT—4 TEOST INDUSTRY OPERATIONALLY VALID DATA

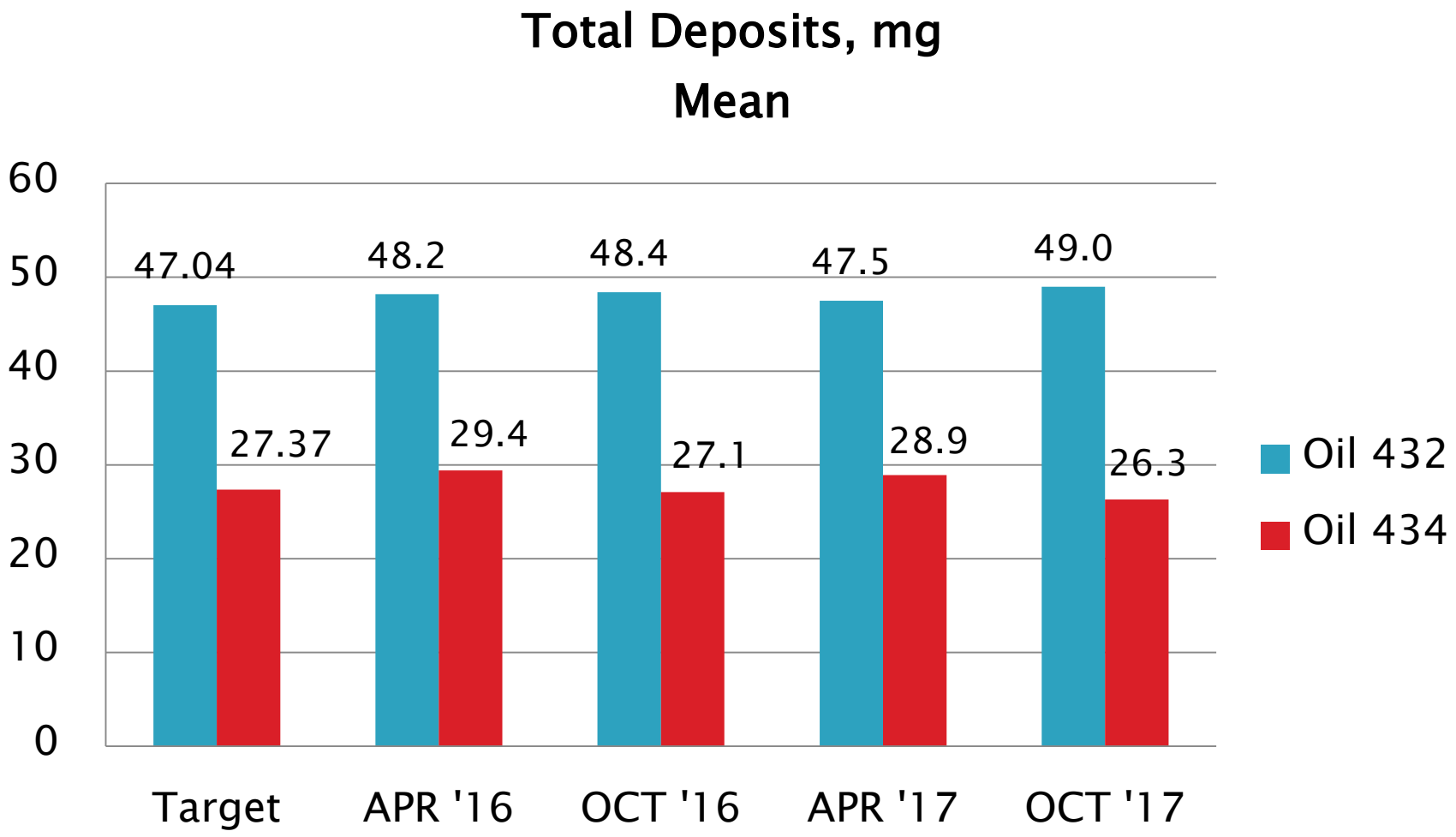


D7097 Performance by Oil

Total Deposits, mg
Performance by Oil

	Targets			4/1/16– 9/30/16				10/1/16 – 3/31/17				4/1/17- 9/30/17			
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	45	48.4	6.84	0.31	51	47.5	5.41	0.11	42	49.0	4.38	0.44
434	30	27.37	6.57	48	27.1	6.58	-0.04	54	28.9	8.41	0.23	41	26.3	5.84	-0.17

D7097 Performance by Oil



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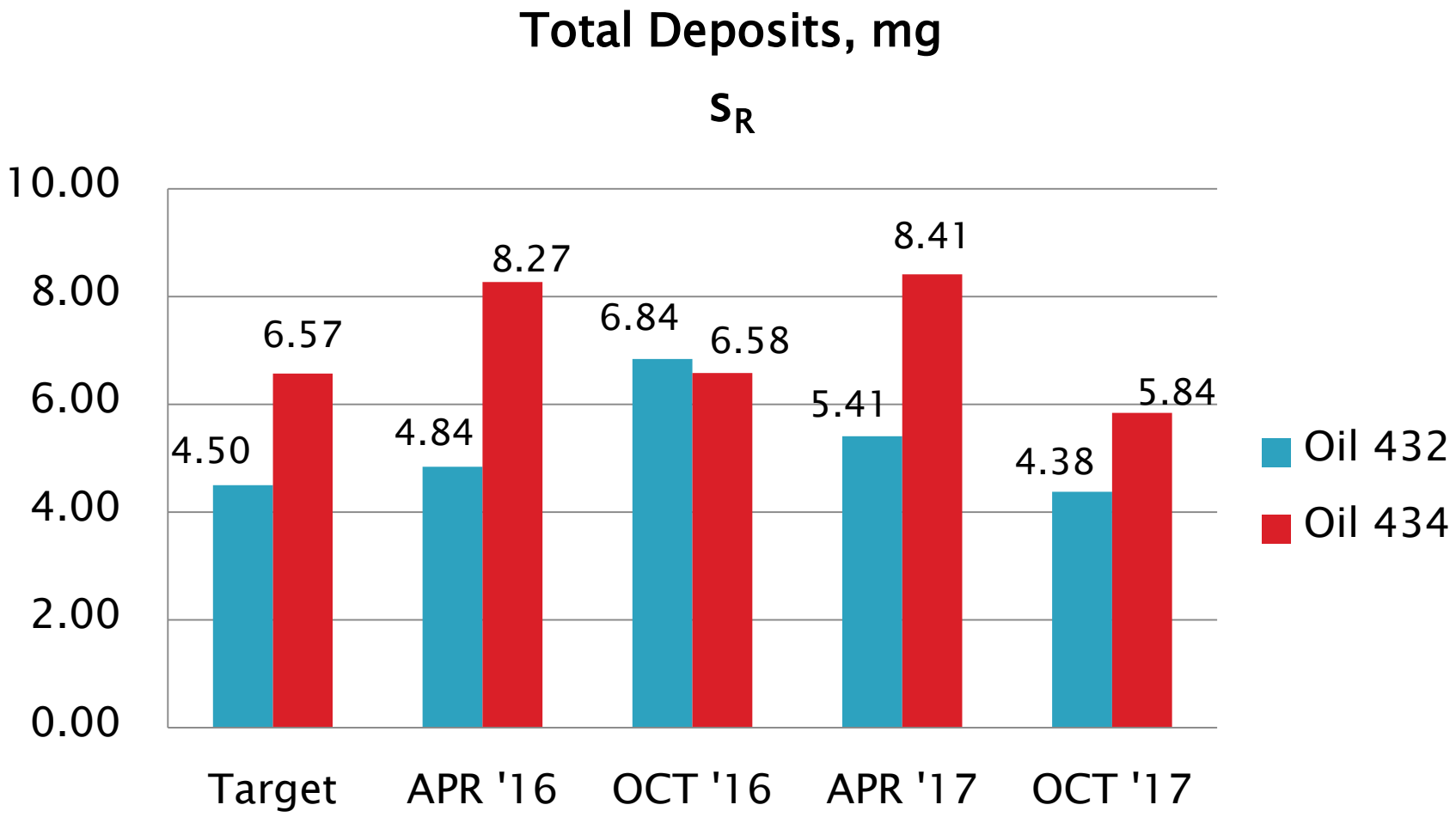
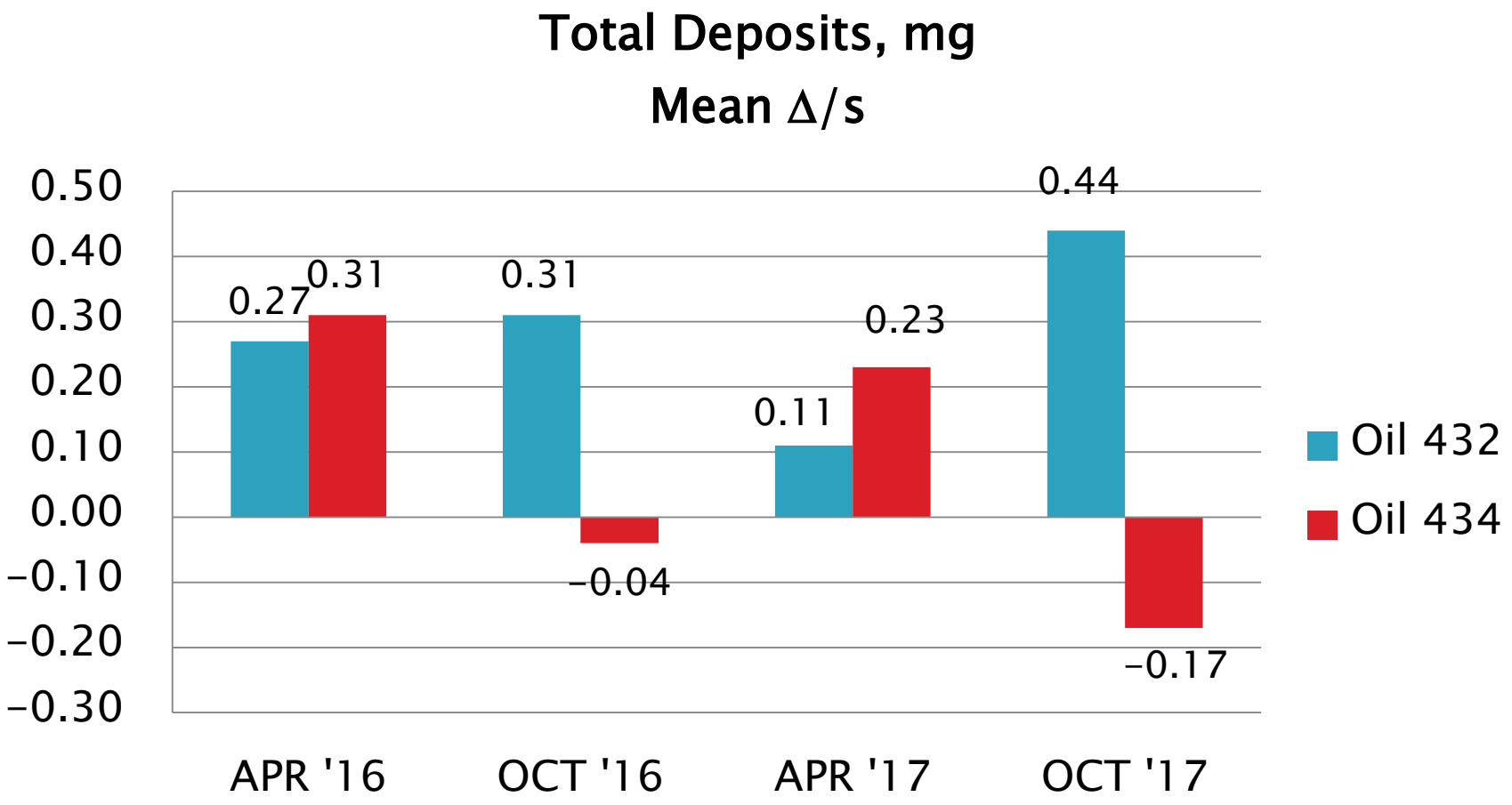
D7097: Deposits by MHT TEOST



D7097: Deposits by MHT TEOST



Return to Executive Summary

D6082: High Temperature Foam

Test Status	Validity Code	No. Tests
Acceptable Calibration Test	AC	12
Acceptable Discrimination Test	AS	5
Failed Calibration Test	OC	0
Operationally Invalidated by Lab	LC, XC	0
Donated New Oil Screener Tests	AG	3
Total		**20**

Number of Labs Reporting Data: 5
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 TMC technical updates were issued this period

D6082: High Temperature Foam

Period Precision and Severity Estimates Oil 1007

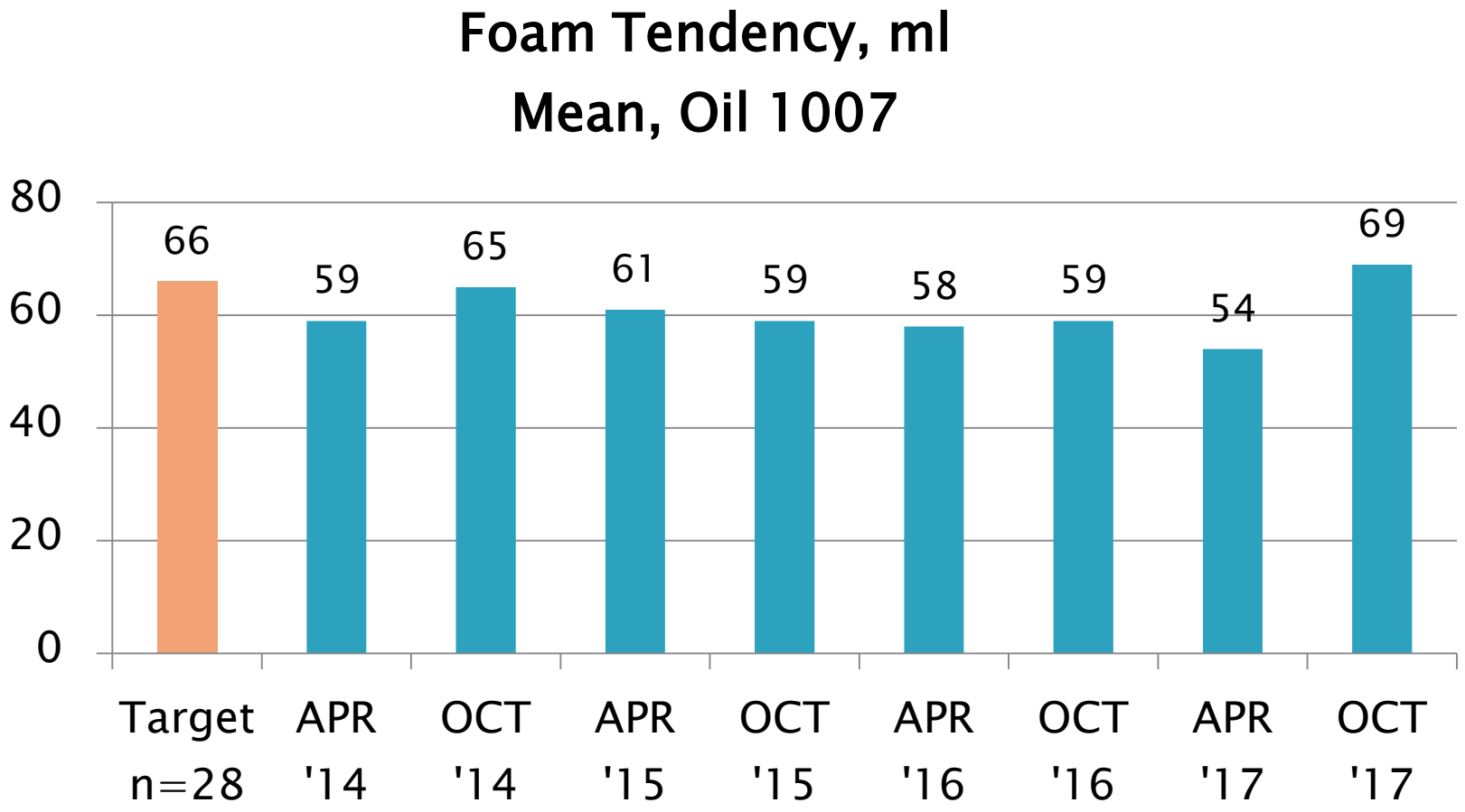
Foam Tendency, ml	n	Mean	Pooled s	Mean Δ/s
Current Targets	28	65.71	19.28	-----
10/1/13 through 3/31/14	11	59	8	-0.39
4/1/14 through 9/30/14	11	65	22	-0.05
10/1/14 through 3/31/15	10	61	12	-0.26
4/1/15 through 9/30/15	11	59	16	-0.36
10/1/15 through 3/31/16	8	58	10	-0.45
4/1/16 through 9/30/16	12	59	18	-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

D6082: High Temperature Foam

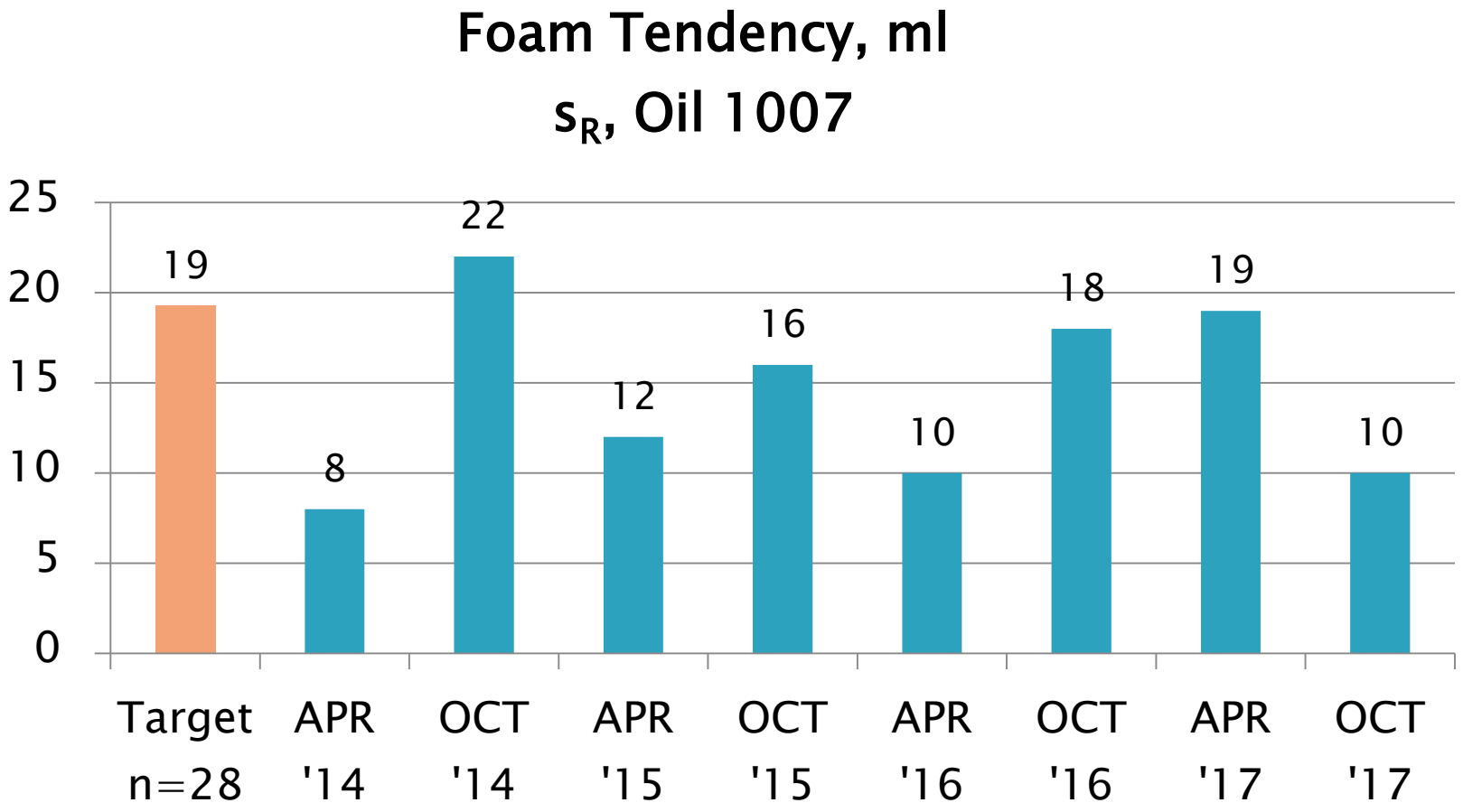
Period Precision and Severity Estimates Oil 1007

Foam Stability @ 1 min, ml	n	Mean	s
Current Targets	28	0.00	0.00
10/1/13 through 3/31/14	11	No non-zero occurrences	
4/1/14 through 9/30/14	11	No non-zero occurrences	
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	5	No non-zero occurrences	
10/1/16 through 3/31/17	14	No non-zero occurrences	
4/1/17 through 9/30/17	5	No non-zero occurrences	

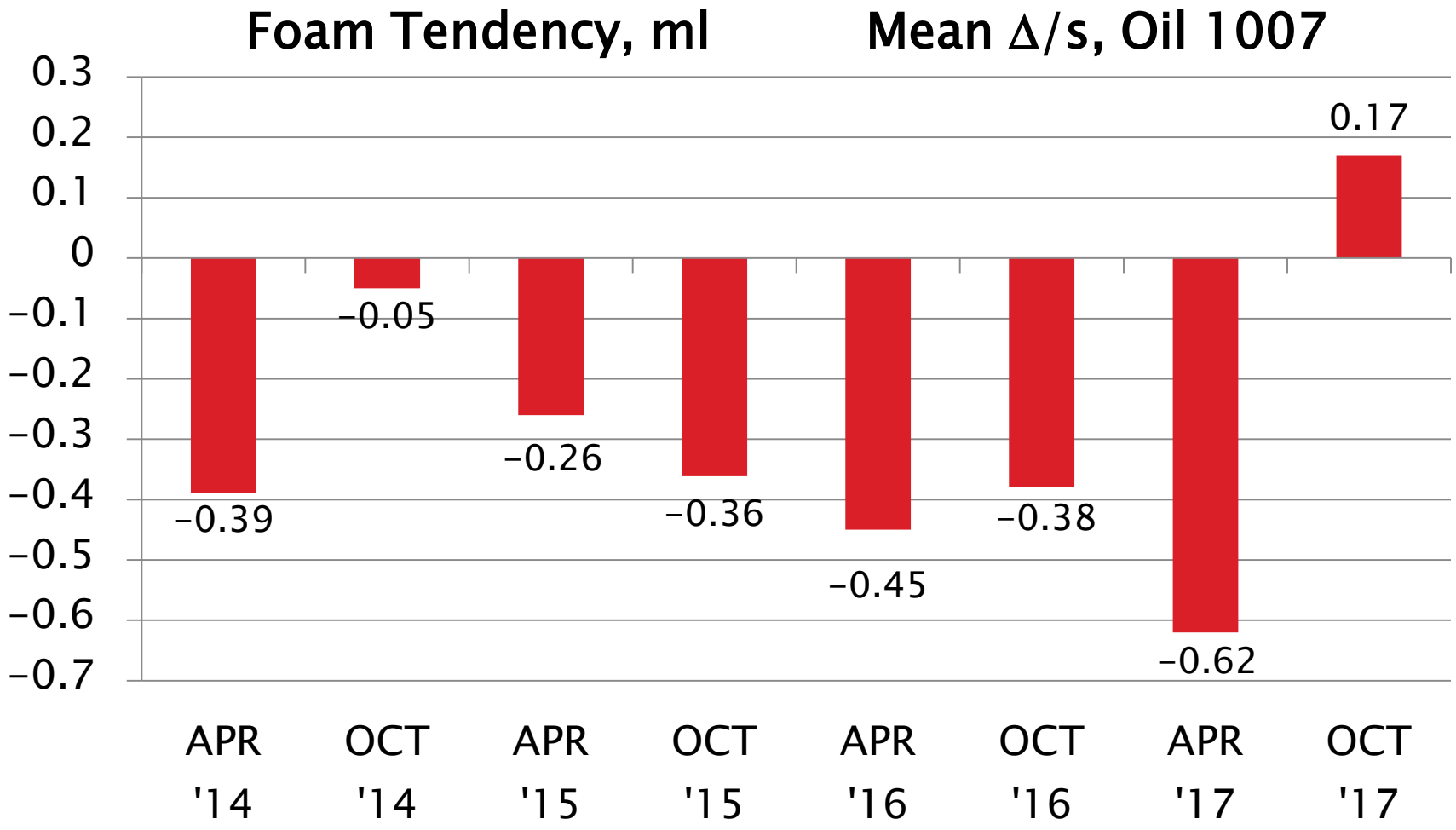
D6082: High Temperature Foam



D6082: High Temperature Foam



D6082: High Temperature Foam

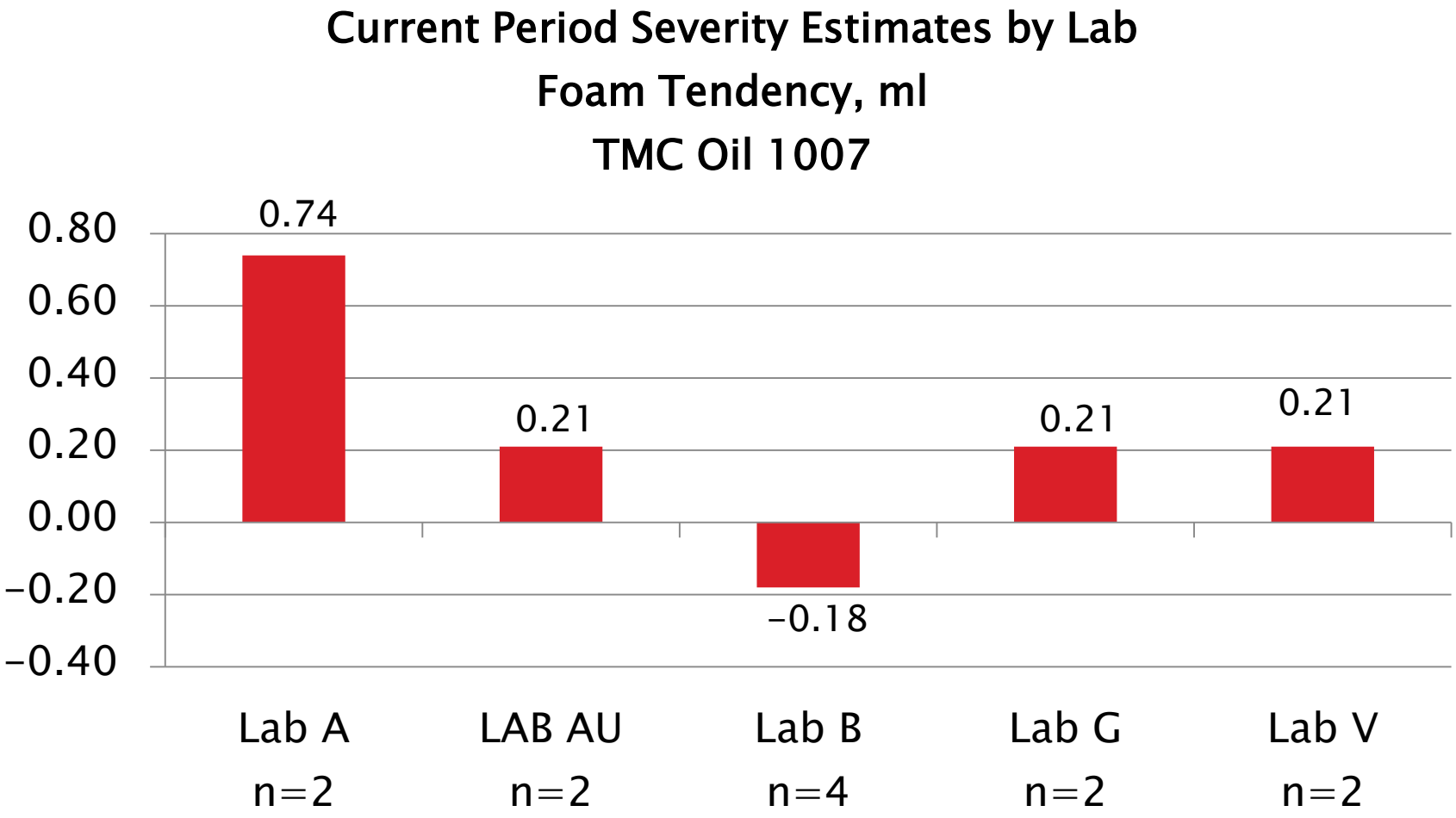


D6082: High Temperature Foam

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	-0.18
Lab G	2	0.21
Lab V	2	0.21

D6082: High Temperature Foam



D6082: High Temperature Foam

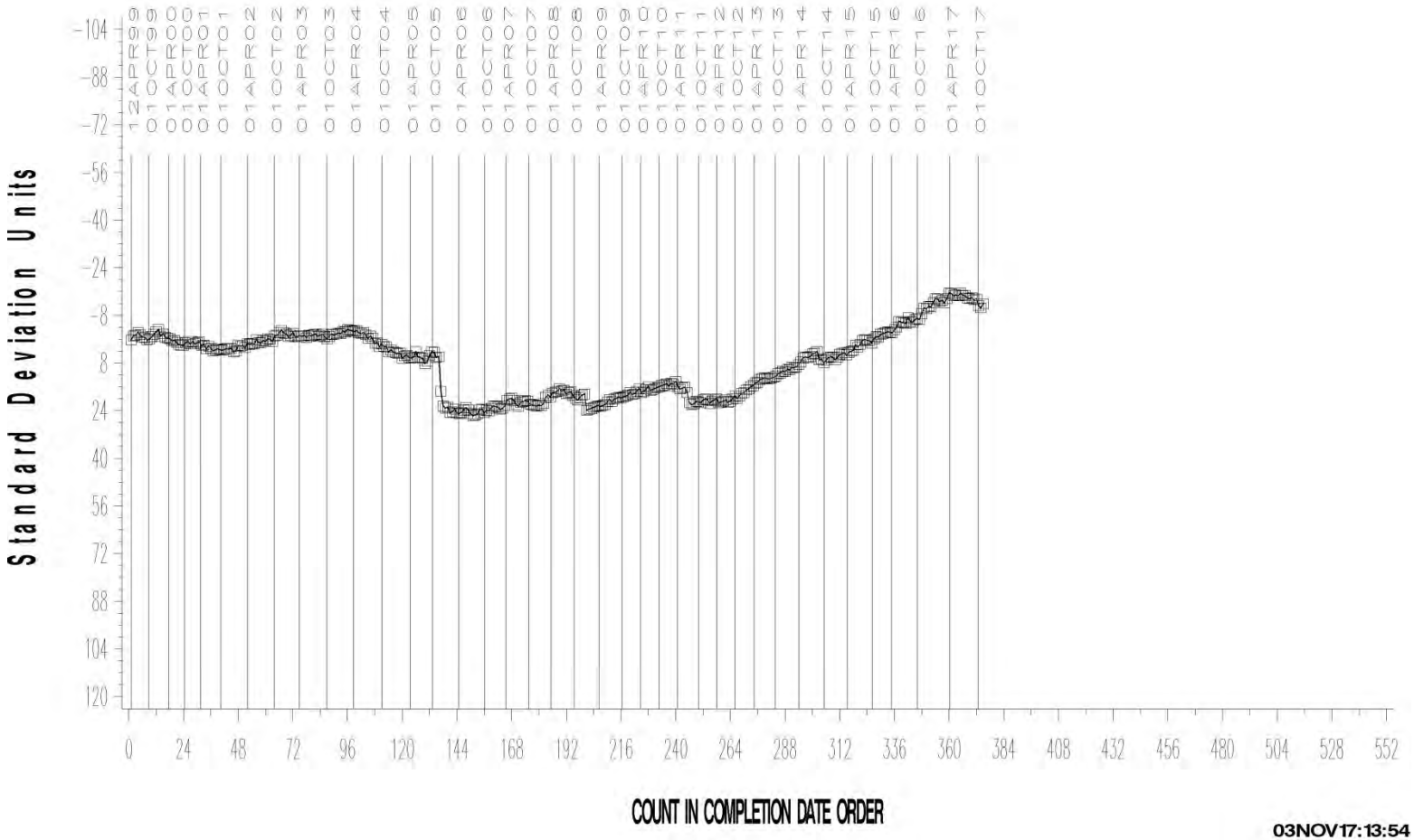
- Foam Tendency Precision (Pooled s) is greatly improved compared to the prior two report periods
  - Also much more precise than target precision
- Performance (Mean Δ/s) is 0.17 s severe
  - Follows the most mild period since at least October 2013
    - Attributable (last period) mostly to Lab B (two instruments, six tests, all between −1.3 and −1.9 s mild)
    - This period, Lab B is only −0.18 s mild (n=4).
- The most accurate AND precise period since at least 2014.
- No non-zero occurrences of Foam Stability (on operationally valid tests)
- All severe oil discrimination runs demonstrated acceptable discrimination.

D6082 HIGH TEMPERATURE FOAM INDUSTRY OPERATIONALLY VALID DATA

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

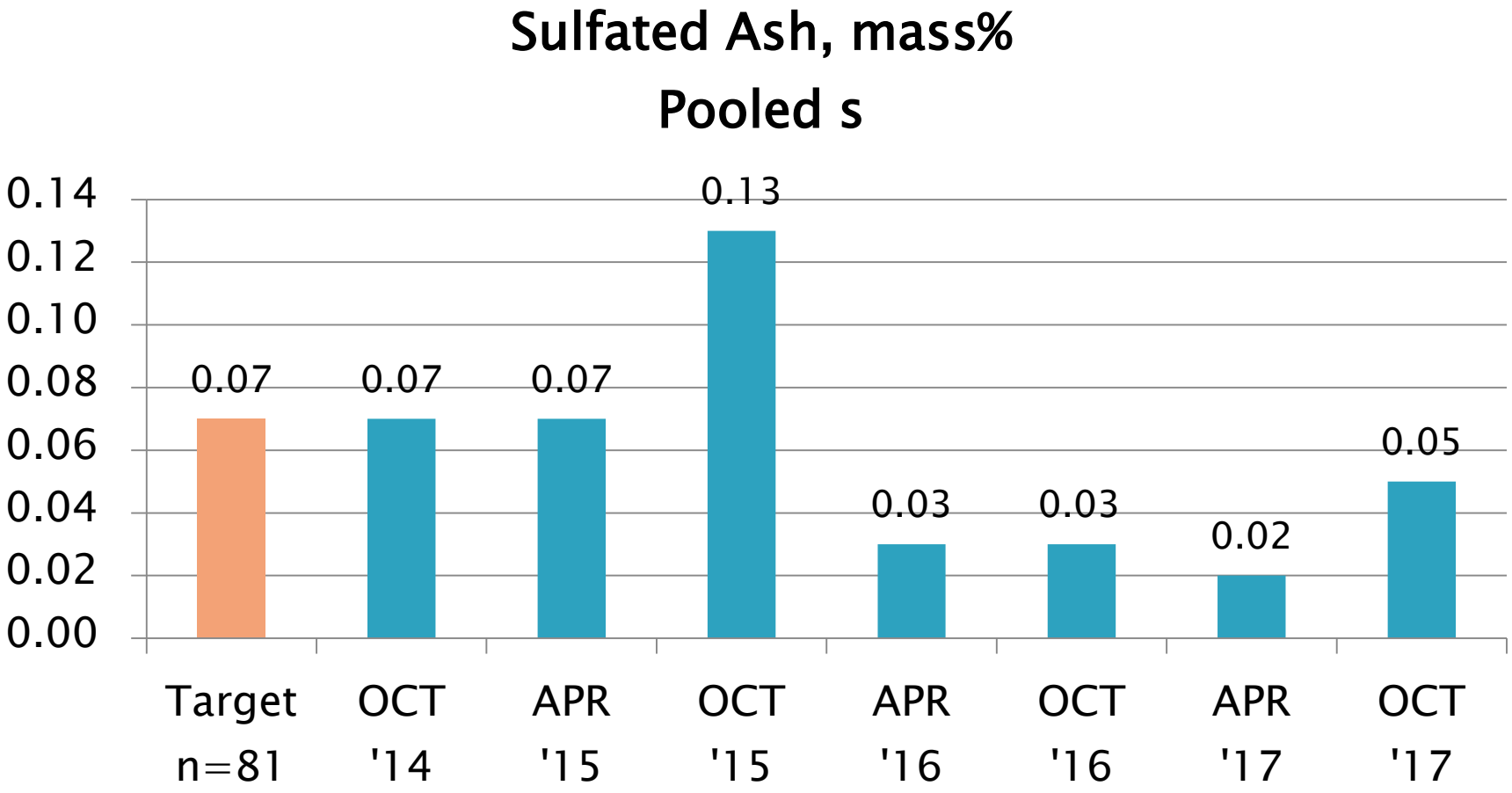
D874: Sulfated Ash

Period Precision and Severity Estimates

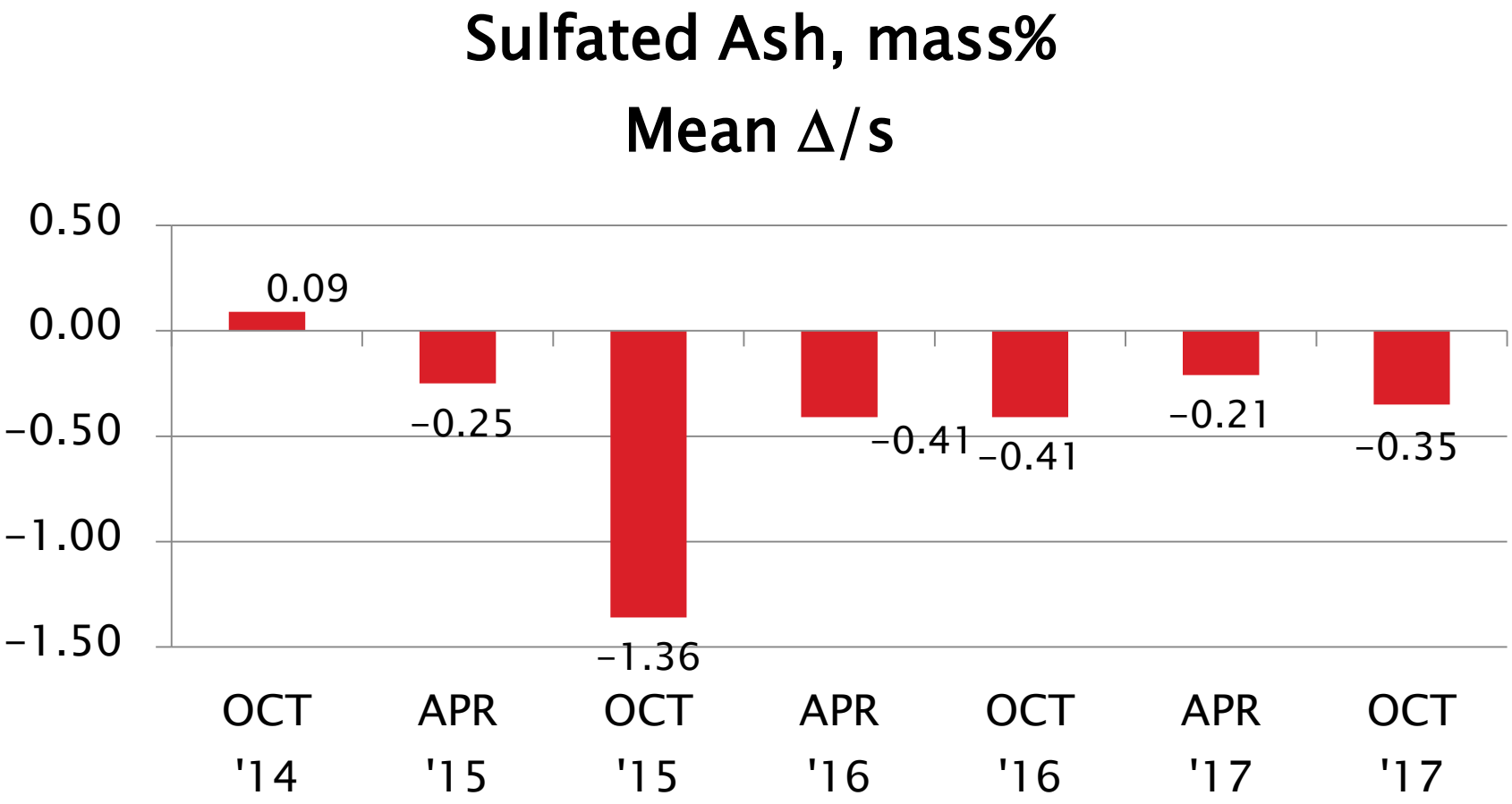
Total Deposits, mg	n	df	Pooled s	Mean Δ/s
Current Targets	81	78	0.07	-----
4/1/14 through 9/30/14	6	3	0.07	0.09
10/1/14 through 3/31/15	6	4	0.07	-0.25
4/1/15 through 9/30/15*	8	5	0.13	-1.36
4/1/15 through 9/30/15*	7	4	0.05	-0.36
10/1/15 through 3/31/16	7	4	0.03	-0.41
4/1/16 through 9/30/16	6	3	0.03	-0.41
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

*Period statistics with and without extreme result included

D874: Sulfated Ash



D874: Sulfated Ash

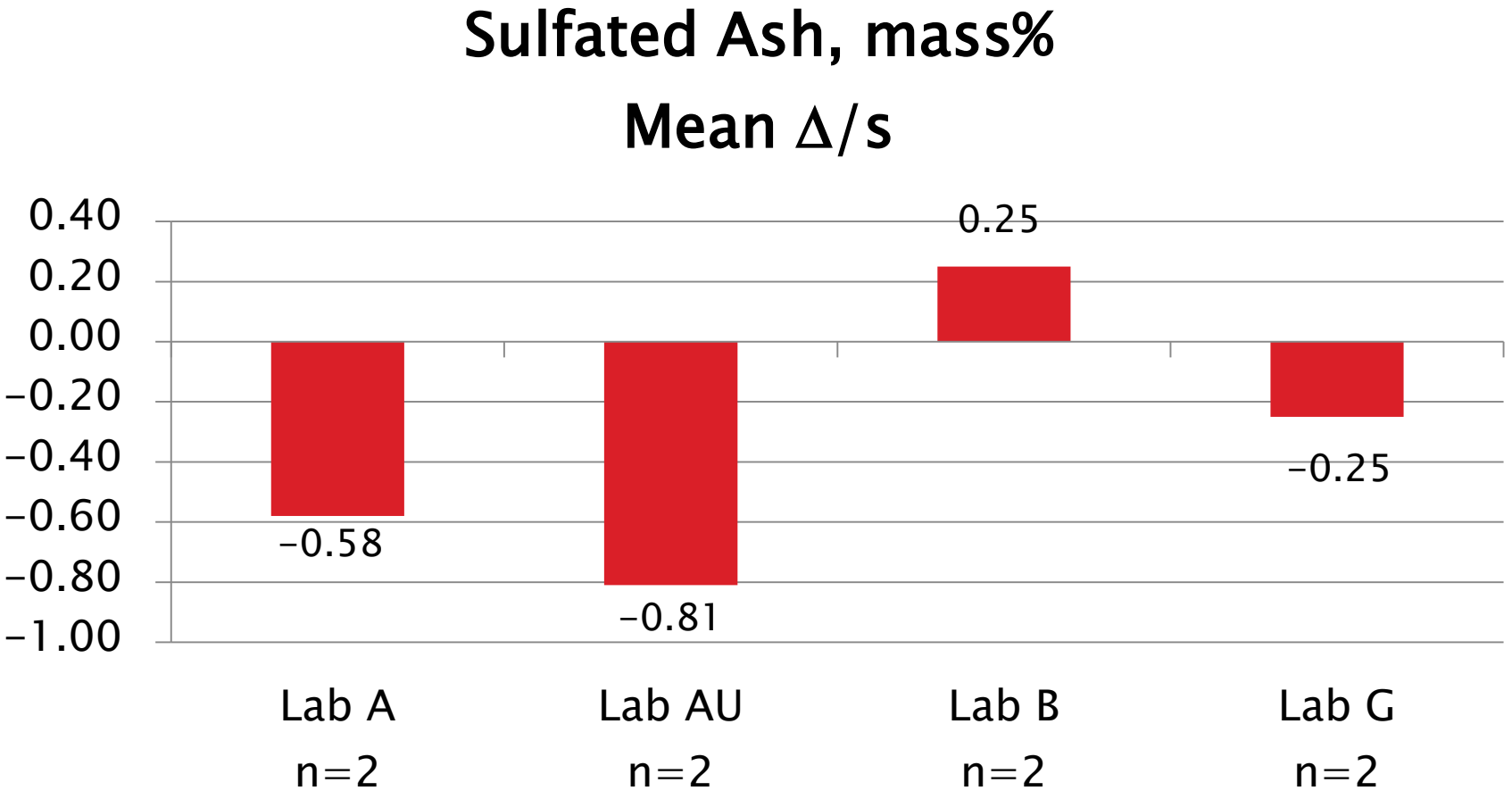


D874: Sulfated Ash

Current Period Severity Estimates by Lab
Sulfated Ash, mass%

	n	Mean Δ/s
Lab A	2	-0.58
Lab AU	2	-0.81
Lab B	2	0.25
Lab G	2	-0.25

D874: Sulfated Ash



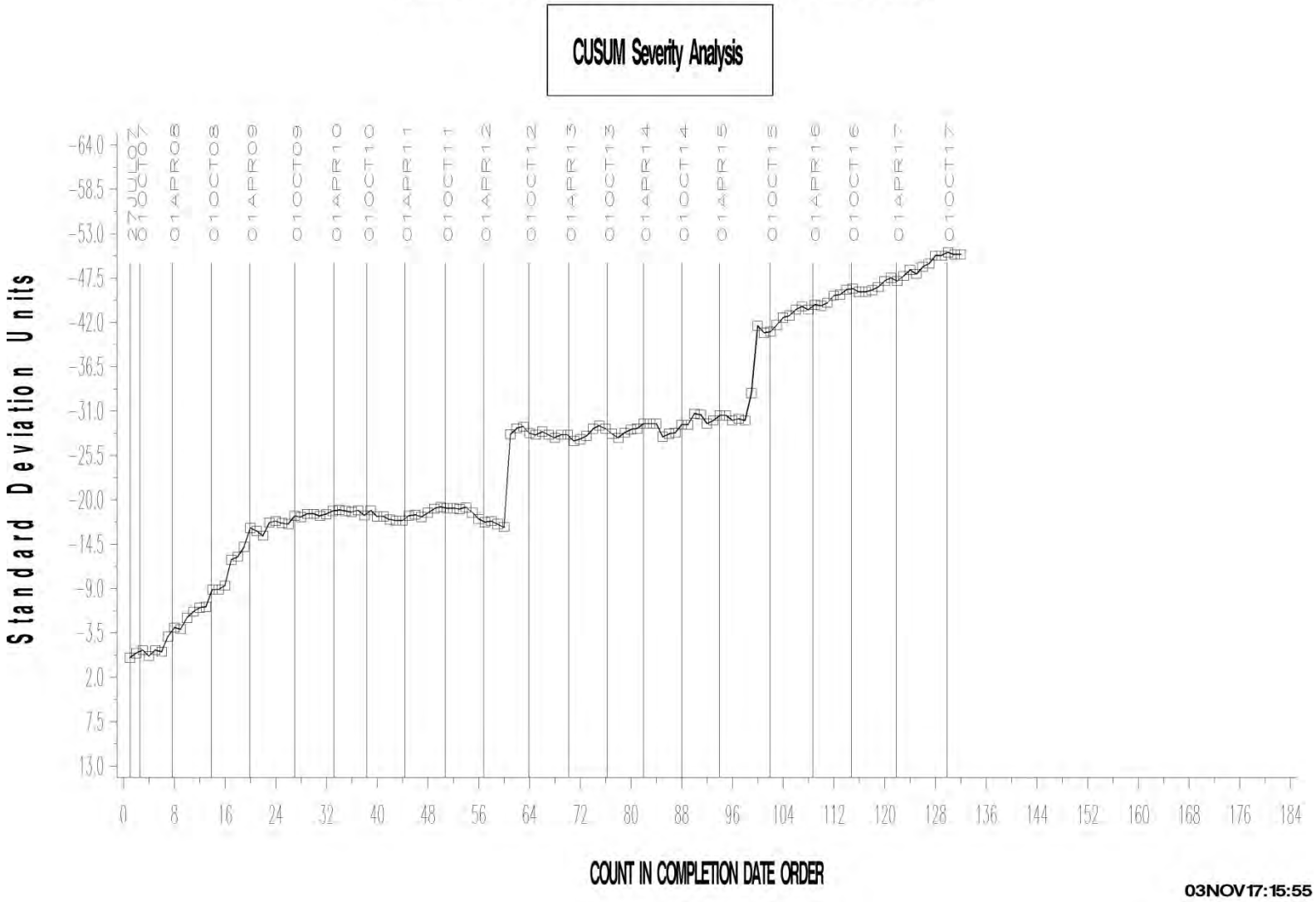
D874: Sulfated Ash

- Precision (Pooled s) is less precise the prior three periods
  - More precise than target precision

- Performance (Mean Δ/s) is -0.35 s mild

D874 INDUSTRY OPERATIONALLY VALID DATA

TEST SAMPLE PERCENT SULFATED ASH



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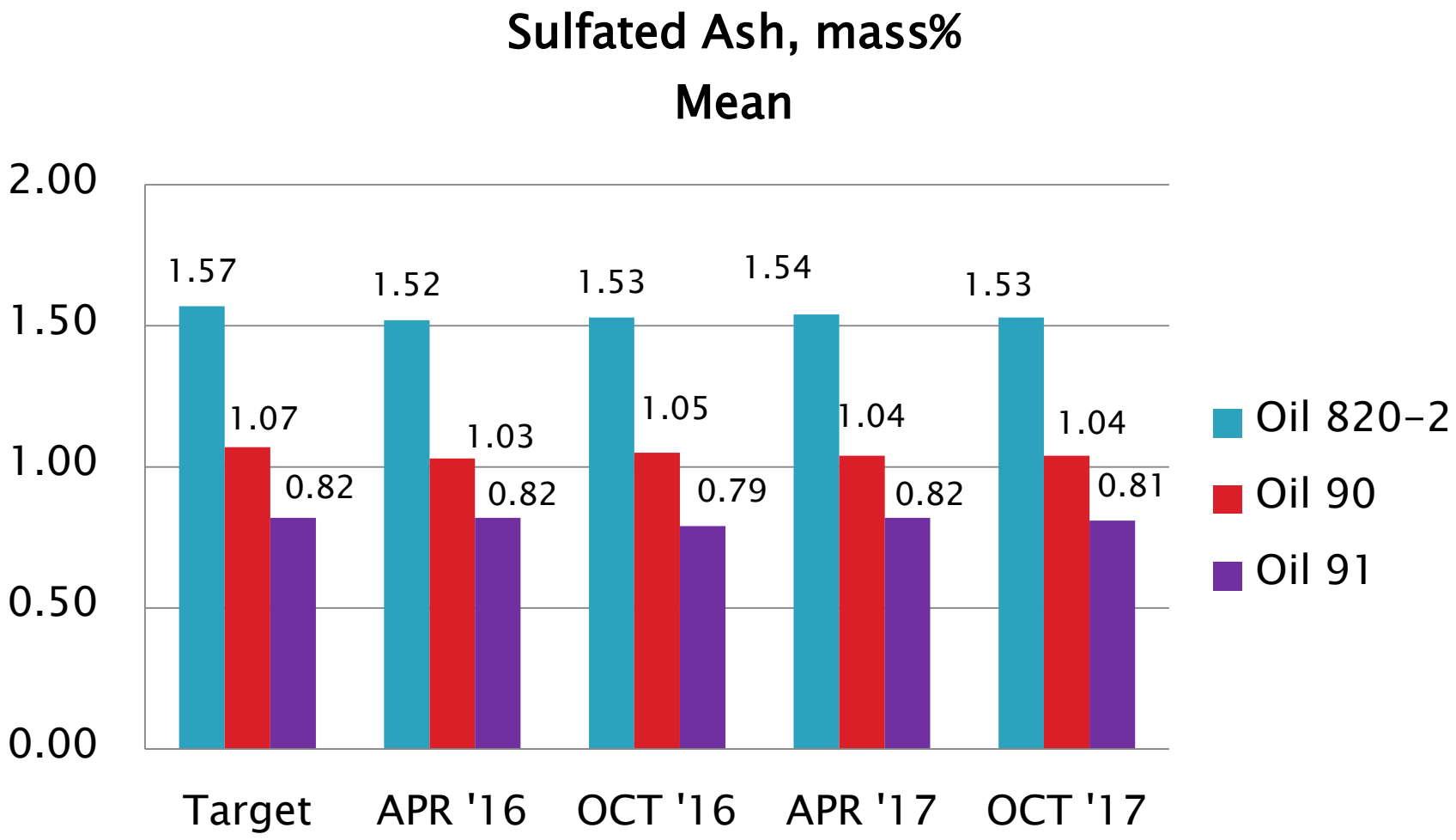
D874: Sulfated Ash

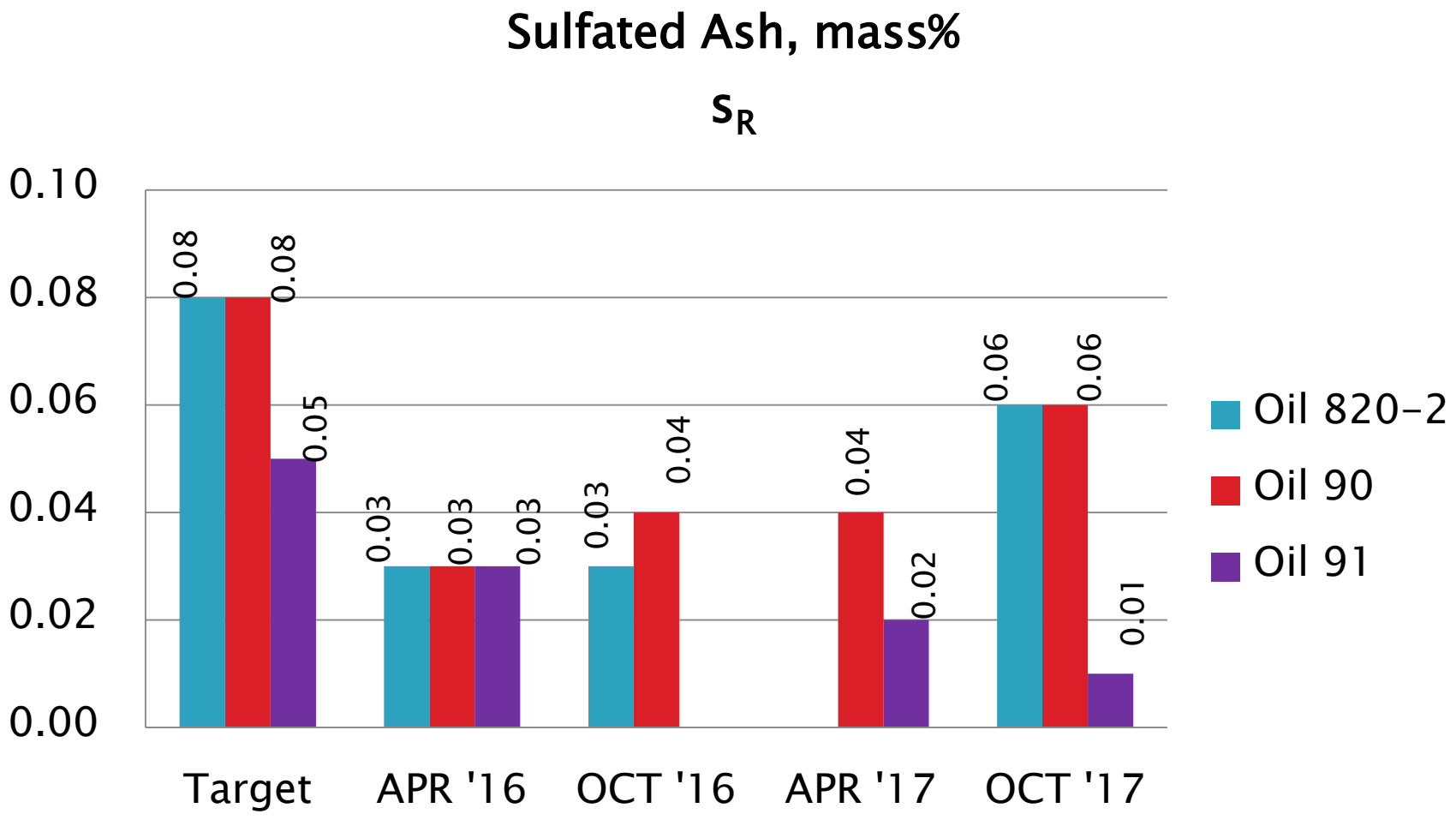
Performance by Oil
Sulfated Ash, mass%

	Targets			4/1/16 – 9/30/16				10/1/16 – 3/31/17				4/1/17 – 9/30/17			
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	0.03	-0.46	1	1.54	---	-0.38	3	1.53	0.06	-0.46
90	27	1.07	0.08	2	1.05	0.04	-0.25	2	1.04	0.04	-0.44	3	1.04	0.06	-0.33
91	27	0.82	0.05	1	0.79	---	-0.60	4	0.82	0.02	-0.05	2	0.81	0.01	-0.20

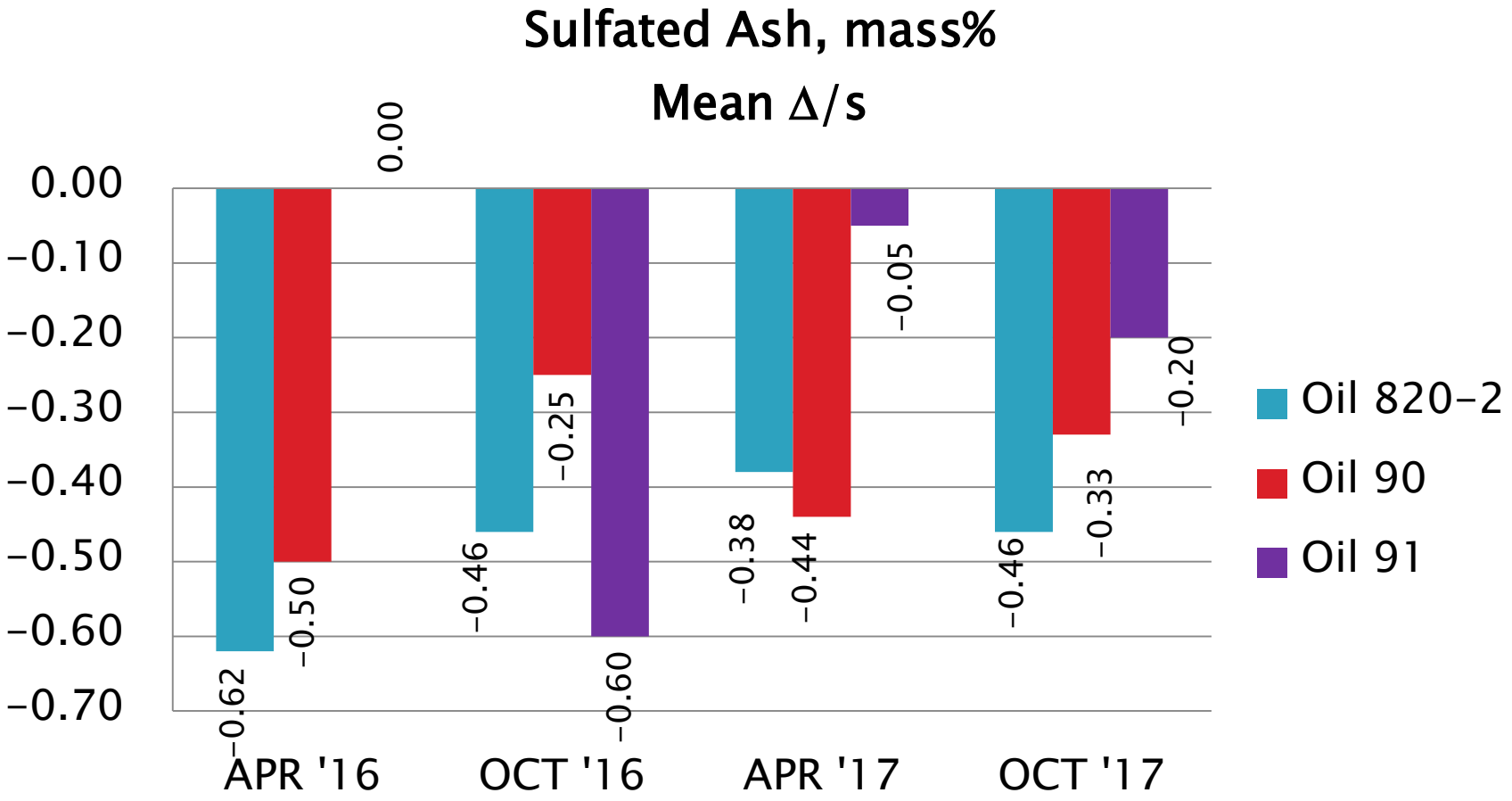
D874: Sulfated Ash



D874: Sulfated Ash



D874: Sulfated Ash



Return to Executive Summary

D7528: Oxidation by ROBO

Test Status	Validity Code	No. Tests
Acceptable Calibration Test	AC	84
Failed Calibration Test	OC	15
Operationally Invalidated by Lab	LC, XC	10
Operationally Invalidated After Initially Reported as Valid	RC	1
Rig Shakedown Runs	NN, XN	3
New Oil Screening Donated Runs	AG	1
Total		**114**

Number of Labs Reporting Data: 6
Fail Rate of Operationally Valid Tests: 15%

D7528: Oxidation by ROBO

Operationally Invalid Tests

- 4 tests heater or heater control failure (XC)
- 1 test wrong vacuum control valve setting (RC)
- 5 tests vacuum failure, vacuum or air leak (XC)
- 1 trap condenser coolant leak (XC)

Other Tests

- 3 tests rig shakedown runs on new rig (one aborted due to power failure) (NN, XN)
- 1 tests donated screener run on proposed replacement reference oil 434-2 (RR spans last period and this).

D7528: Oxidation by ROBO

Statistically Unacceptable Tests (OC)	No. Of Tests
Natural Log (MRV Viscosity) Mild	14
Natural Log (MRV Viscosity) Severe	1

- 10 tests mild on oil 435-1
- 1 test severe on oil 435-1
- 4 test mild on oil 434-2

- Two ROBO Technical memos were issued this period:
  - 17-023, June 6, 2017, Updated test method D7528-17
    - Missing IL 16-1 updates
  - 17-035, November 1, 2017, Updated test method D7528-17a
    - Includes IL 16-1 updates!
- ROBO Calibration Requirements were also updated
  - New version 20170713 (reference oil 434-2 added)

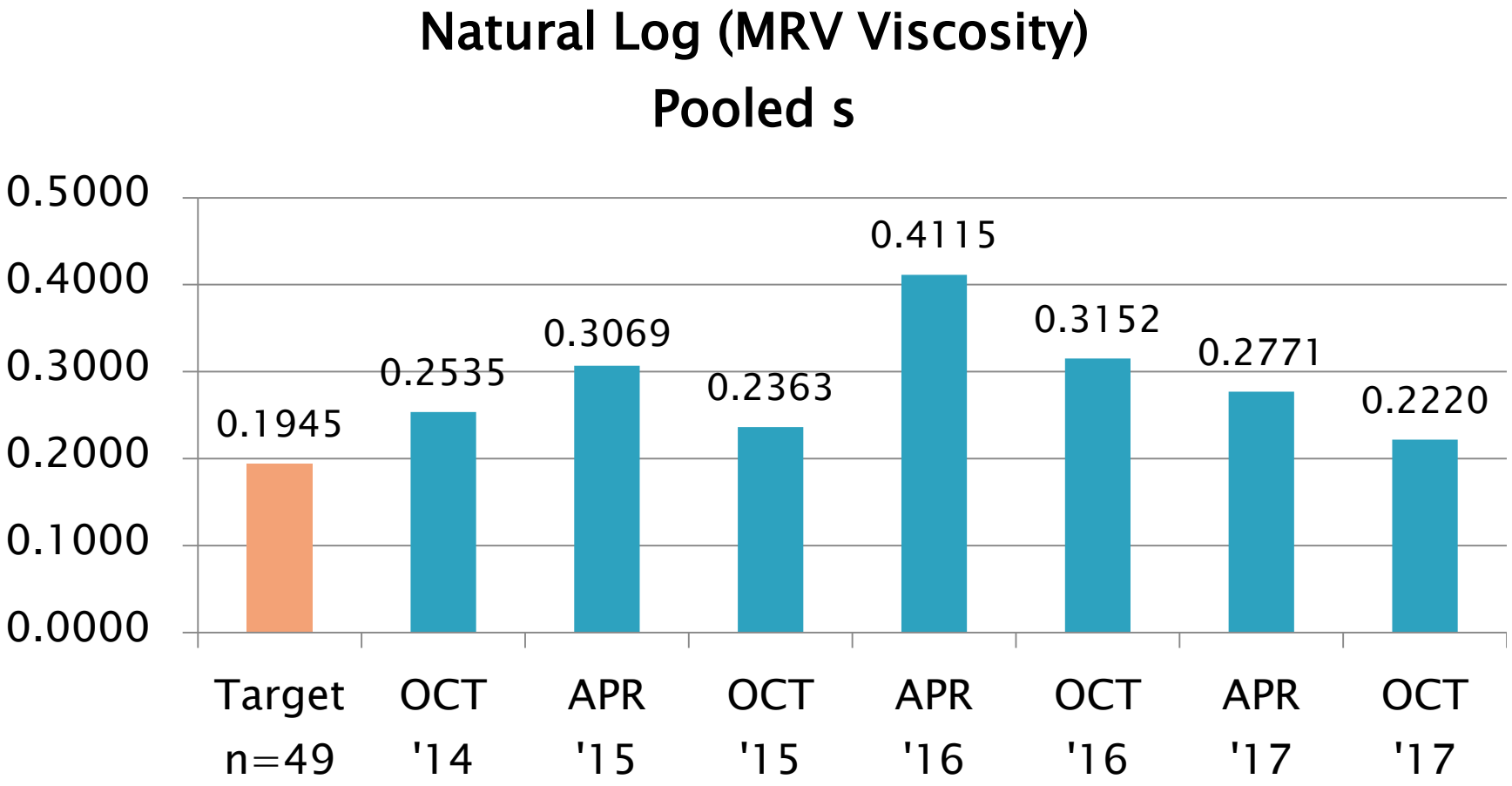
D7528: Oxidation by ROBO

Period Precision and Severity Estimates

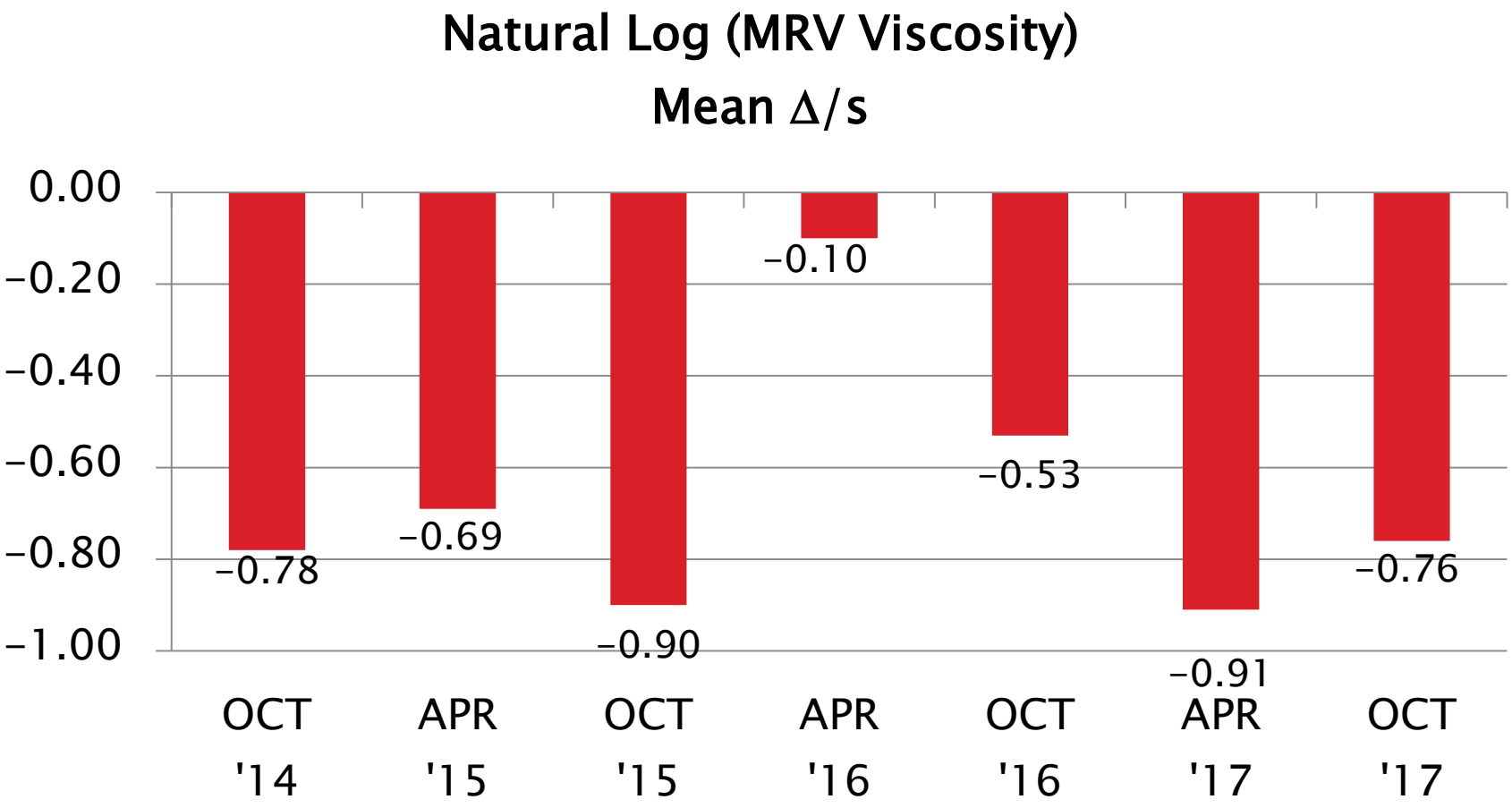
Natural Log (MRV Viscosity)	n	df	Pooled s	Mean Δ/s
Current Targets	49	46	0.1945	-----
4/1/14 through 9/30/14	83	80	0.2535	-0.78
10/1/14 through 3/31/15	97	94	0.3069	-0.69
4/1/15 through 9/30/15	85	82	0.2363	-0.90
10/1/15 through 3/31/16* 10/1/15 through 3/31/16*	92 91	89 88	0.4115 0.3661	-0.10 -0.20
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

*Period statistics with and without extreme result included

D7528: Oxidation by ROBO



D7528: Oxidation by ROBO

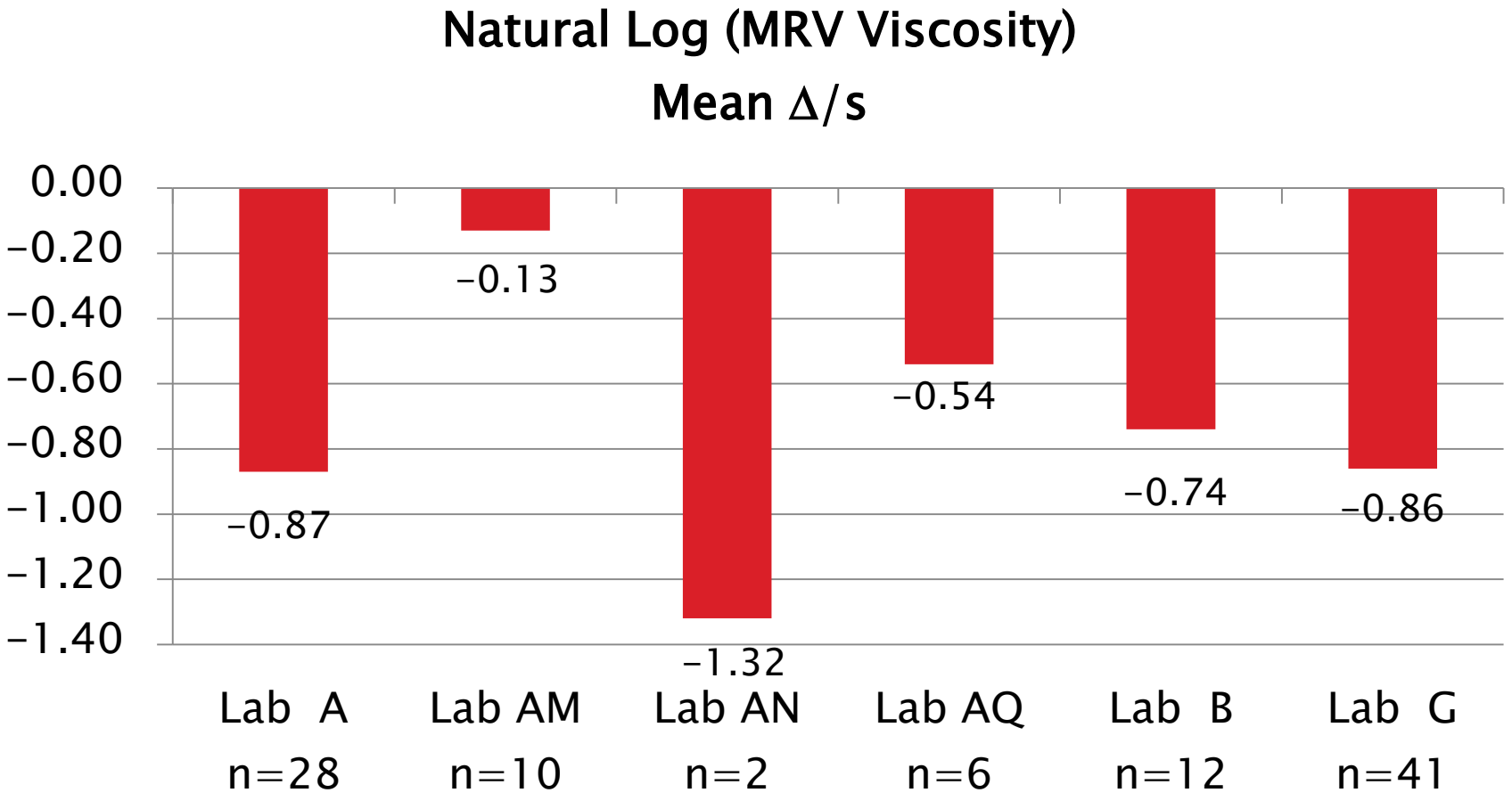


D7528: Oxidation by ROBO

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

	n	Mean Δ/s
Lab A	28	-0.87
Lab AM	10	-0.13
Lab AN	2	-1.32
Lab AQ	6	-0.54
Lab B	12	-0.74
Lab G	41	-0.86

D7528: Oxidation by ROBO



D7528: Oxidation by ROBO

- Precision (Pooled s) is more precise than all prior periods since at least October 2104.
  - But, continues to be less precise than target precision
- Performance (Mean Δ/s) is -0.76 s mild with all labs mild to some degree and all four oils performing overall mild
- Lab G, with, by far, the highest n size of any lab this period has a few issues of note:
  - Only three tests exceed 3 s (severe or mild) this period: (-3.8, 3.4, -3.5), but all are from Lab G, and each failing result is on a different rig.
  - Rig G6 has 4 failing OC runs this period (three mild and one severe; two consecutive fails), alternating with passing (AC) runs.
  - Rig G2 has 3 failing OC runs (all mild, two consecutive), alternating with passing (AC) runs.
  - These two rigs (G2 and G6) account for 7 of the 15 OC tests reported this period.

D7528: Oxidation by ROBO

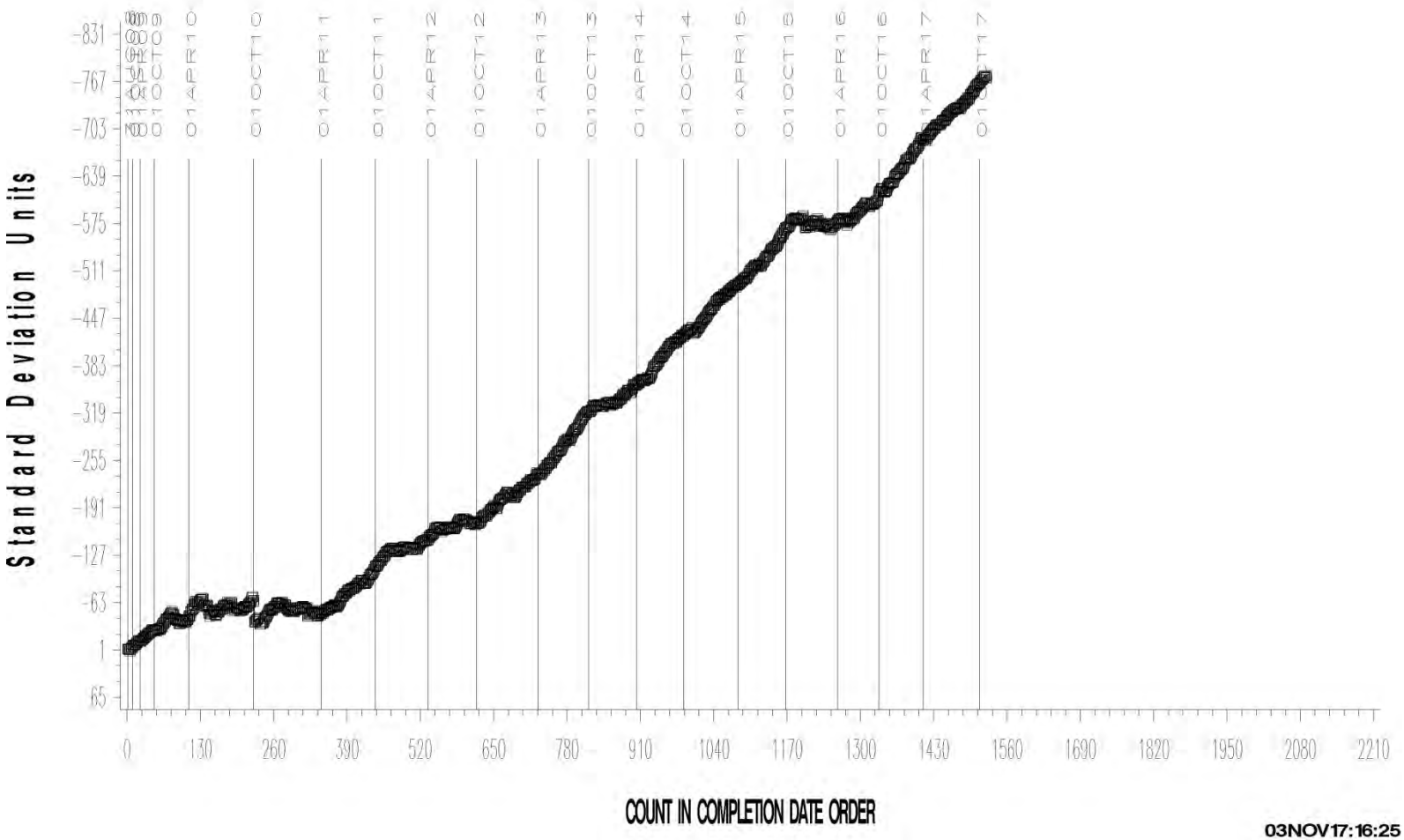
- Oil 434-1 is nearly depleted, Reblend 434-2 has been introduced with preliminary targets set by round robin.
  - 434-2 is running -1.34 s mild on nine tests, however targets were set with consideration of preserving (or not canceling out) the mild trend on oil 434-1, and the 434-2 performance reflects 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

CUSUM Severity Analysis



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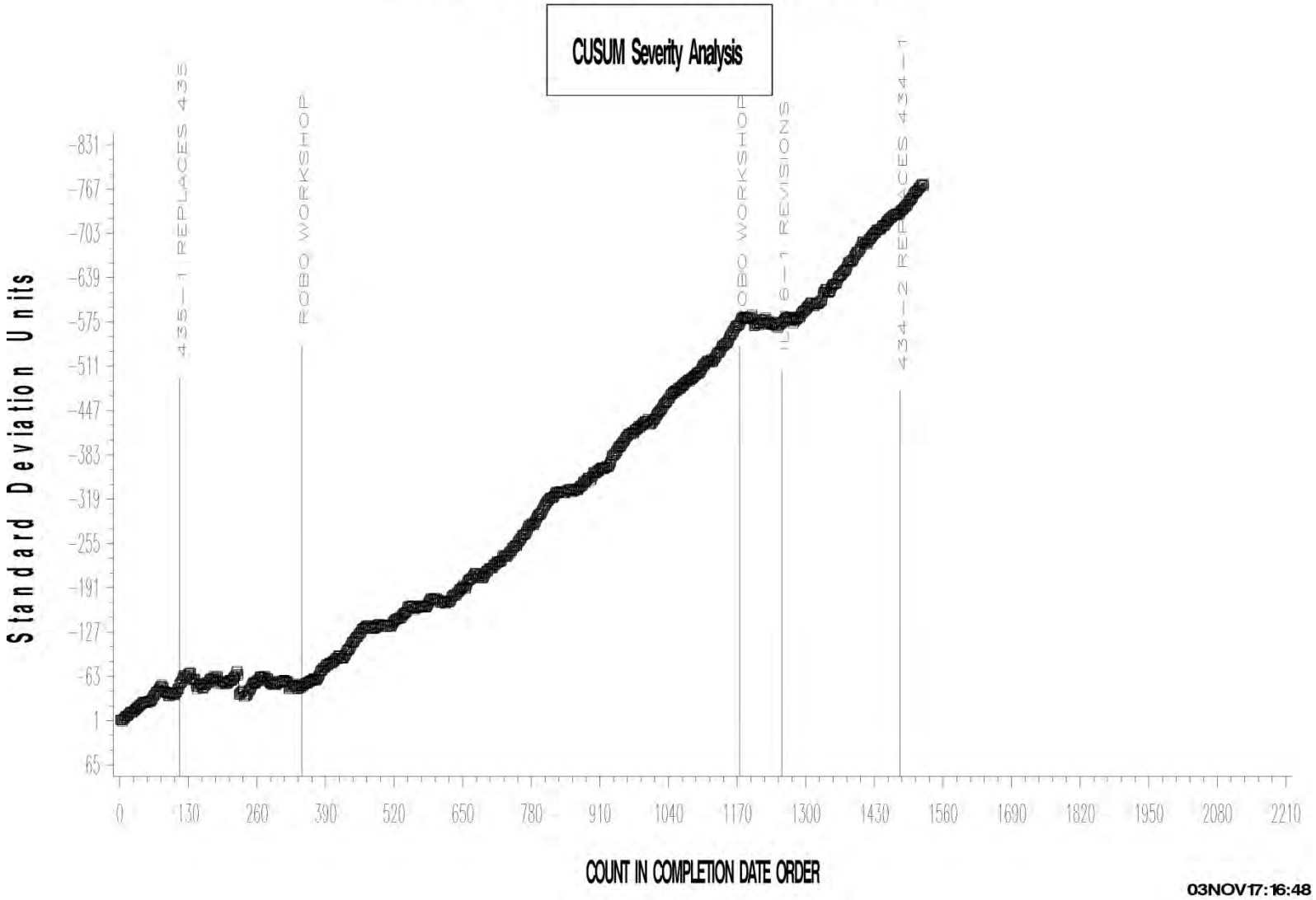
ROBO TEST INDUSTRY OPERATIONALLY VALID DATA

AGED OIL MRV APPARENT VISCOSITY



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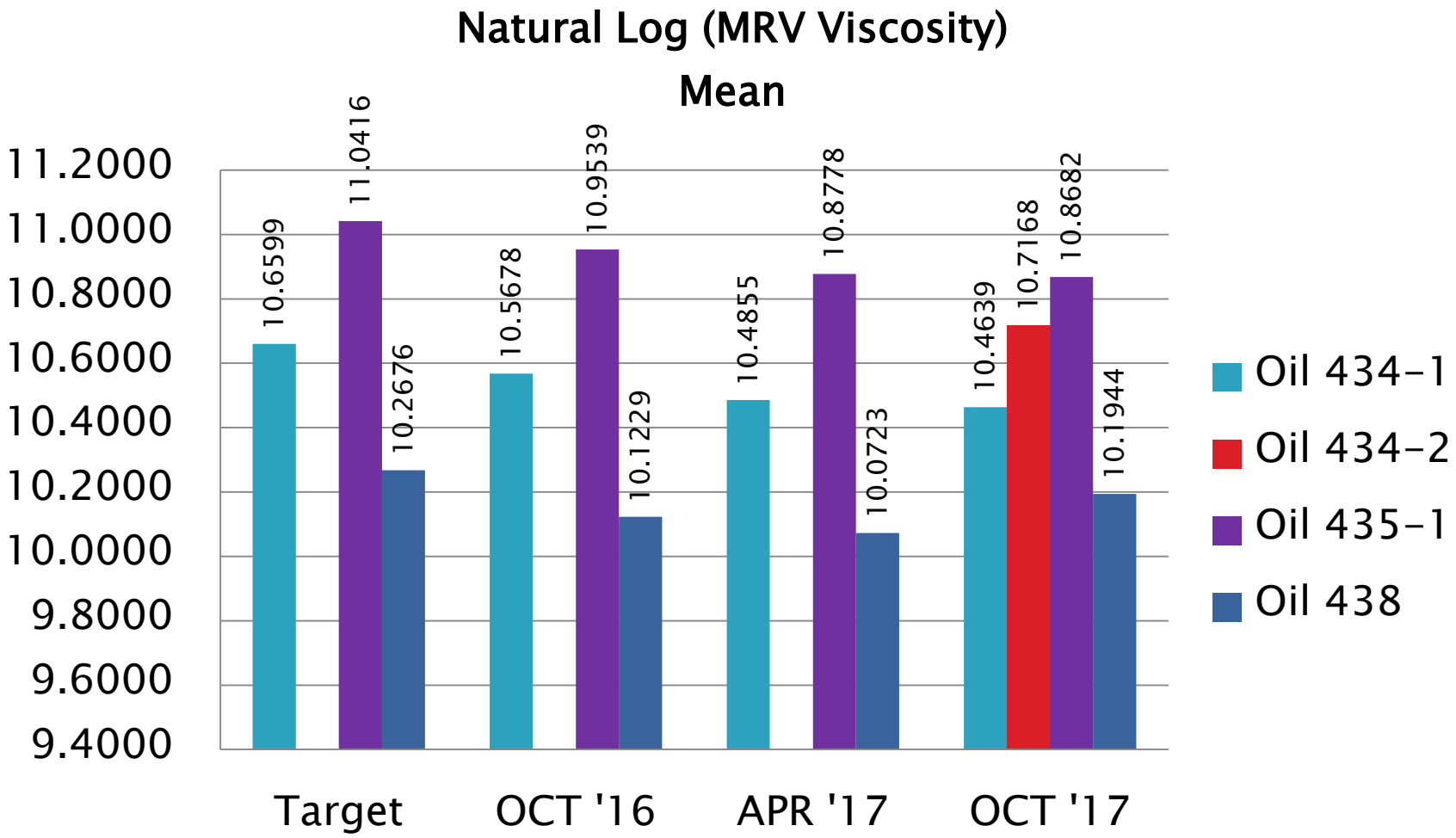
D7528: Oxidation by ROBO

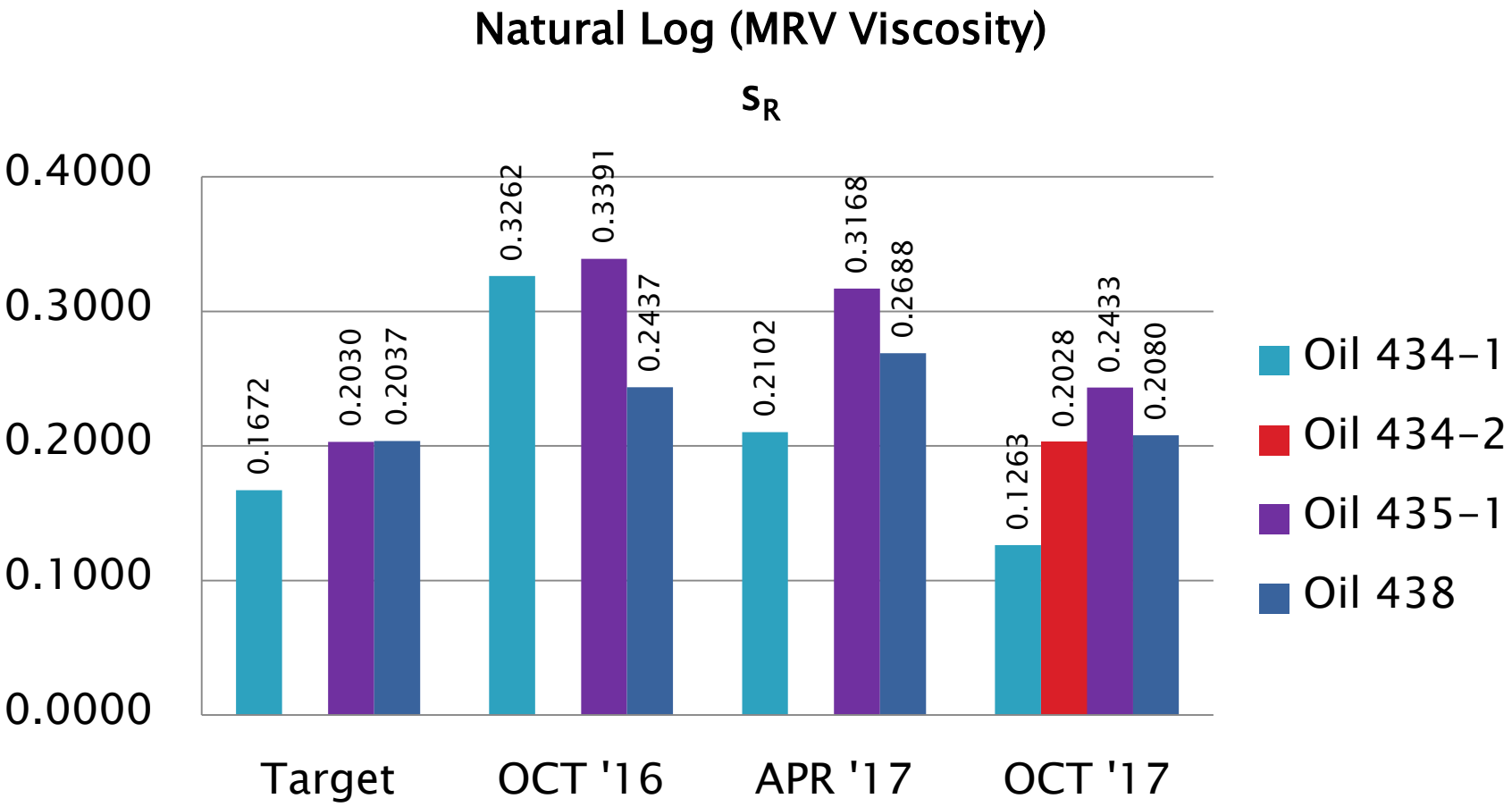
Performance by Oil
Natural Log (MRV Viscosity)

	Targets			4/1/16- 9/30/16				10/1/16 - 3/31/17				4/1/17 - 9/30/17			
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	20	10.5678	0.3262	-0.55	23	10.4855	0.2102	-1.04	8	10.4639	0.1263	-1.17
434-2	--	-----	-----	--	-----	-----	-----	--	-----	-----	-----	9	10.7168	0.2028	-1.34
435-1	22	11.0416	0.2030	36	10.9539	0.3391	-0.43	38	10.8778	0.3168	-0.81	50	10.8682	0.2433	-0.85
438	14	10.2676	0.2037	18	10.1229	0.2437	-0.71	17	10.0723	0.2688	-0.96	32	10.1944	0.2080	-0.36

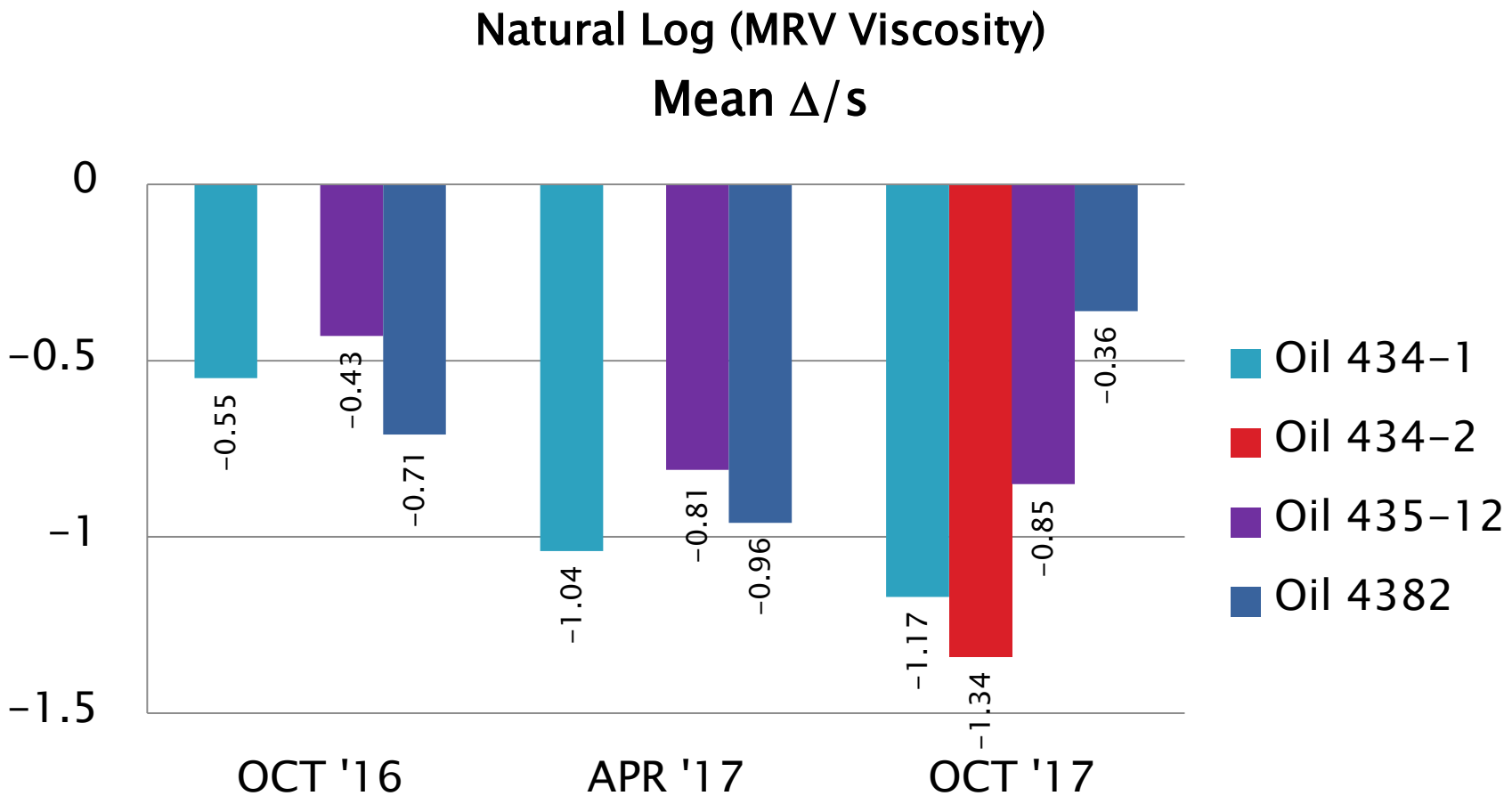
D7528: Oxidation by ROBO



D7528: Oxidation by ROBO



D7528: Oxidation by ROBO



Return to Executive Summary

Non-monitored Bench Tests

- **D6922 Homogeneity and Miscibility**
  - The TMC distributes six D6922 reference oils.
  - The TMC does not collect reference data or monitor test results for this test at this time.
  - **Oils rec'd by TMC 2002 – 2003**
    - **Formulations are at least 14 years old now**
    - **Should section or panel consider updating?**

- **D7563 Emulsification**
  - The TMC distributes two D7563 reference oils.
  - The TMC does not collect reference data or monitor test results for this test at this time.

Reference Oil Inventory

- As of 9/30/2017

Reference Oil Inventory

D5800, D6417, GI

Oil	Year Rec'd By TMC	Tests	TMC Inventory, gallons	Gallons Shipped last 12 months
VOLC12	2013	D5800	42.3	5.0
VOLD12	2013	D5800	44.7	4.9
VOLE12	2013	D5800	43.5	5.0
VOLD14	2014	D5800QC	165.0	117.9
52	1995	D6417	59.1	0.0
55	1995	D6417	66.2	0.0
58	1998	D6417, GI	116.0	0.4
62	1996	GI	0.5	0.4
1009*	2002	GI	40.4	3.7

*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	107.9	0.5
434	2003	MTEOS	2.4	0.5
75	2010	TEOST	2.0	1.2
75-1	2016	TEOST (proposed)	9.3	0.7
435-2*	2010	TEOST	43.2	0.1
~~434-1~~	~~2008~~	~~ROBO~~	~~Depleted~~	~~----~~
434-2*	2014	ROBO	25.8	3.6
435-1	2008	ROBO	439.7	11.4
438*	2003	ROBO	5.2	4.8

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

Reference Oil Inventory

D6082 & D874

Oil	Year Rec'd By TMC	Tests	TMC Inventory, gallons	Gallons Shipped last 12 months
1007	1998	D6082	35 samples	30 samples
66	2002	D6082	84.1	2.8
820-2	2001	D874	10.1	0.1
90*	2005	D874	20.1	4.3
91	2006	D874	3.9	0.1

*Oil 90 is also used as a D874 QC Check Oil

Reference Oil Inventory

D6922 Homogeneity & Miscibility Oils

Oil	Year Rec'd By TMC	Tests	TMC Inventory, gallons	Gallons Shipped last 12 months
HMA	2002	H&M	117.5	10.3
HMB	2002	H&M	121.0	10.3
HMC	2003	H&M	110.5	10.3
HMD	2002	H&M	115.2	10.3
HME	2002	H&M	102.3	10.3
HMF	2002	H&M	124	10.3

Reference Oil Inventory

D7563 Emulsion Retention Oils

Oil	Year Rec'd By TMC	Tests	TMC Inventory, gallons	Gallons Shipped last 12 months
EM2	2011	Emulsion	6.9	1.1
EM2-1	2011	Emulsion	25.0	0.0
EM5	2011	Emulsion	6.9	1.1
EM5-1	2011	Emulsion	25.0	0.0

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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