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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)

April 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 0.77 s severe
  - By far the most severe performance since at least 2014
  - Three labs this period performing more than 1 s severe
  - Those three labs are consistently severe, even on different oils
    - And, Lab A severe on two different instruments.
- Lab D was a new lab/instrument last period driving overall severe performance, but is on target this period.
- CUSUM plot shows overall much more severe performance this period.

B0.07 Bench Testing
Executive Summary

- D5800 (Volatility by Noack)
- A new LTMS monitoring system was implemented just after the start of this report period, which now includes severity adjustments by instrument. Six tests were reported under the prior Shewhart severity only system, and 137 under the new LTMS.
- Reported tests have increased from 65 total last period to 143 tests this period, mostly due to a reduced calibration period and new two-test calibration requirements.
- Precision (Pooled s), at 0.70 mass %, is comparable to the new target LTMS pooled precision of 0.73 mass %.
- Performance (Mean Δ/s) is 0.53 s severe using the updated LTMS target precision (now a common 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) dropped to 5% compared to 26% last period 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 monthly by LTMS calibration evaluation.

B0.07 Bench Testing Executive Summary

- D5133 (Gelation Index)
- Precision (Pooled s) is more precise than prior period
  - More precise than target precision
  - Precision on oil 58 is worsening over past three periods.
- Performance (Mean Δ/s) is -0.25 s mild
  - Three labs performing 1 s or more severe or mild.
  - Oil 58 performing 1 s severe, while oil 1009 is nearly 1 s mild.
- Fail rate of operationally valid tests is up to 26%, compared to 6% last period, with two rigs having consecutive failing runs, and another rig with two fails during the period, but not consecutive. All subsequently passed calibration.
  - Six of the 7 OC fails were on borderline oil 1009.
- With non-gelling oil 58 performing at 1 s severe, and low gelling oil 1009 nearly -1 s mild, the overall period mean GI performances on those oils do not show adequate discrimination over the report period.
- Reference oil 62 inventory is down to 0.7 gallons remaining (with 0.35 gallon shipped prior 12 months).

B0.07 Bench Testing Executive Summary

- D6335 (TEOST-33C)

- Precision (Pooled s) is more precise than prior period
  - Less precise than target precision
  - Severe oil 75 performance continues to be imprecise

- Performance (Mean Δ/s) is -0.14 s mild
  - Improvement follows two very mild and imprecise periods
    - Instrument G2 having problems for last three periods (biasing results past two periods, but mostly shakedown runs this period before successfully calibrating)

- All tests this period report using Rod Batch M

B0.07 Bench Testing Executive Summary

- D7097 (MHT-4 TEOST)
- Instrument J2 has four consecutive failing two-test sequence calibration attempts with four failing (OC) runs, two on each oil. Overall statistics in this report are shown with these eight tests included and excluded; the lab has not yet successfully re-calibrated the instrument.
  - Under prior calibration requirements, this instrument likely would have passed calibration on just one passing run. The new two-test requirements have appropriately flagged this instrument as statistically problematic.
- New end cap flask seals were added this period by test method update
- Precision (Pooled s) is somewhat better to prior period (with J2 excluded)
  - Remains less precise than target precision
- Performance (Mean Δ/s) is on target (-0.03 s) (with J2 excluded)
- All operationally valid tests this period report using Rod Batch L or M
- All operationally valid calibration tests this period report using Catalyst Batch 14AA (n=3) or 15AA (n=102)

B0.07 Bench Testing Executive Summary

- D7097 (MHT-4 TEOST) continued

- CUSUM severity plot shows some leveling the past two periods (except for a single very severe result)
  - However, lab performance differences persist

- Precision on oil 434 has improved compared to last period, but still not near to target precision, while precision on oil 432 is again much worse.

- Catalyst batch 15AA appears to have less of a bias on test results than prior catalyst batches, especially on severe oil 432

B0.07 Bench Testing Executive Summary

- D6082 (High Temperature Foam)
- Foam Tendency Precision (Pooled s) is comparable to prior period
  - Comparable to target precision
- Performance (Mean Δ/s) is -0.62 s mild
  - Most mild period since at least October 2013
  - Attributable mostly to Lab B (two instruments, six tests, all between -1.3 and -1.9 s mild)
- No non-zero occurrences of Foam Stability (on operationally valid tests)
- All but one operationally valid discrimination runs demonstrated acceptable discrimination, the one fail passed on retest.

- 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 the last two periods
  - Continues to be less precise than target precision
  - Seven tests on various rigs are between 3 and 5 s mild or severe this period (rig A1 @ 3.4 s, A1 @ -3.5 s, AN2A @ -3.9 s, AQ2 @ -4.5 s, G4 @ 4.4 s, G4 @ -3.3 s, G7 @ -3.2 s)
  - Rig G4 had 3 OC failing runs alternating with 3 AC passing runs this period
- Performance (Mean Δ/s) is -0.91 s mild with all labs mild and all three oils performing more than -0.8 s mild

B0.07 Bench Testing Executive Summary

- D7528 (ROBO) continued
- Precision on oil 434-1 has improved somewhat, but 435-1 continues to be especially imprecise

- 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.

- Oil 434-1 is nearly depleted, a round robin has been started on proposed replacement oil 434-2.
  - **There is no longer enough 434-1 to meet the current calibration or pre-calibration shakedown requirements.**

Calibrated Labs and Stands*

Test	Labs	Stands
D6417	6	7
D5800	10	25
D5133 (GI)	7	8
D6335 (TEOST)	6	9
D7097 (MTEOS)	10	40
D6082	5	6
D874	3	--
D7528 (ROBO)	5	16

*As of 3/31/2017

D02.B0.07
TMC Monitored Tests

- October 1, 2016 –
  March 31, 2017

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D6417: Estimation of Engine Oil Volatility by Capillary GC

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

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 technical memos issued this period for D6417.

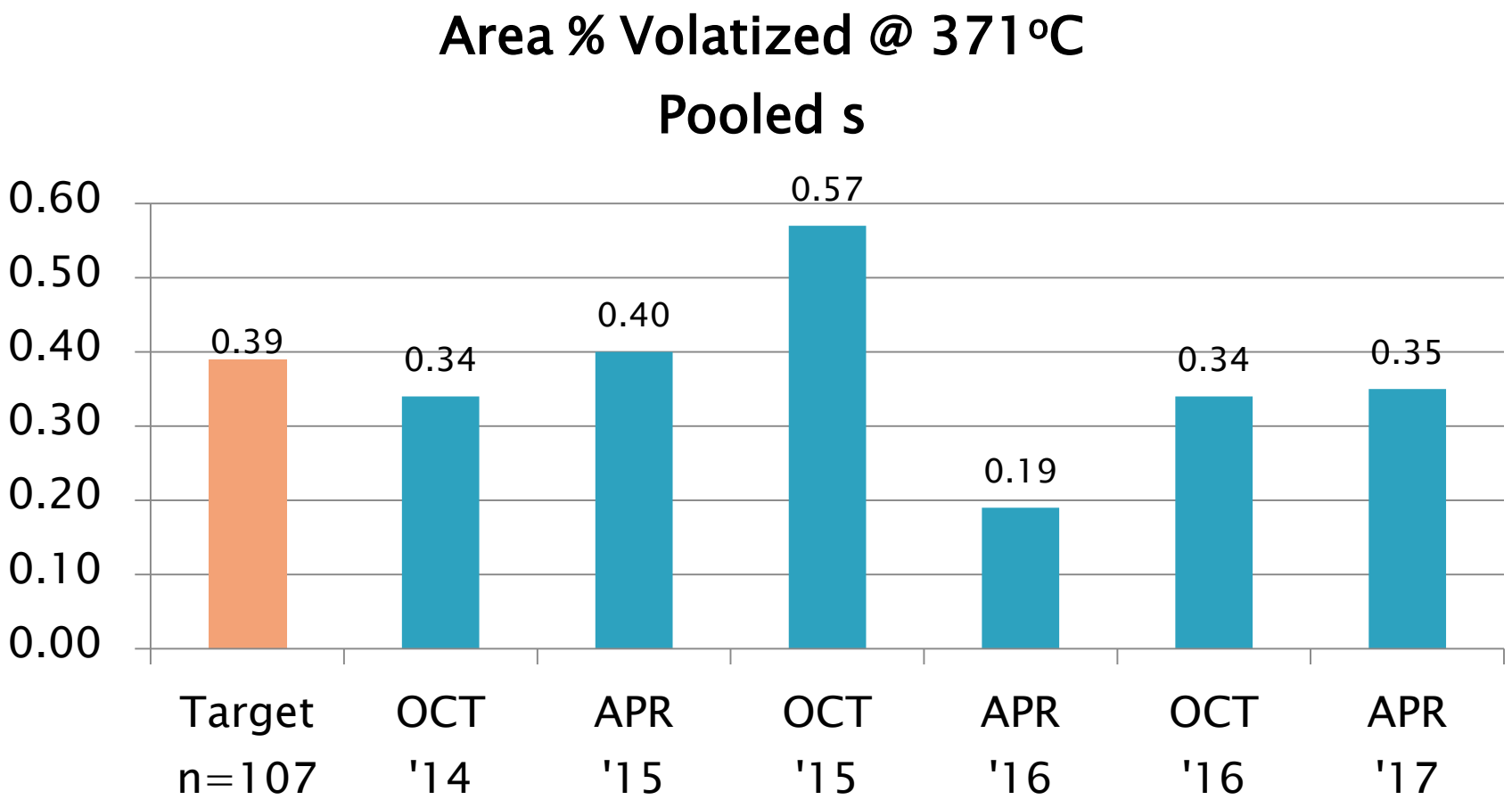
D6417: Estimation of Engine Oil Volatility by Capillary GC

Period Precision and Severity Estimates

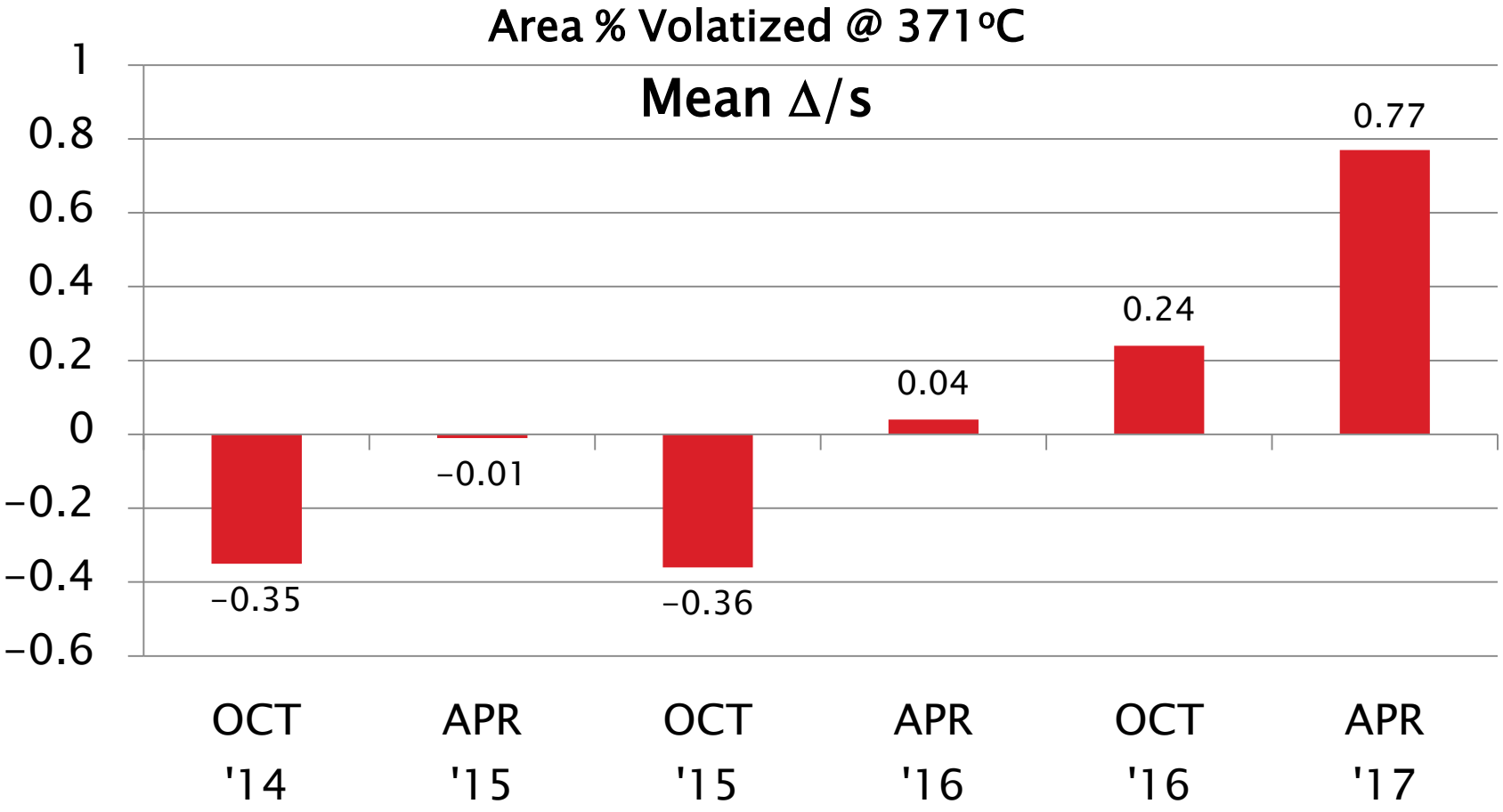
Area % Volatized @ 371°C	n	df	Pooled s	Mean Δ/s
Initial Selected Oils from RR	54	51	0.39	-----
4/1/14 through 9/30/14	15	12	0.34	-0.35
10/1/14 through 3/31/15	14	11	0.40	-0.01
4/1/15 through 9/30/15*	16	13	0.57	-0.36
4/1/15 through 9/30/15*	15	12	0.42	-0.04
10/1/15 through 3/31/16	13	10	0.19	0.04
4/1/16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

*Extreme OC result included and excluded

D6417 Precision Estimates



D6417 Severity Estimates

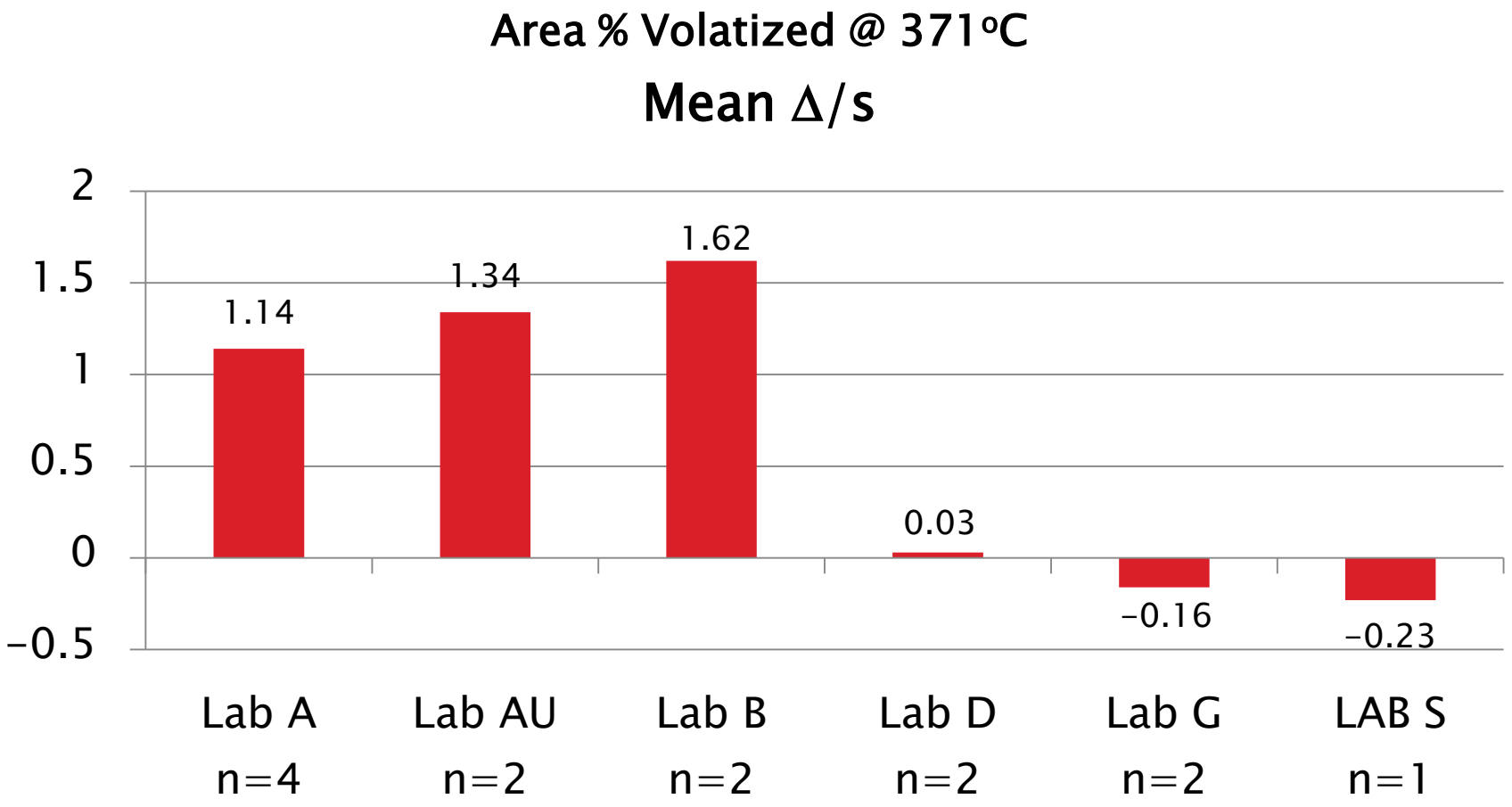


D6417: Estimation of Engine Oil Volatility by Capillary GC

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

	n	Mean Δ/s
Lab A	4	1.14
Lab AU	2	1.34
Lab B	2	1.62
Lab D	2	0.03
Lab G	2	-0.16
Lab S	1	-0.23

D6417 Lab Severity Estimates



D6417: Estimation of Engine Oil Volatility by Capillary GC

- Precision (Pooled s) is comparable to prior period
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- Performance (Mean Δ/s) is 0.77 s severe
  - By far the most severe performance since at least 2014
  - Three labs this period performing more than 1 s severe
  - Those three labs are consistently severe, even on different oils
    - And, Lab A severe on two different instruments.
- Lab D was a new lab/instrument last period driving overall severe performance, but is on target this period.
- CUSUM plot shows overall much more severe performance this period.

D6417 VOLATILITY BY GC INDUSTRY OPERATIONALLY VALID DATA

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SAMPLE AREA % VOLATIZED

CUSUM Severity Analysis

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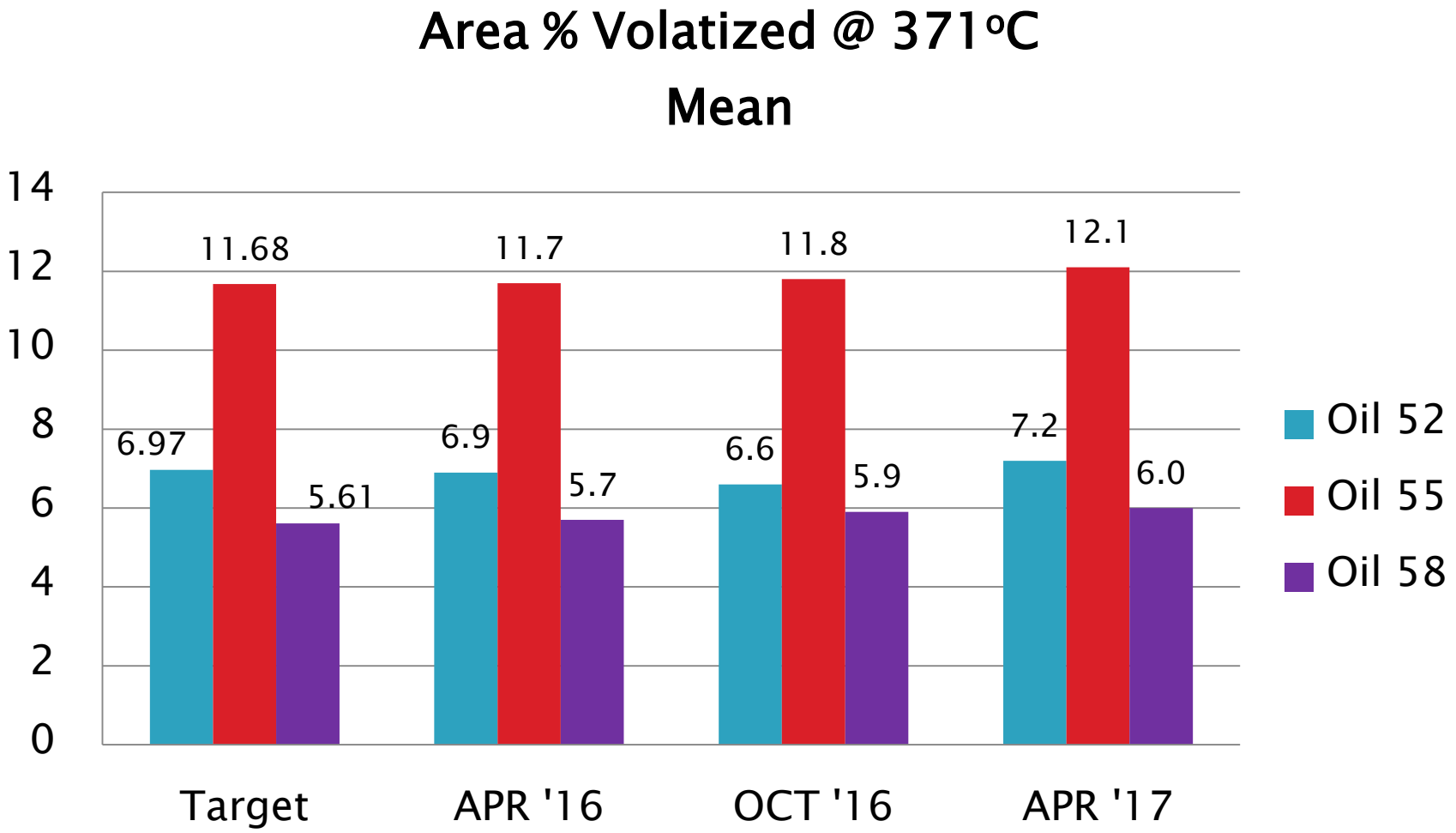
D6417: Estimation of Engine Oil Volatility by Capillary GC

Area % Volatized @ 371°C
Performance by Oil

	Targets			10/1/15 - 3/31/16				4/1/16 - 9/30/16				10/1/16 - 3/31/17			
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	4	6.9	0.24	-0.23	2	6.6	0.35	-1.03	6	7.2	0.28	0.63
55	18	11.68	0.51	5	11.7	0.15	0.12	4	11.8	0.47	0.14	5	12.1	0.44	0.78
58	18	5.61	0.30	4	5.7	0.19	0.22	5	5.9	0.18	0.83	2	6.0	0.21	1.13

D6417 Performance by Oil



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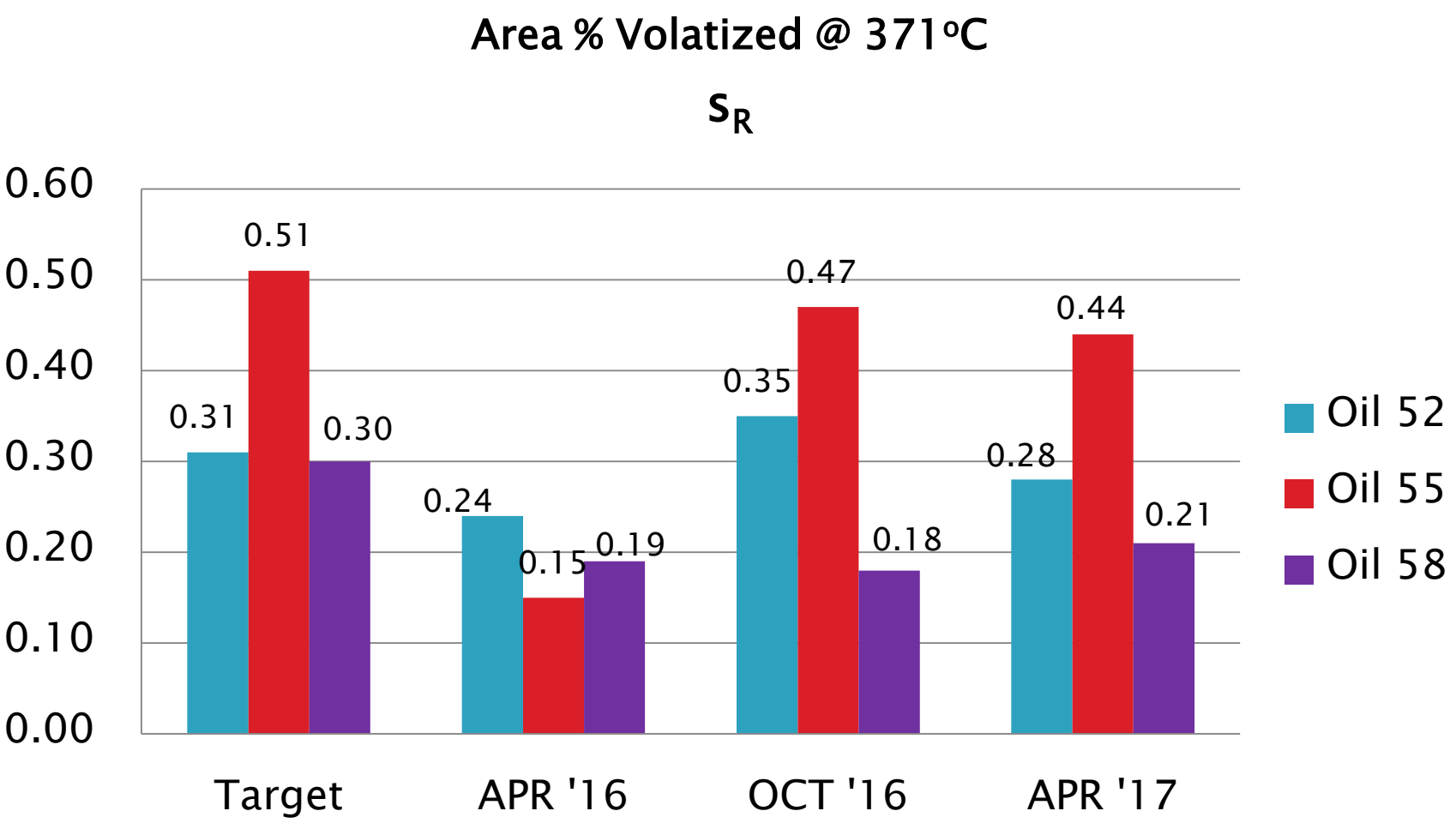
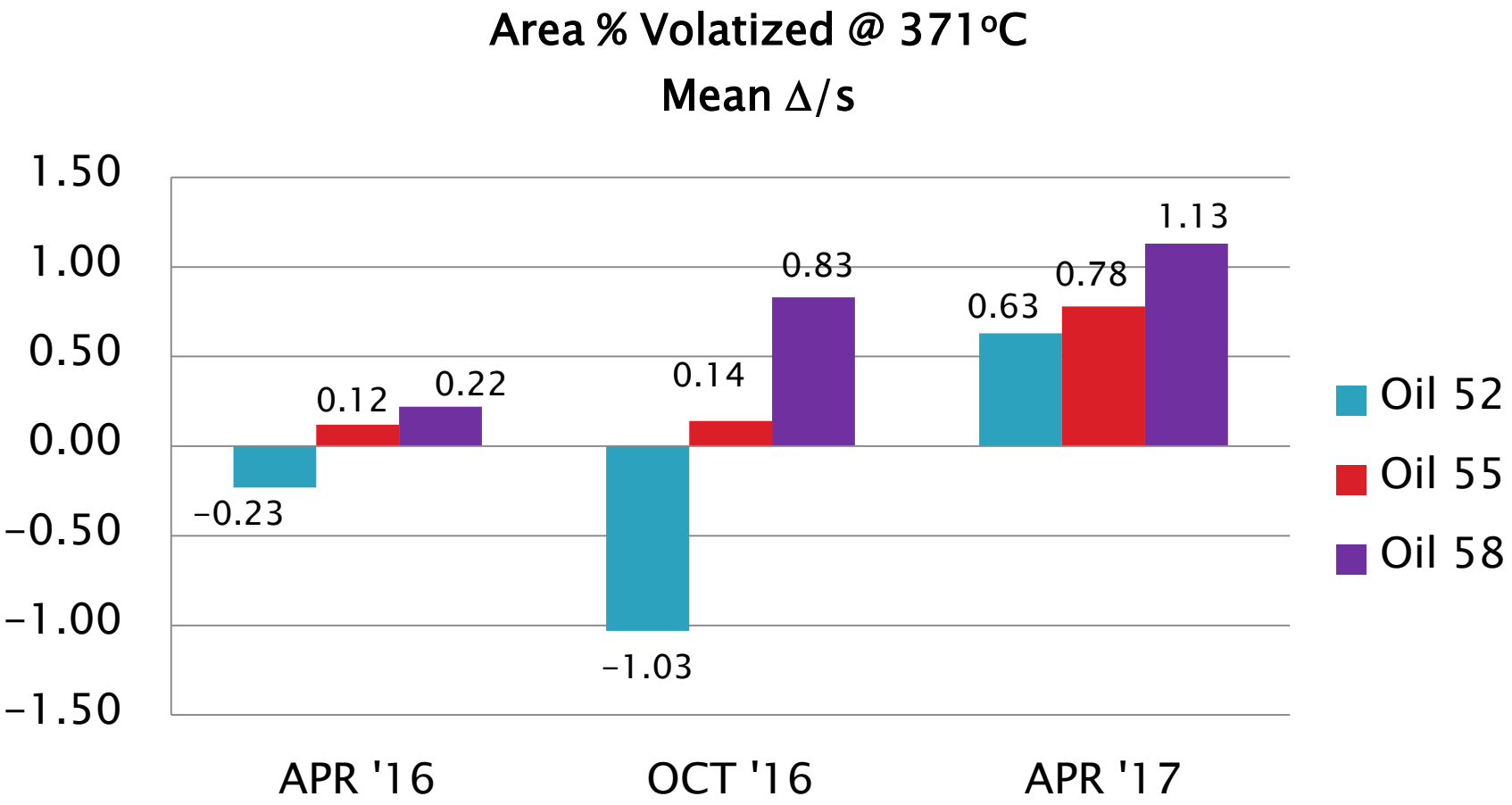
D6417 Performance by Oil



D6417 Performance by Oil



Return to Executive Summary

D5800: Evaporation Loss of Lubricating Oil by Noack Method

Test Status	Validity Code	No. Tests
Acceptable Calibration Test	AC	129
Failed Calibration Test	OC	7
Operationally Invalidated by Lab	LC, XC	0
Operationally Invalidated After Initially Reported as Valid	RC	0
Excluded from Statistics (New Rig)	MC	6
Non-Blind Instrument Shakedown	NN	1
Total		**143**

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
Evaporation Loss Severe (Non-LTMS)	2
Ei Level 3 Precision Alarm Mild	2
Ei Level 3 Precision Alarm Severe	3
Zi Level 2 Severity Severe	1

- Six tests were reported this period under prior non-LTMS Shewhart bands evaluation; 2 failed severe.
- One test triggered both Ei L3 severe and Zi L2 severe alarms.
- Six tests excluded from statistics (MC) because lab had not demonstrated a passing run on new rig; rig eventually calibrated.
- One shakedown requested to evaluate a rig after four consecutive failing runs under non-LTMS system. Rig calibrated on fifth try under the new LTMS system (with a severity adjustment).

D5800: Evaporation Loss of Lubricating Oil by Noack Method

- There were two technical updates issued last report period but became effective this period:
  - Report Packet Revision Notice D5800-20160919 Effective October 19, 2016
  - Memo 16-029, September 19, 2016, New D5800 Calibration Monitoring Requirements Effective October 19, 2016

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	-----
10/1/13 through 3/31/14	38	34	0.59	0.37
4/1/14 through 9/30/14	55	52	1.04	0.38
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

*Extreme OC result included and excluded

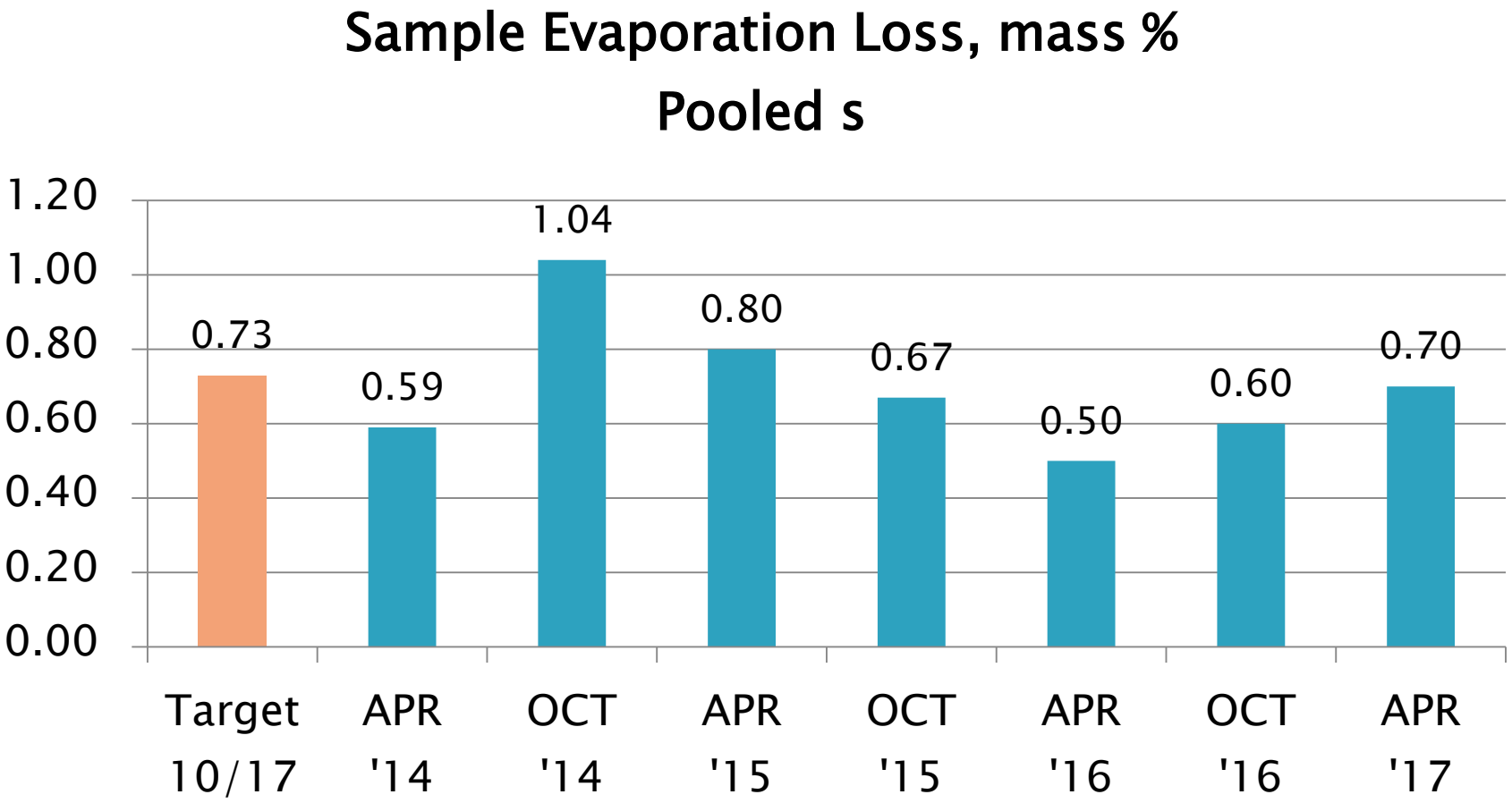
D5800: Evaporation Loss of Lubricating Oil by Noack Method

Performance Comparison by Procedure & Model
Sample Evaporation Loss, Mass %

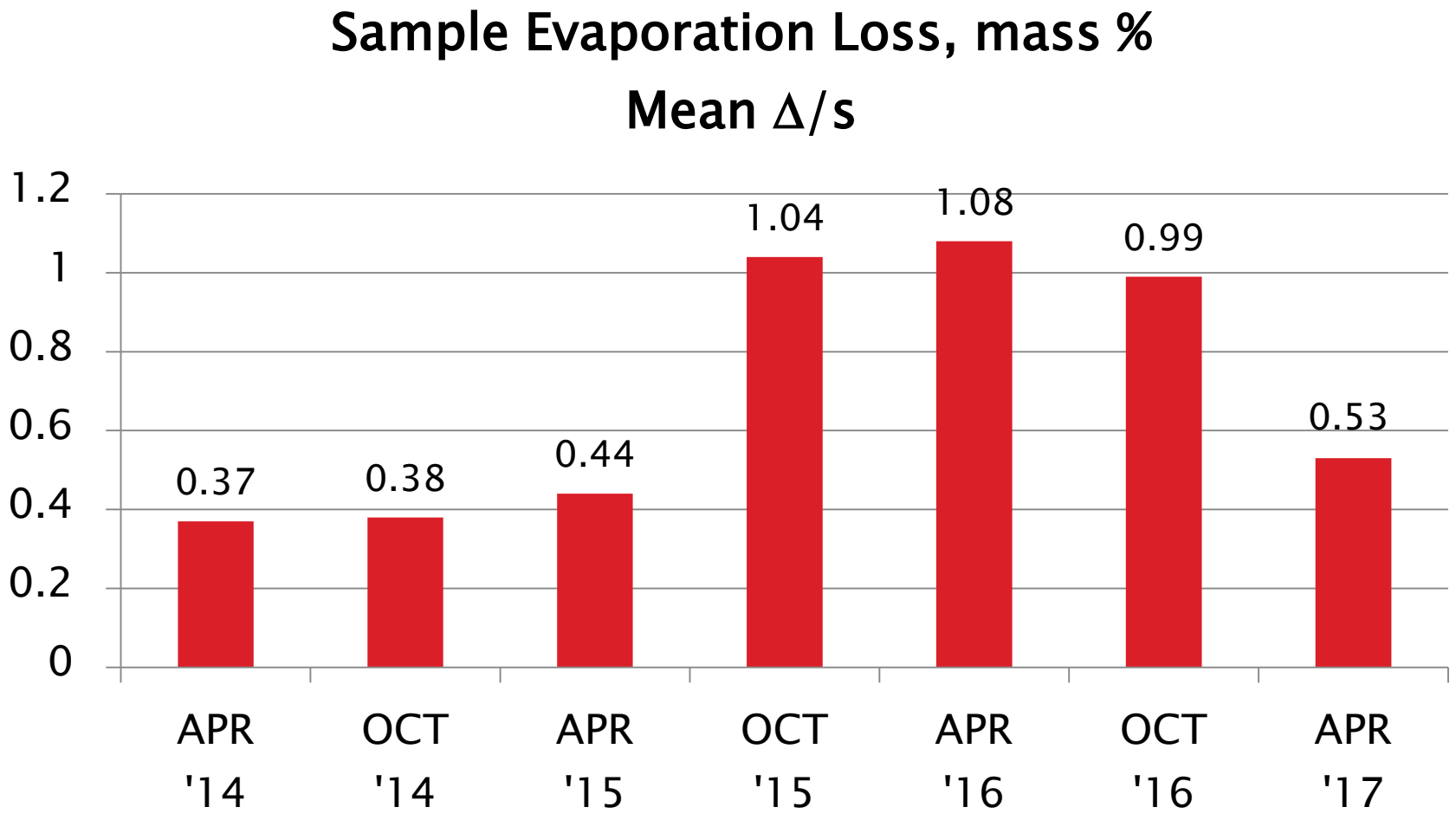
	n	df	Pooled s	Mean Δ/s
Procedure B	119	116	0.61	0.65
Procedure C	17	14	0.95	-0.26

Model	n	df	Pooled s	Mean Δ/s
NCK2	15	12	0.37	0.34
NCK25G	104	101	0.63	0.69
SVT1	17	14	0.95	-0.26

D5800 Precision Estimates



D5800 Severity Estimates



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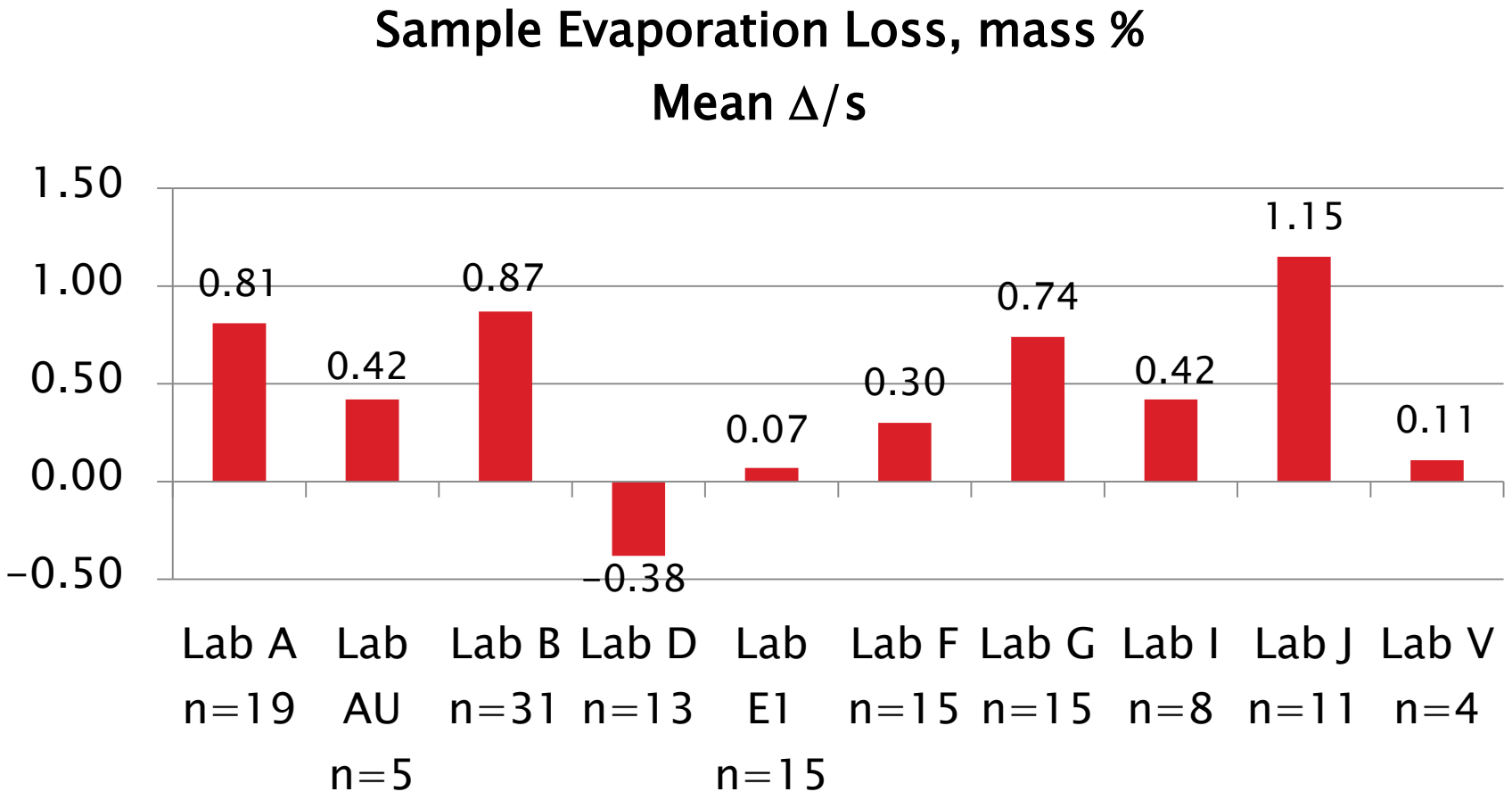
D5800: Evaporation Loss of Lubricating Oil by Noack Method

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

Lab	n	Mean Δ/s	Lab	n	Mean Δ/s
Lab A	19	0.81	Lab F	15	0.30
Lab AU	5	0.42	LAB G	15	0.74
Lab B	31	0.87	Lab I	8	0.42
Lab D	13	-0.38	Lab J	11	1.15
Lab E1	15	0.07	Lab V	4	0.11

D5800 Lab Severity Estimates



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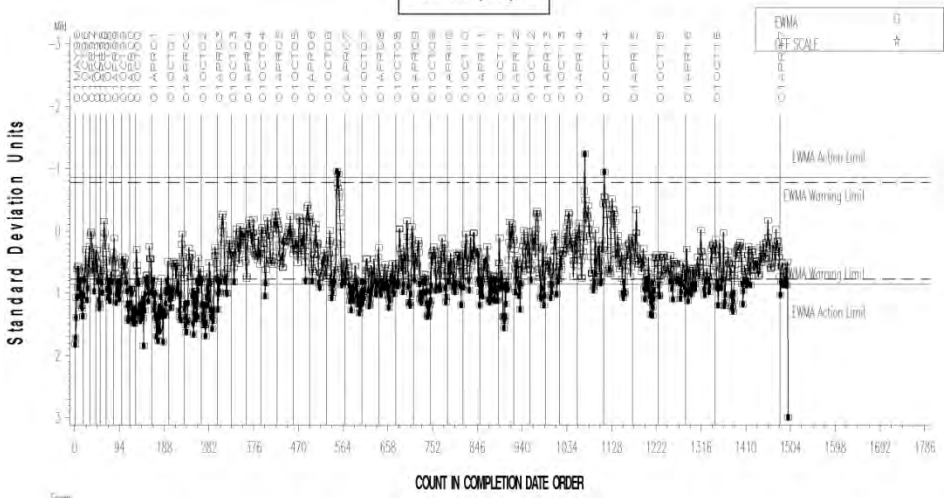
D5800: Evaporation Loss of Lubricating Oil by Noack Method

- A new LTMS monitoring system was implemented just after the start of this report period, which now includes severity adjustments by instrument. Six tests were reported under the prior Shewhart severity only system, and 137 under the new LTMS.
- Reported tests have increased from 65 total last period to 143 tests this period, mostly due to a reduced calibration period and new two-test calibration requirements.
- Precision (Pooled s), at 0.70 mass %, is comparable to the new target LTMS pooled precision of 0.73 mass %.
- Performance (Mean Δ/s) is 0.53 s severe using the updated LTMS target precision (now a common 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) dropped to 5% compared to 26% last period 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 monthly by LTMS calibration evaluation.

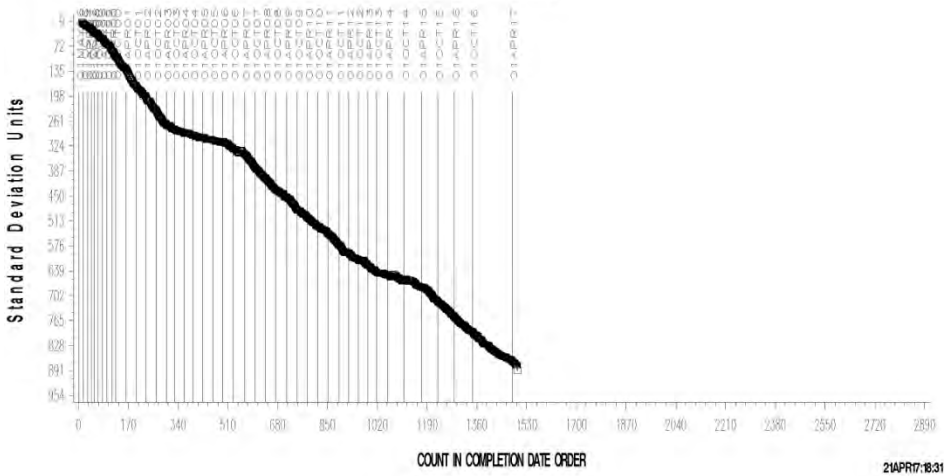
D5800 VOLATILITY BY NOACK INDUSTRY OPERATIONALLY VALID DATA

EVAPORATION LOSS, MASS%

LTMS Severity Analysis



CUSUM Severity Analysis



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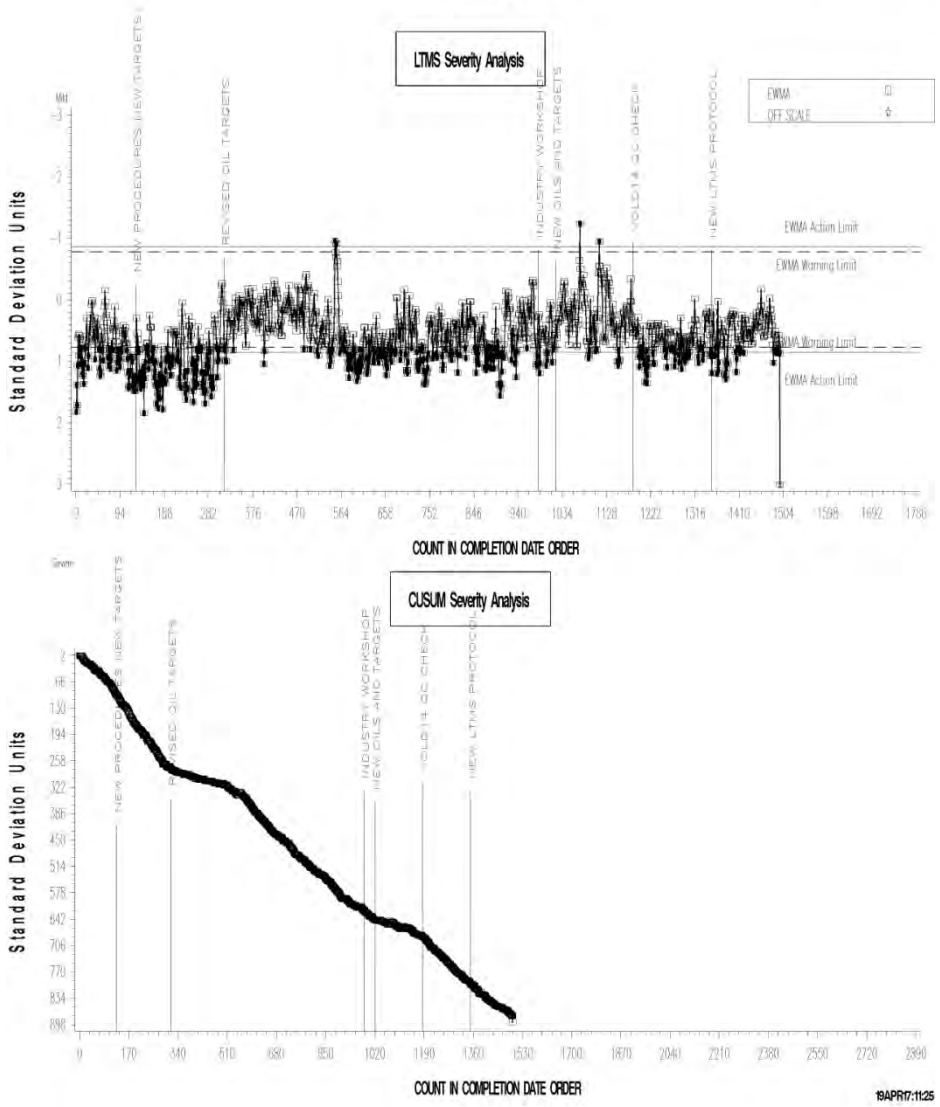
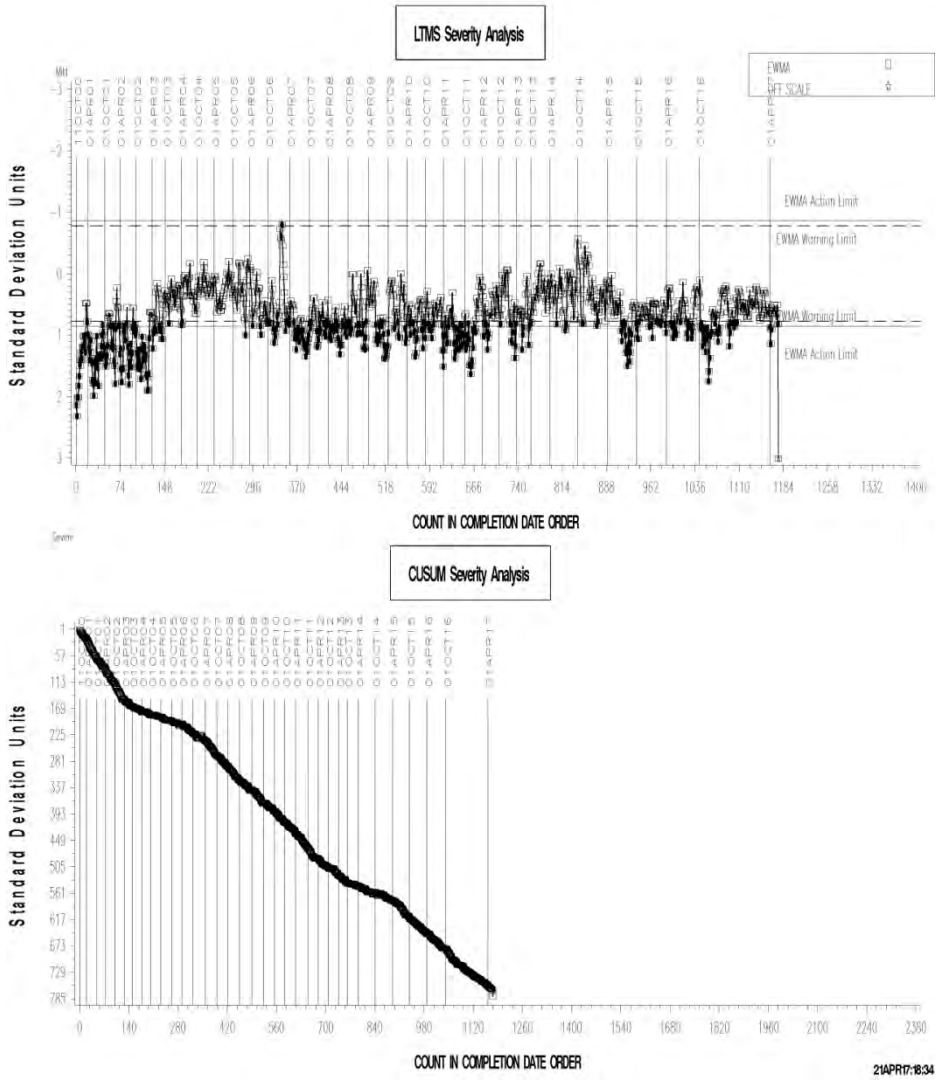
D5800 VOLATILITY BY NOACK INDUSTRY OPERATIONALLY VALID DATA

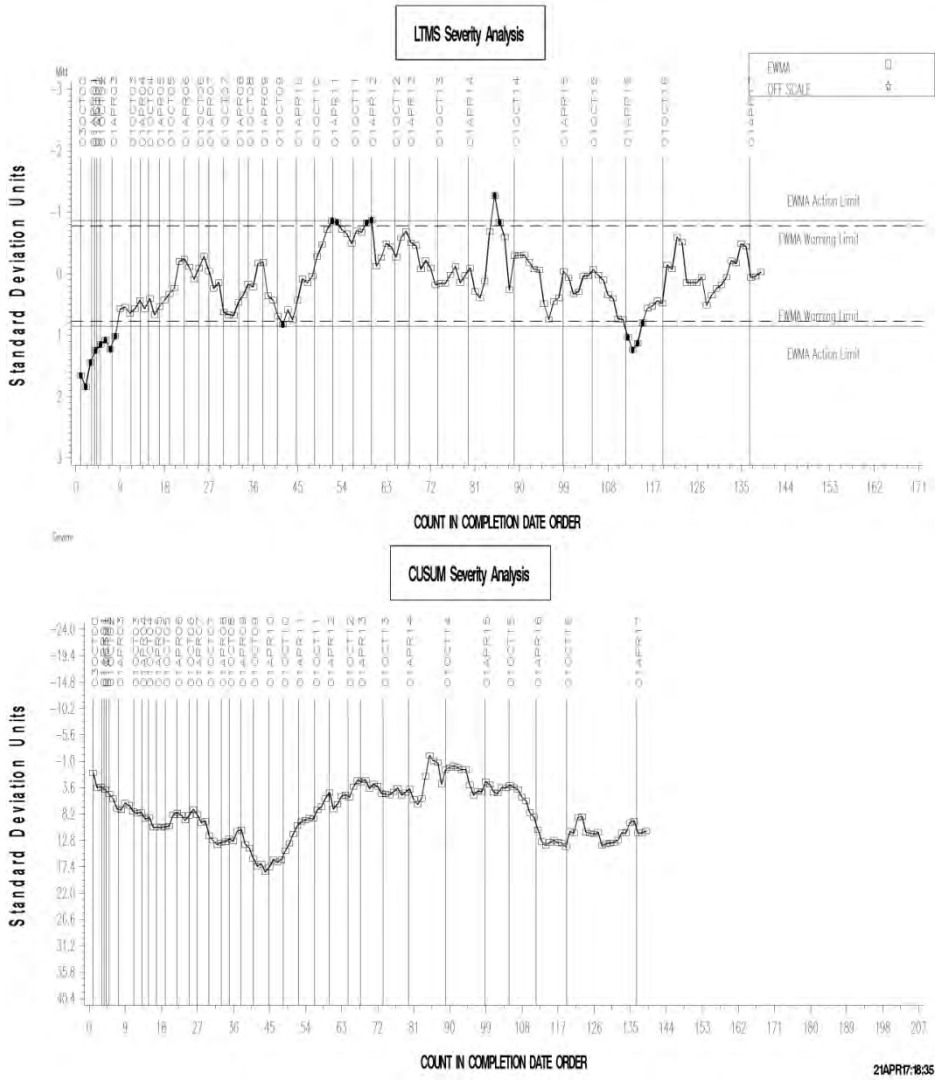
EVAPORATION LOSS, MASS%



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



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

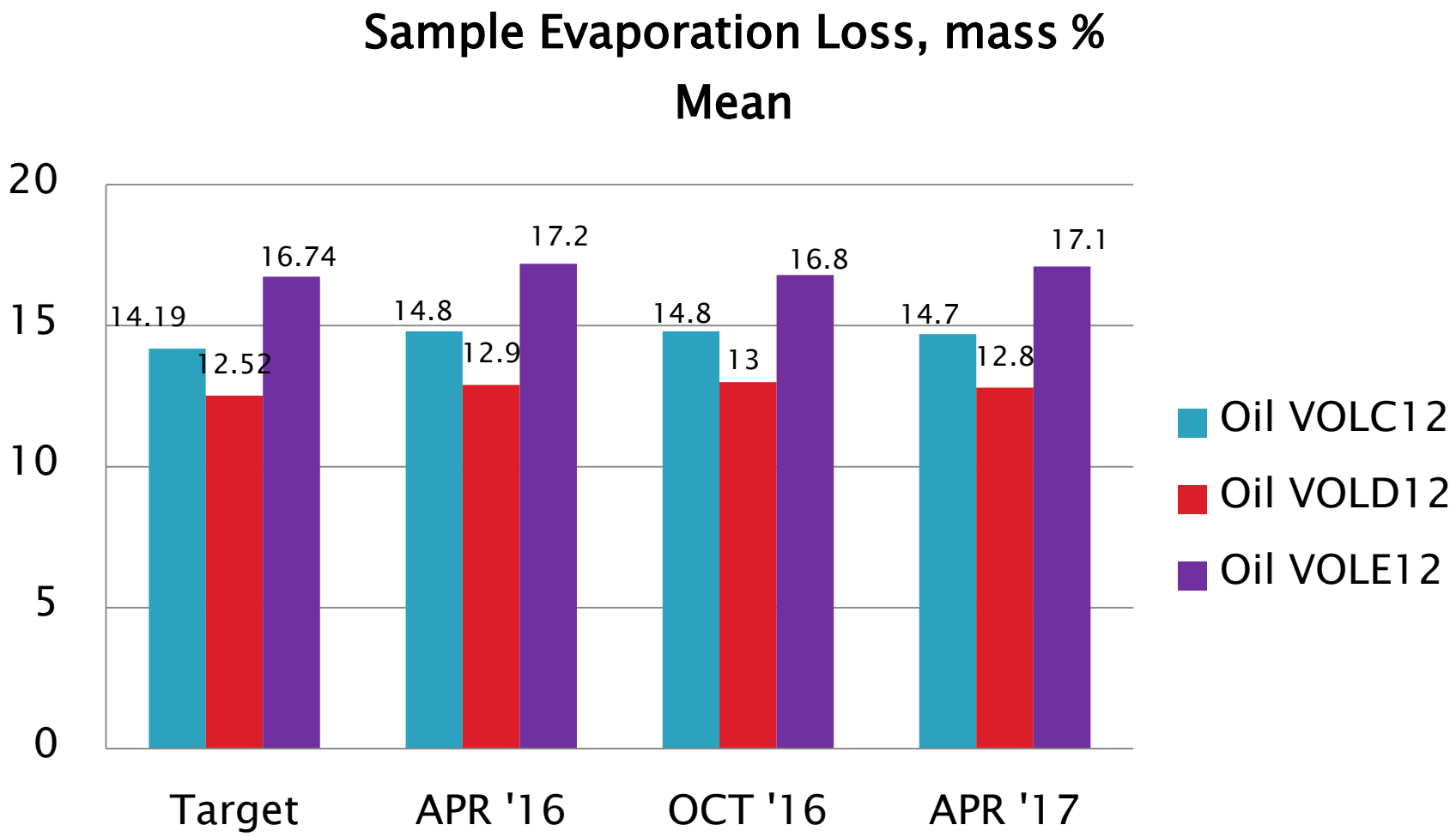


D5800: Evaporation Loss of Lubricating Oil by Noack Method

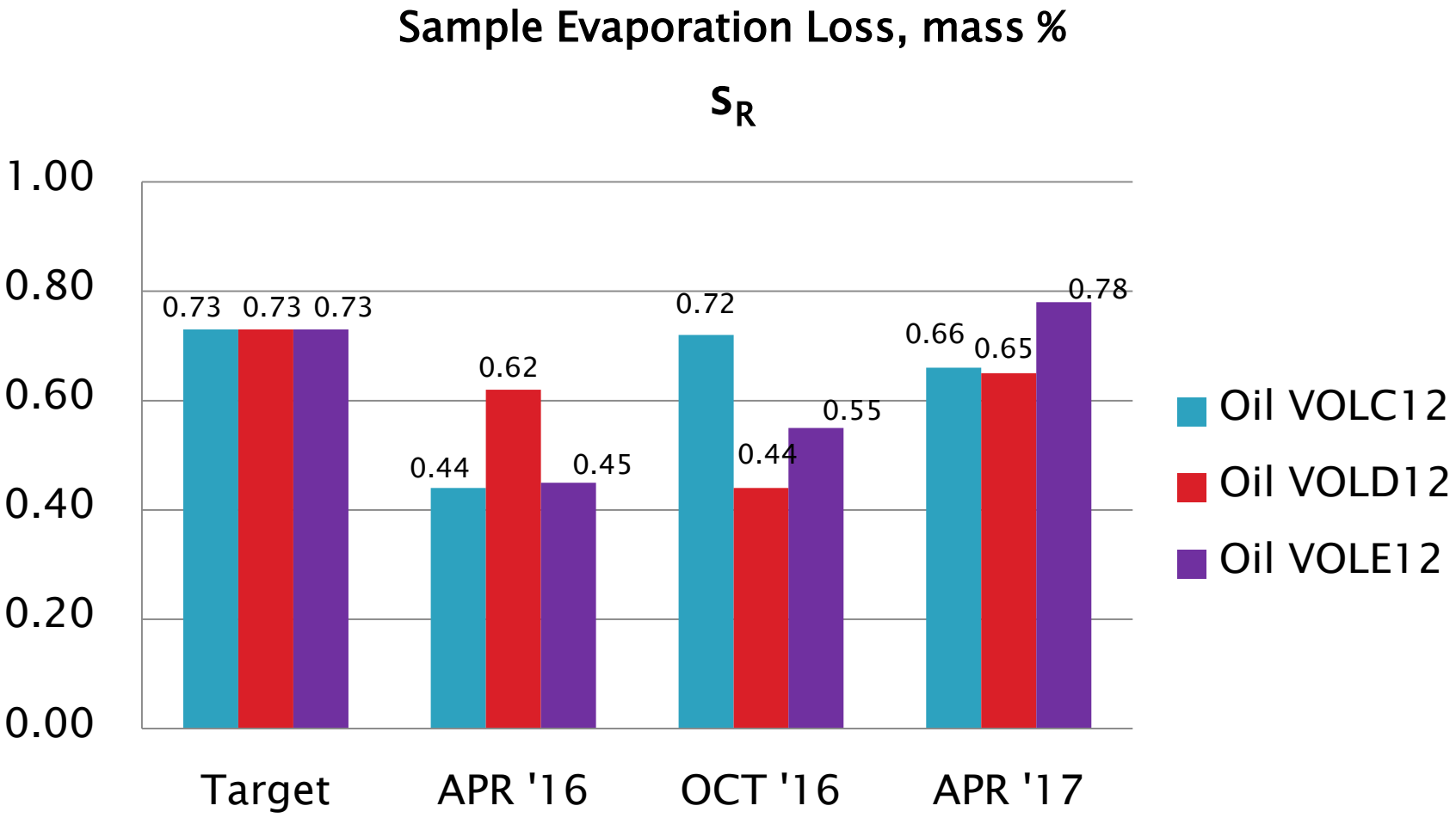
Sample Evaporation Loss, mass %
Performance by Oil

	Targets			10/1/15 – 3/31/16				4/1/16 – 9/30/16				10/1/156– 3/31/17			
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	18	14.8	0.44	1.57	29	14.8	0.72	1.40	47	14.7	0.66	0.69
VOLD12	27	12.52	0.73	16	12.9	0.62	0.77	22	13.0	0.44	0.89	40	12.8	0.65	0.45
VOLE12	27	16.74	0.73	23	17.2	0.45	0.92	11	16.8	0.55	0.09	49	17.1	0.78	0.46

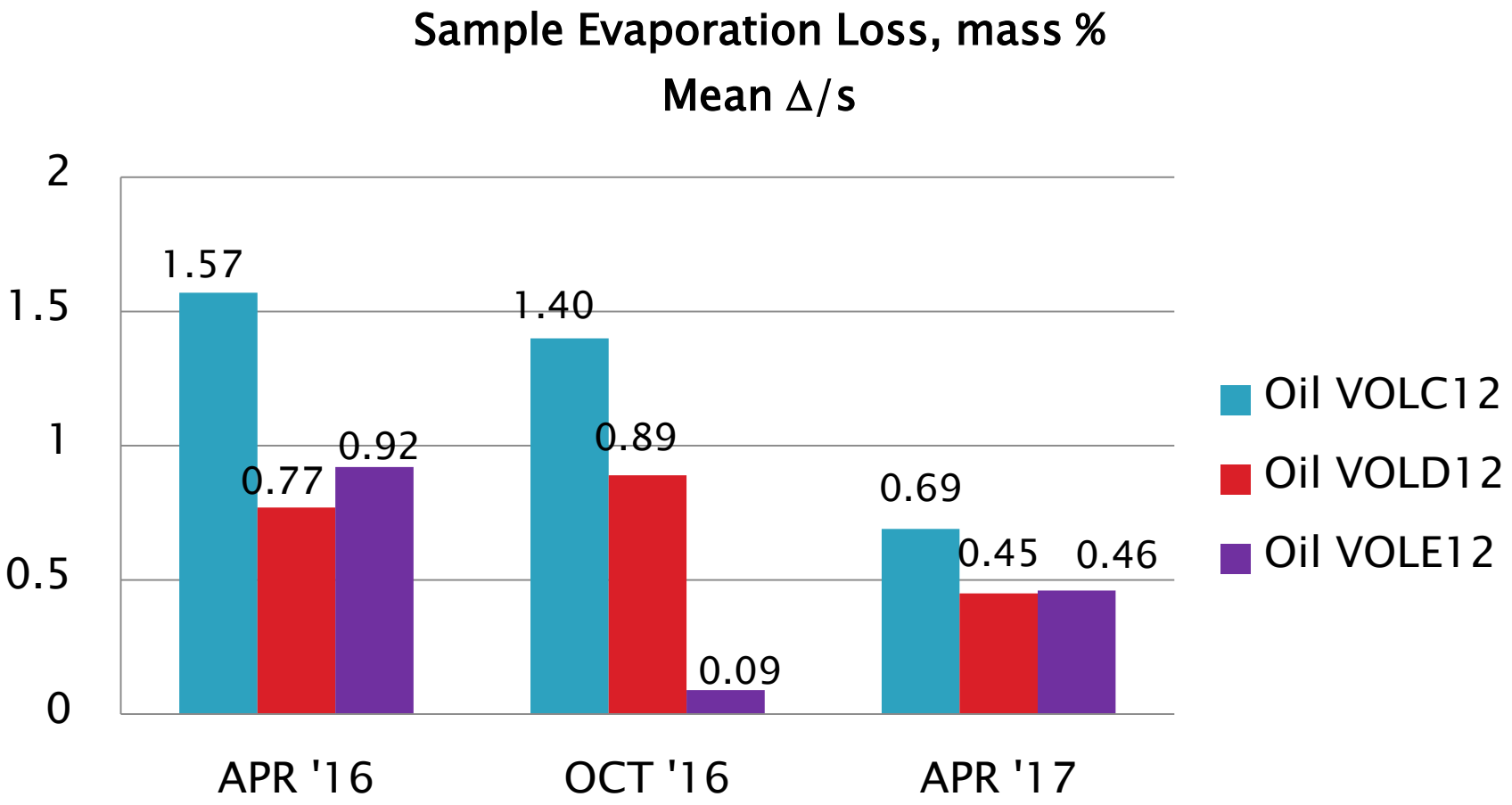
D5800 Performance by Oil



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	8
Operationally Invalidated by Lab	LC, XC	0
Operationally Invalidated After Initially Reported as Valid	RC	5
Excluded from statistics (New Rig)	MC	1
Non-blind Instrument Shakedowns	NN	5
Total		**46**

Number of Labs Reporting Data: 9
Fail Rate of Operationally Valid Tests: 23%

D5133: Gelation Index

Statistically Unacceptable Tests (OC)	No. Of Tests
Gelation Index Mild	6
Gelation Index Severe	2

- Five consecutive failing tests on instrument I3 were corrected from operationally valid (OC), to invalid (RC) after it was determined the rig had two bad heads that needed repaired or replaced.

- Same rig (I3) ran the five NN shakedowns (and more into next report period) to check the status of all the remaining heads before recalibrating.

- One failing test on a new rig was excluded from the statistics (MC) because the rig had not yet demonstrated a passing calibration, making the result suspect.

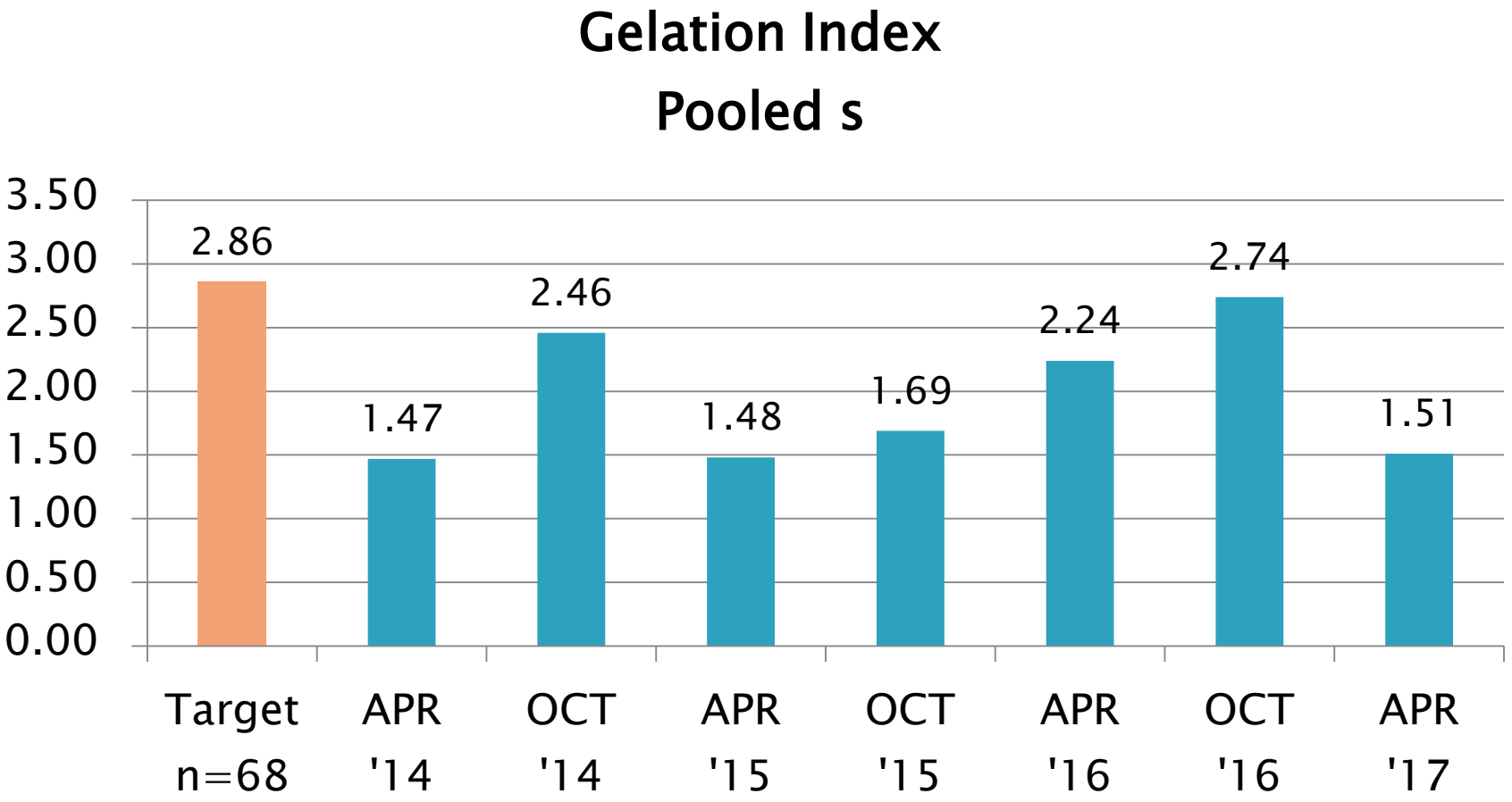
- No TMC technical updates issued this period

D5133: Gelation Index

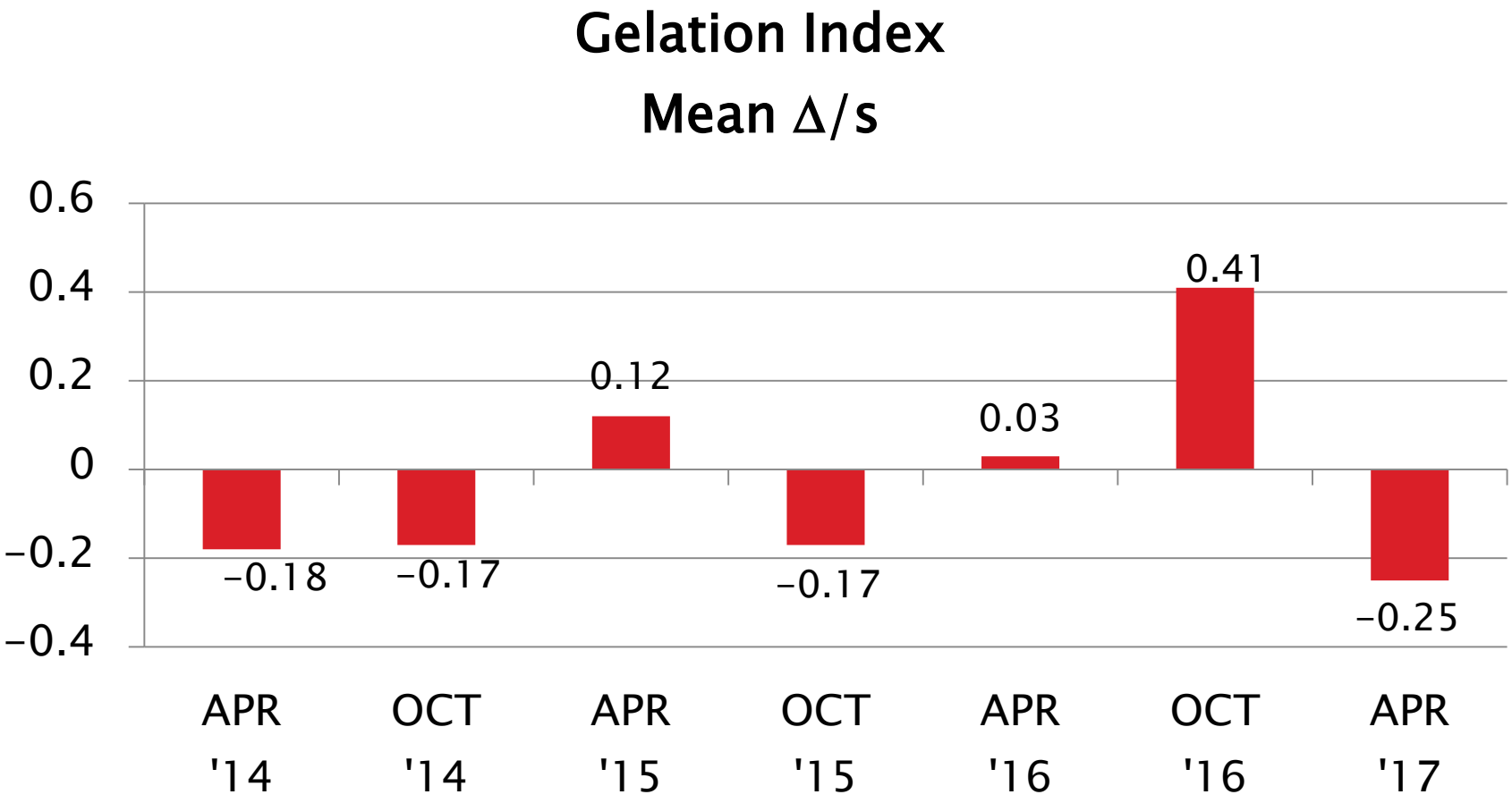
Period Precision and Severity Estimates

Gelation Index	n	df	Pooled s	Mean Δ/s
Current Targets 7/15/2003	68	65	2.86	-----
10/1/13 through 3/31/14	14	11	1.47	-0.18
4/1/14 through 9/30/14	24	21	2.46	-0.17
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

D5133 Precision Estimates



D5133 Severity Estimates



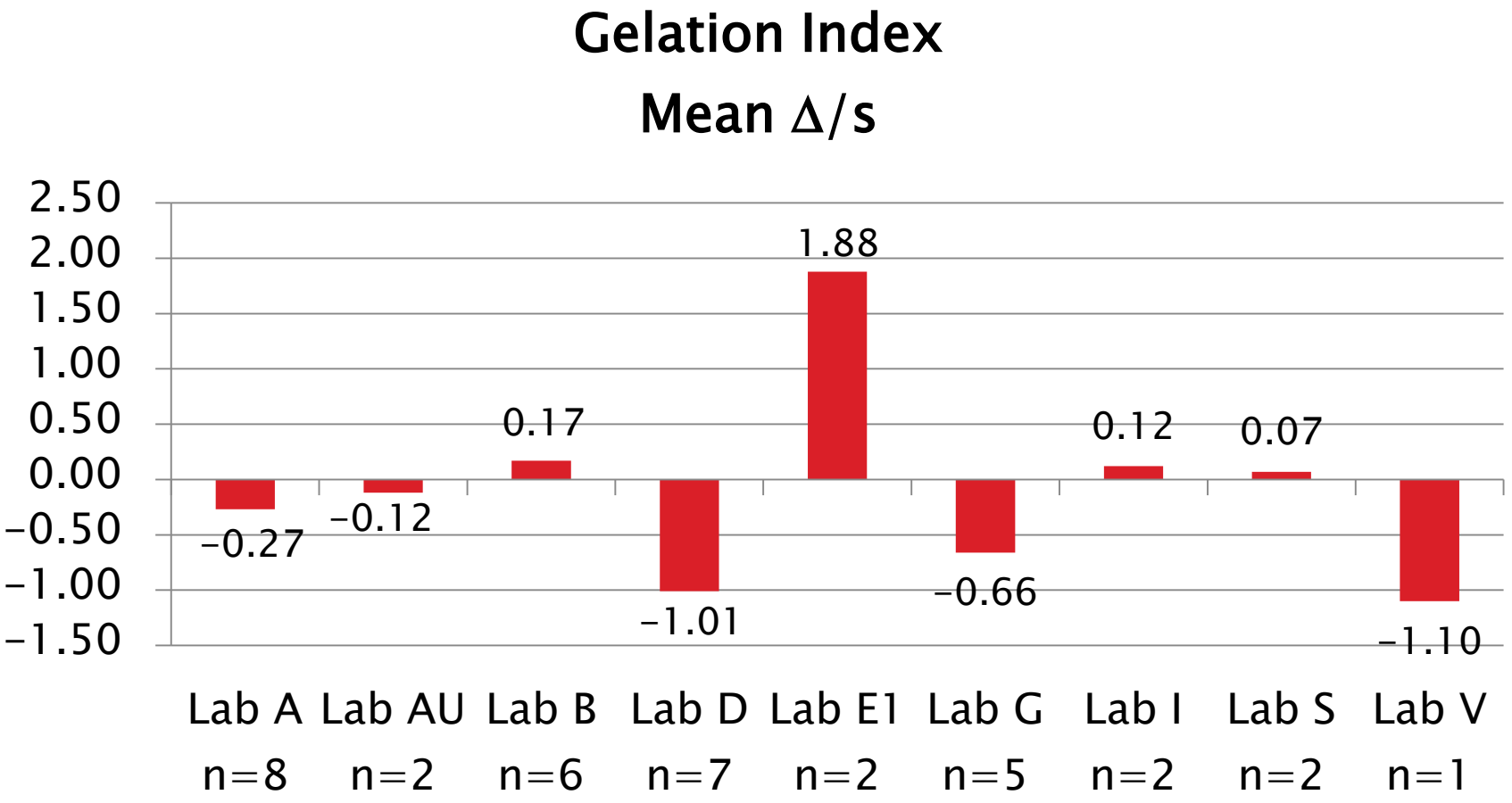
D5133: Gelation Index

Current Period Severity Estimates by Lab

Gelation Index

	n	Mean Δ/s
Lab A	8	-0.27
LAB AU	2	-0.12
Lab B	6	0.17
Lab D	7	-1.01
Lab E1	2	1.88
Lab G	5	-0.66
Lab I	2	0.12
Lab S	2	0.07
Lab V	1	-1.10

D5133 Lab Severity Estimates



D5133: Gelation Index

- Precision (Pooled s) is more precise than prior period
  - More precise than target precision
  - Precision on oil 58 is worsening over past three periods.
- Performance (Mean Δ/s) is -0.25 s mild
  - Three labs performing 1 s or more severe or mild.
  - Oil 58 performing 1 s severe, while oil 1009 is nearly 1 s mild.
- Fail rate of operationally valid tests is up to 26%, compared to 6% last period, with two rigs having consecutive failing runs, and another rig with two fails during the period, but not consecutive. All subsequently passed calibration.
  - Six of the 7 OC fails were on borderline oil 1009.
- With non-gelling oil 58 performing at 1 s severe, and low gelling oil 1009 nearly -1 s mild, the overall period mean GI performances on those oils do not show adequate discrimination over the report period.
- Reference oil 62 inventory is down to 0.7 gallons remaining (with 0.35 gallon shipped prior 12 months).

D5133 GELATION INDEX INDUSTRY OPERATIONALLY VALID DATA

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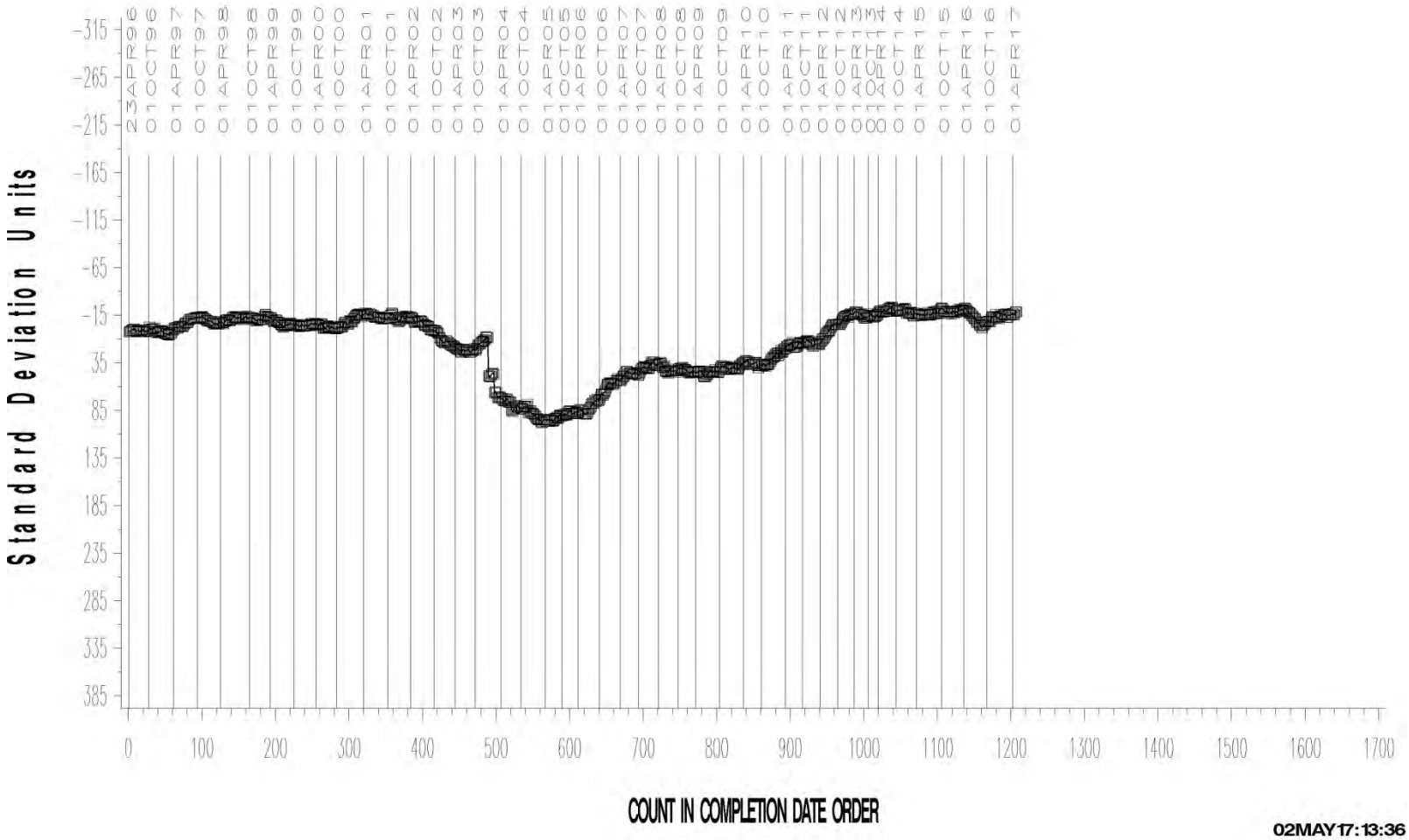
GELATION INDEX

CUSUM Severity Analysis



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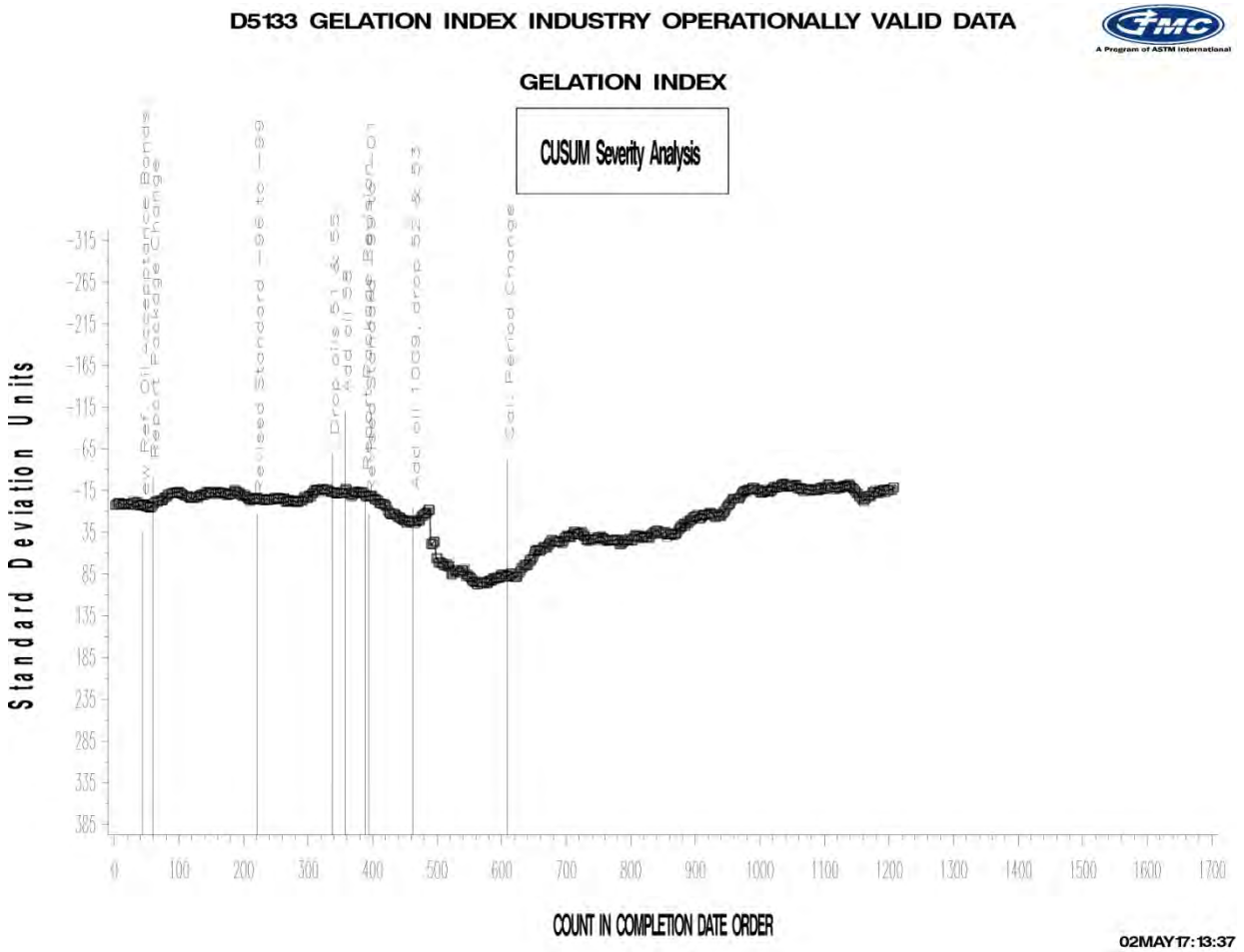
D5133: Gelation Index



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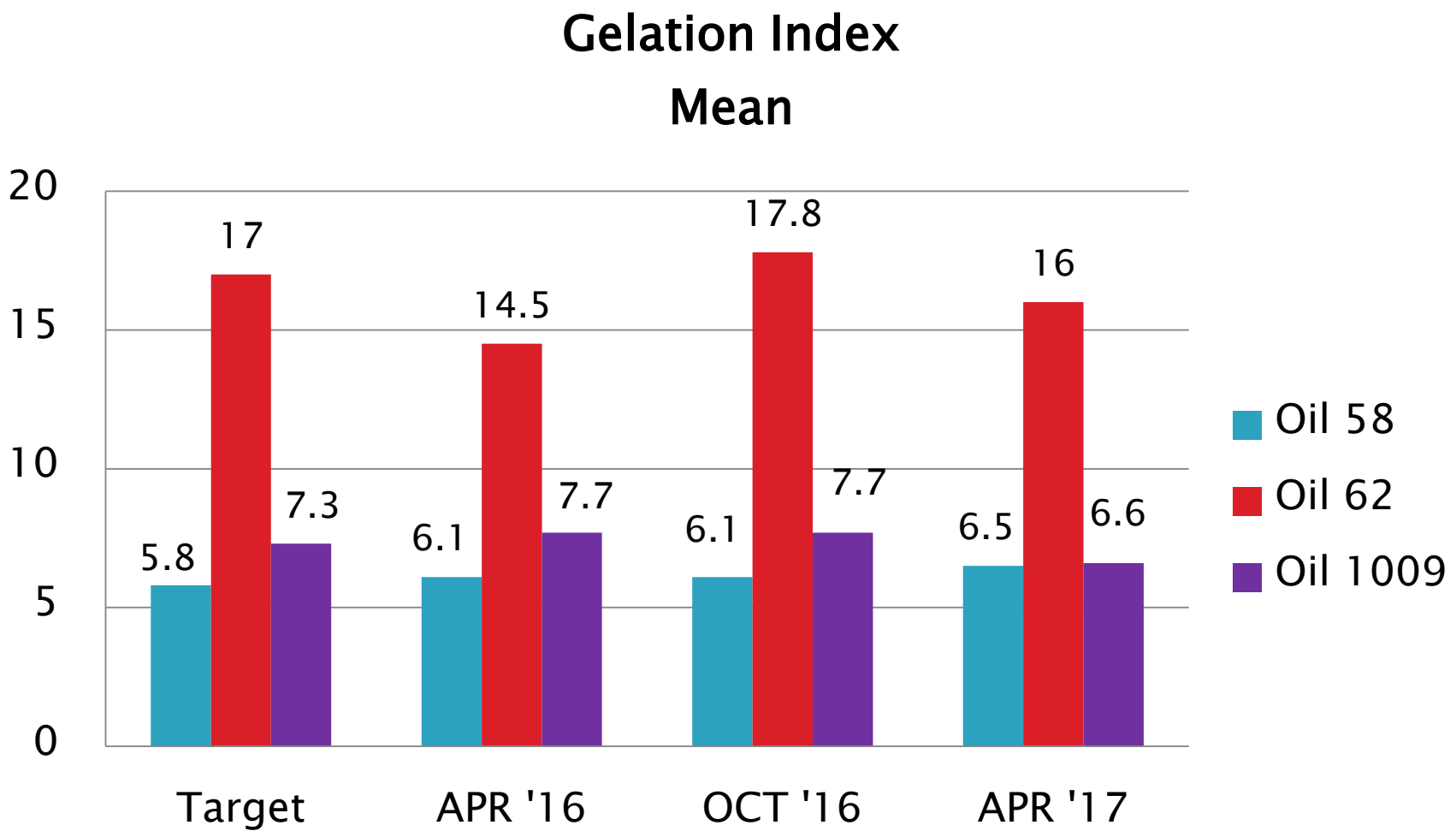
D5133 Performance by Oil

Gelation Index
Performance by Oil

	Targets			10/1/15 – 3/31/16				4/1/16 – 9/30/16				10/1/16– 3/31/17			
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	0.86	0.46	11	6.1	1.09	0.47	9	6.5	1.20	1.05
62	35	17.0	3.90	13	14.5	3.29	-0.64	9	17.8	4.92	0.21	10	16.0	2.33	-0.26
1009	16	7.30	0.68	7	7.7	0.69	0.61	11	7.7	0.60	0.52	16	6.6	0.91	-0.97

D5133 Performance by Oil



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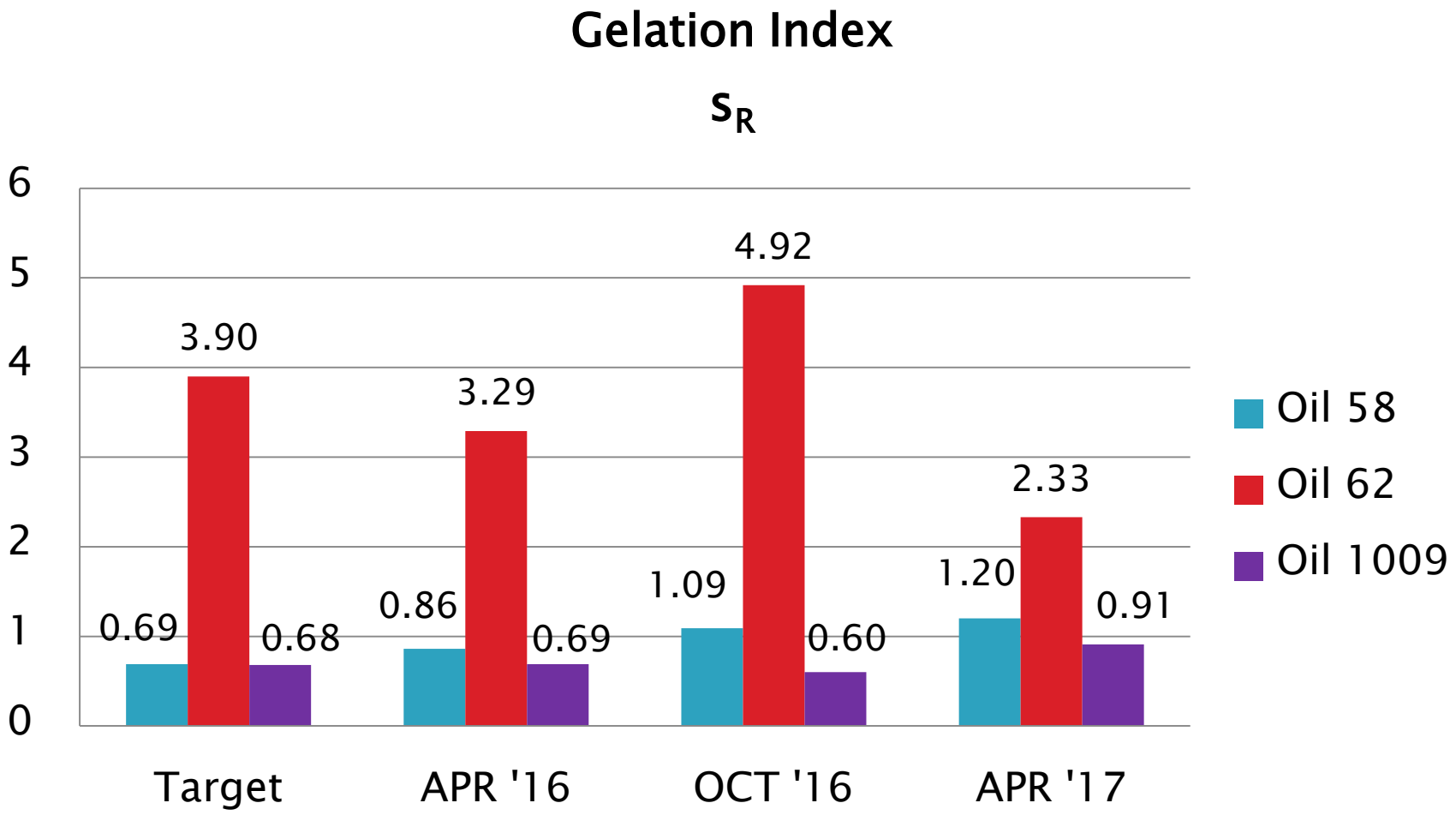
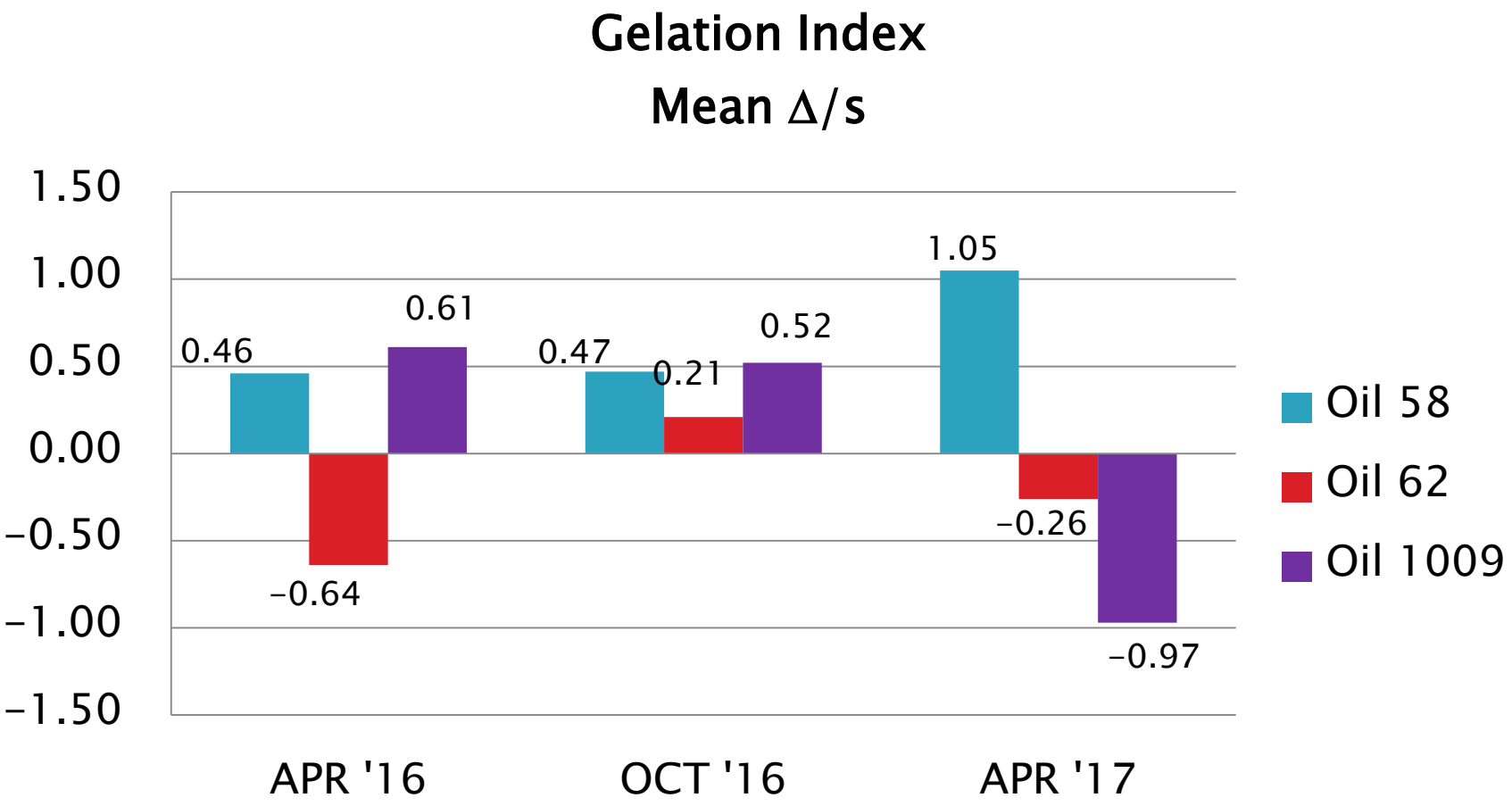
D5133 Performance by Oil



D5133 Performance by Oil



Return to Executive Summary

D6335: Deposits by TEOST-33C

Test Status	Validity Code	No. Tests
Acceptable Calibration Test	AC	20
Failed Calibration Test	OC	1
Operationally Invalidated by Lab	LC, XC	1
Operationally Invalidated After Initially Reported as Valid	RC	1
Excluded from statistics (New Rig)	MC	1
Instrument Shakedown	NN, RN	4
Total		**28**

Number of Labs Reporting Data: 7

Fail Rate of Operationally Valid Tests: 5%

D6335: Deposits by TEOST-33C

Statistically Unacceptable Tests (OC)	No. Of Tests
Total Deposits Mild	0
Total Deposits Severe	1

- Three operationally invalid tests reported this period:
  - All three report bad thermocouples (LC, RN & RC)

- One failing test excluded from statistics because lab had not demonstrated a passing run on new instrument (MC).

- Four shakedown runs reported to troubleshoot:
  - Two on a new instrument and two existing instrument
  - Both instruments found to have bad thermocouples
  - Both rigs subsequently passed calibration.

D6335: Deposits by TEOST-33C

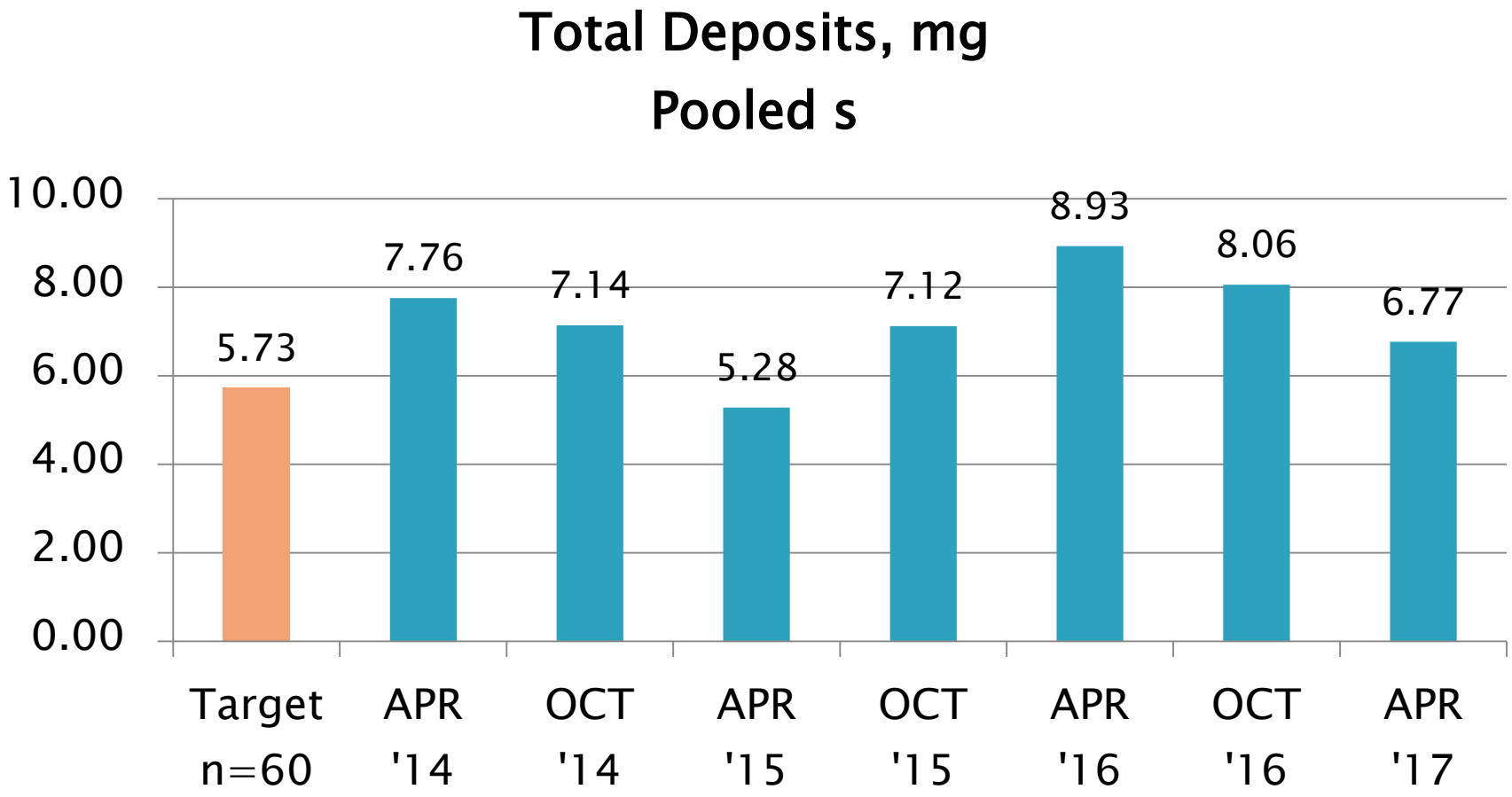
- One TMC technical update was issued this report period:
  - Memo 16-034, October 18, 2016, New TMC Calibration Requirements Effective November 14, 2016
    - Introduces two-test calibration requirement for new rigs and after two consecutive OC fails on same instrument.

D6335: Deposits by TEOST-33C

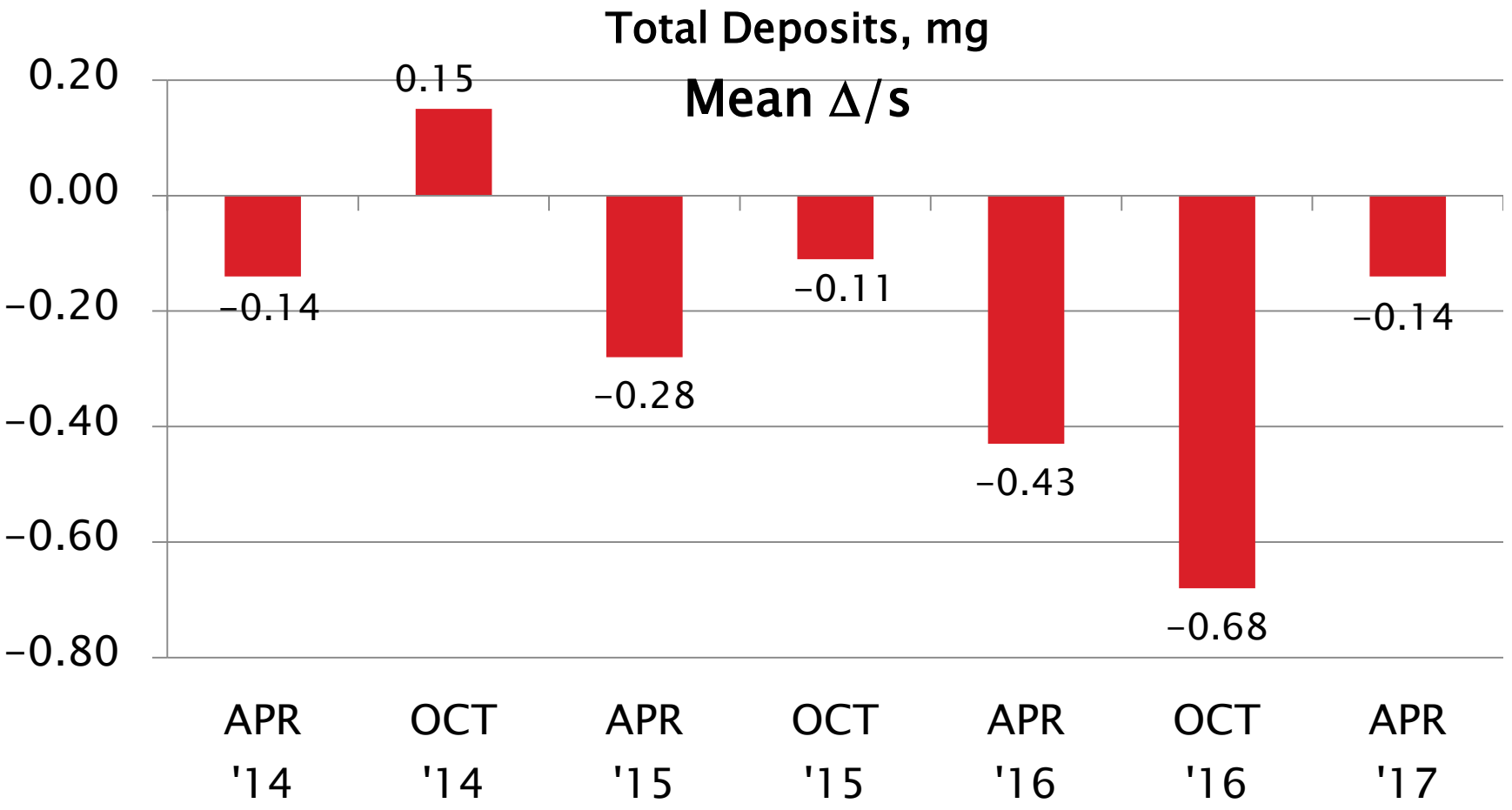
Period Precision and Severity Estimates

Total Deposits, mg	n	df	Pooled s	Mean Δ/s
Updated Targets 20130415	60	58	5.73	-----
10/1/13 through 3/31/14	16	14	7.76	-0.14
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

D6335 Precision Estimates



D6335 Severity Estimates

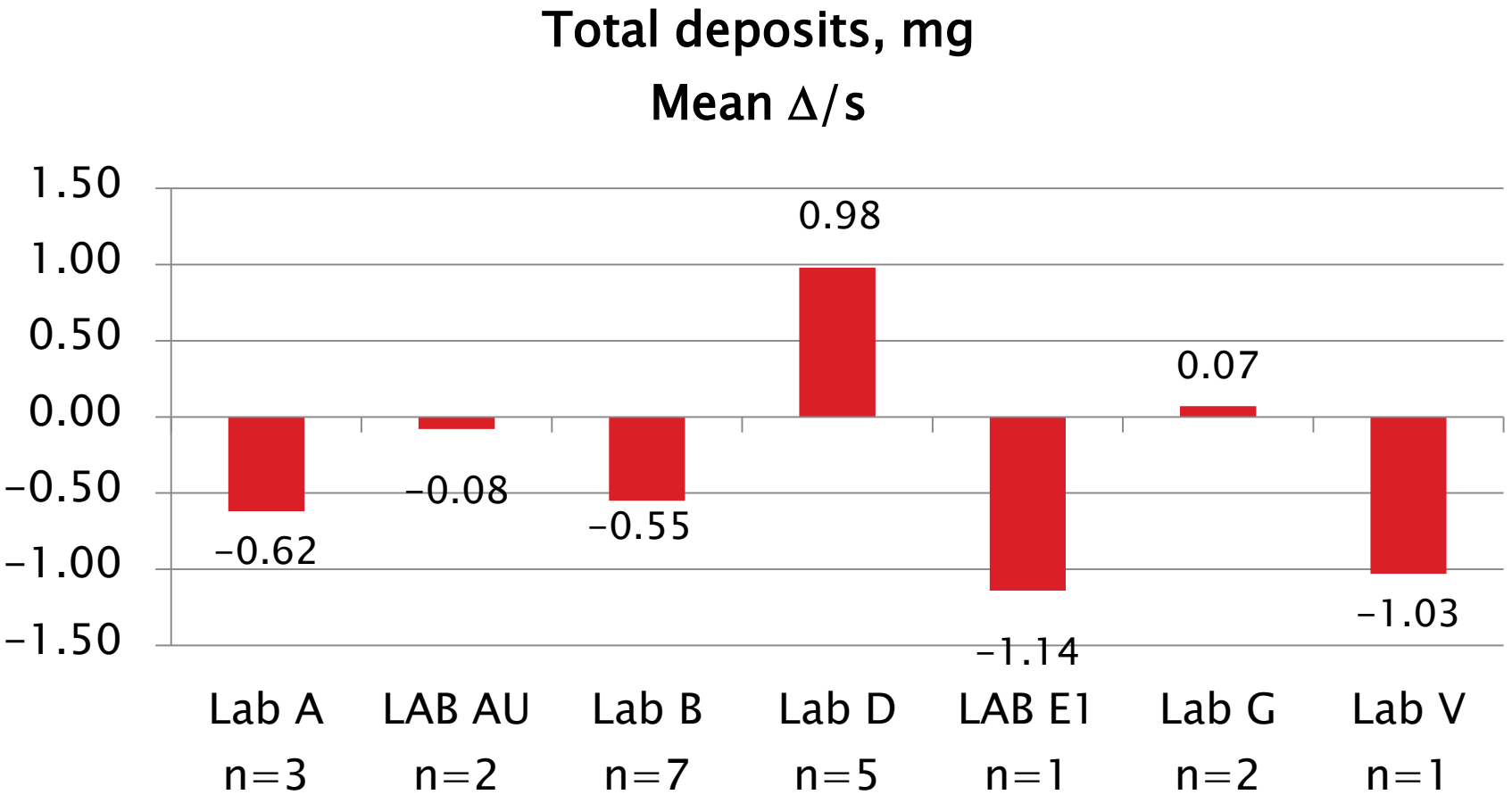


D6335: Deposits by TEOST-33C

Current Period Severity Estimates by Lab
Total Deposits, mg

	n	Mean Δ/s
Lab A	3	-0.62
Lab AU	2	-0.08
Lab B	7	-0.55
Lab D	5	0.98
Lab E1	1	-1.14
Lab G	2	0.07
Lab V	1	-1.03

D6335 Lab Severity Estimates



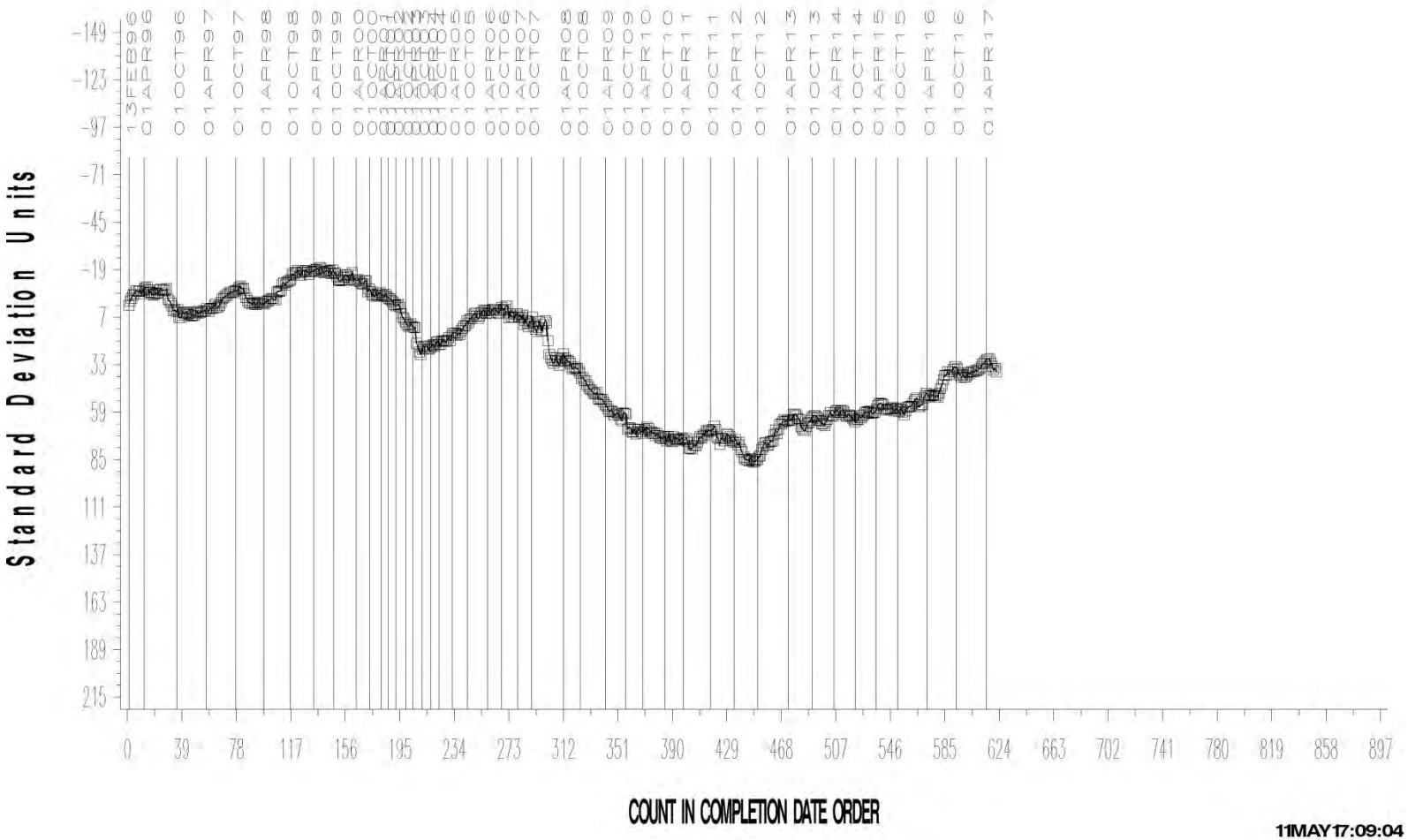
D6335: Deposits by TEOST-33C

- Precision (Pooled s) is more precise than prior period
  - Less precise than target precision
  - Severe oil 75 performance continues to be imprecise
- Performance (Mean Δ/s) is -0.14 s mild
  - Improvement follows two very mild and imprecise periods
  - Influenced by a single instrument having problems for last three periods (biasing results past two periods, but mostly shakedown runs this period before successfully calibrating)
- 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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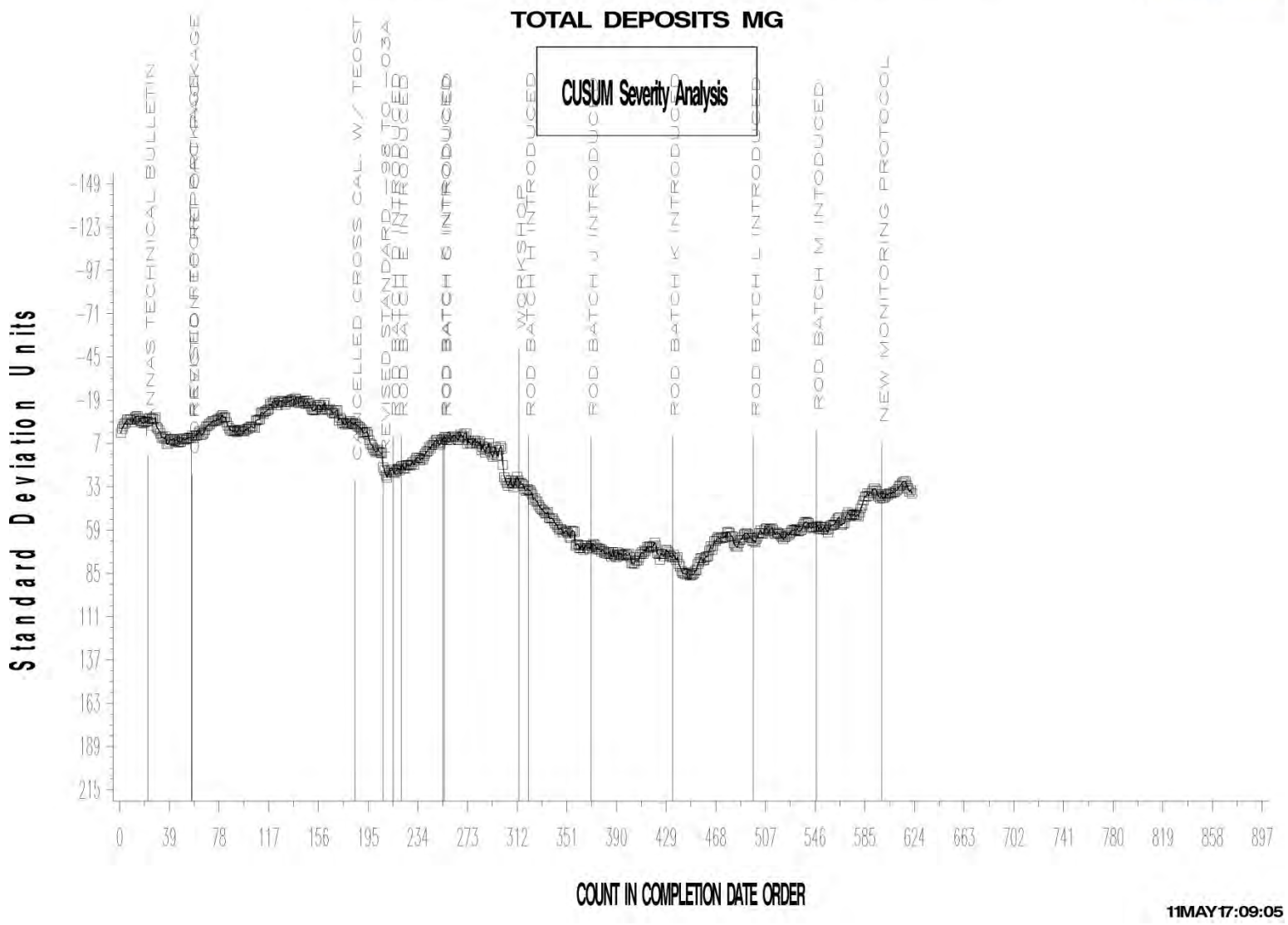
TEOST–33C INDUSTRY OPERATIONALLY VALID DATA



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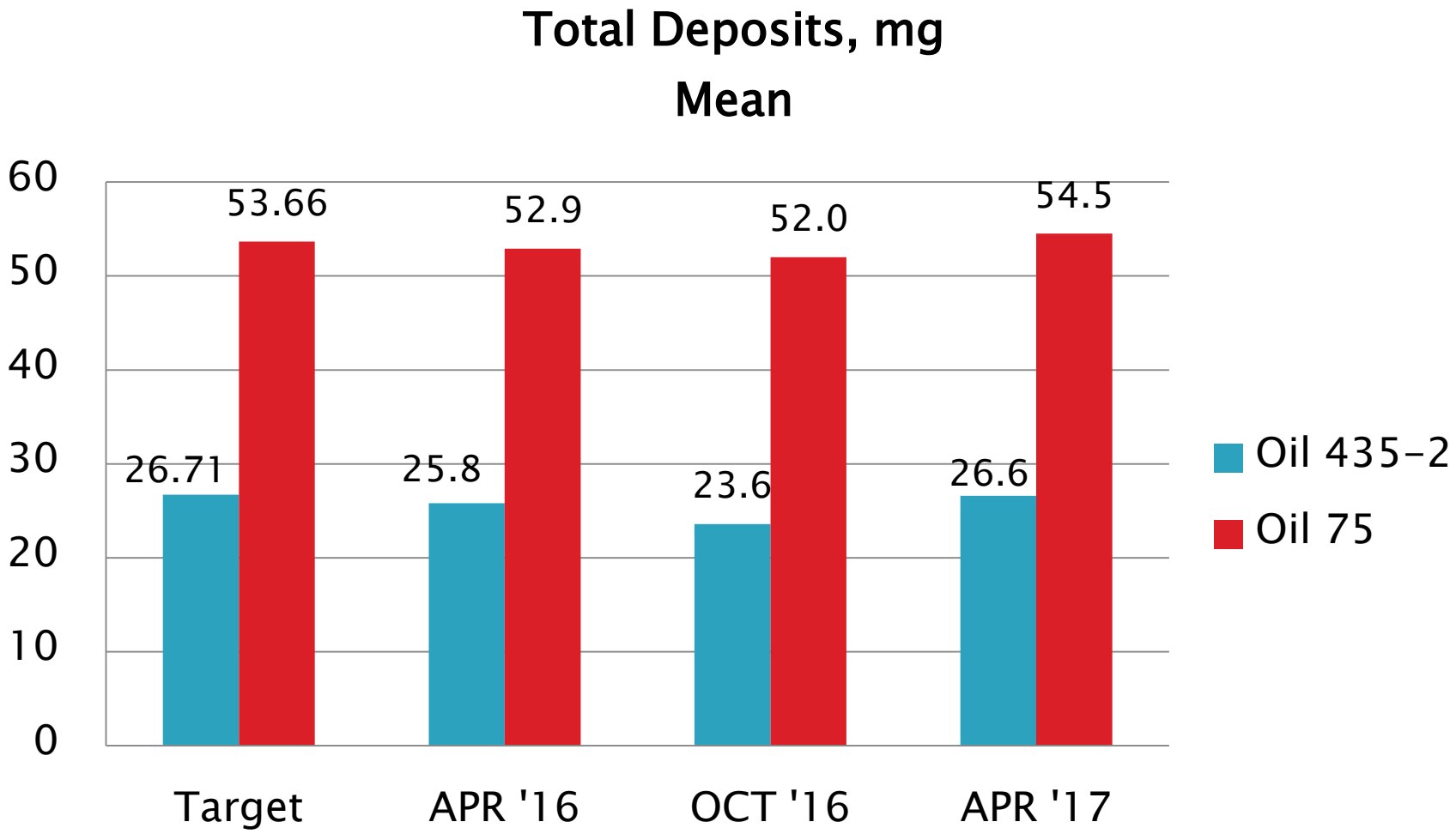
D6335 Performance by Oil

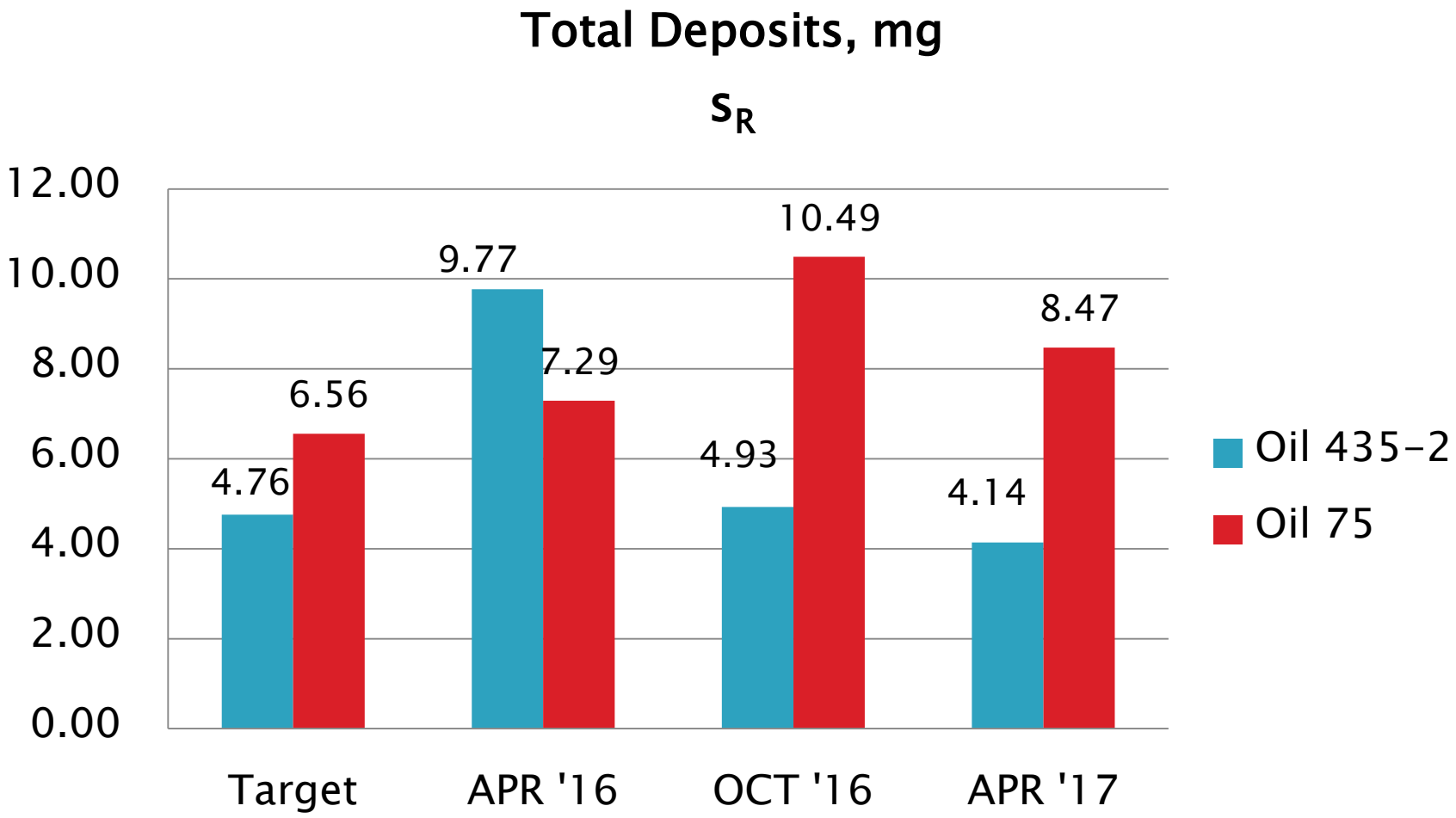
Total Deposits, mg
Performance by Oil

	Targets 20130415			10/1/15 – 3/31/16				4/1/16– 9/30/16				10/1/16 – 3/31/17			
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	13	25.8	9.8	-0.62	11	23.6	4.93	-1.07	10	26.6	4.14	-0.45
75	30	53.66	6.56	8	52.9	7.3	-0.11	10	52.0	10.49	-0.25	11	54.5	8.47	0.13

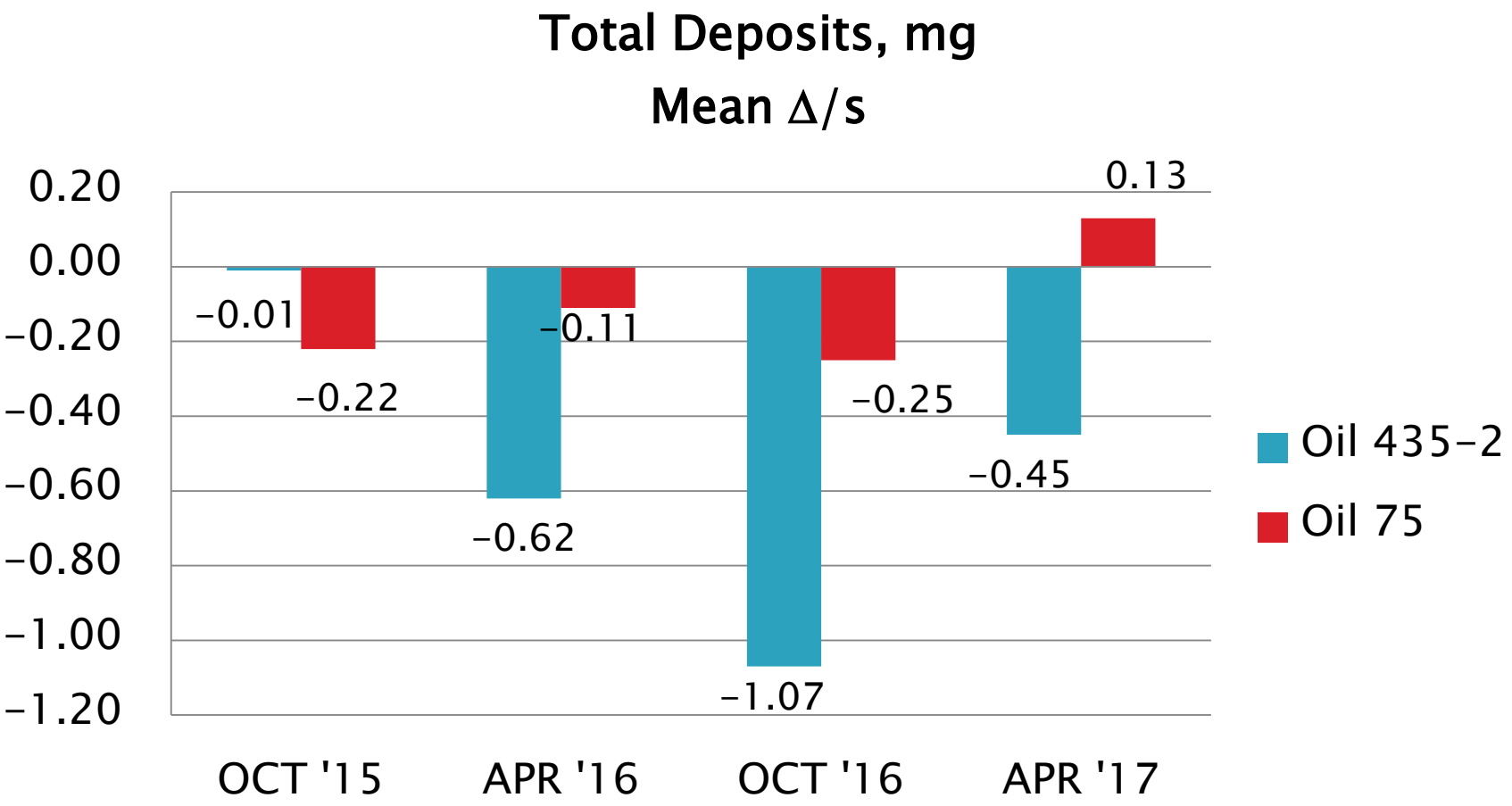
D6335 Performance by Oil



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	93
Failed Calibration Test	OC	12
Operationally Invalidated by Lab	LC, XC	1
Operationally Invalidated After Initially Reported as Valid	RC	0
Instrument Shakedown	NN	4
Total		**110**

Number of Labs Reporting Data: 10
Fail Rate of Operationally Valid Tests: 11%

D7097: Deposits by MHT TEOST

Statistically Unacceptable Tests (OC)	No. Of Tests
Total Deposits Mild	5
Total Deposits Severe	7

- One operationally invalid calibration test reported this period:
  - Heater failure during run (XC)

- Four shakedown runs reported to troubleshoot instruments

- One instrument has four consecutive failing two-test calibration sequences, comprised of eight consecutive tests total
  - Four severe fails on both oils (two on 432 and two on 434).
  - Also met acceptance bands on both oils, just not on two consecutive runs, as is now required
  - Instrument still not calibrated as of this report
  - Illustrates usefulness of new two-test calibration requirement

D7097: Deposits by MHT TEOST

- One TMC technical update issued last report period:
  - Memo 16-031, September 20, 2016, Updated Test method D7097-16A
  - This update requires the use of new flask end-cap air seals.
  - One test reported/completed at end of last period using the new flask seal
  - All tests reported this period use new flask end-cap air seals.

- One TMC technical update was issued this report period:
  - Memo 16-033, October 18, 2016, New TMC Calibration Requirements Effective November 14, 2016
    - Introduces two-test calibration requirement for new rigs and after two consecutive OC fails on same instrument.

D7097: Deposits by MHT TEOST

Period Precision and Severity Estimates

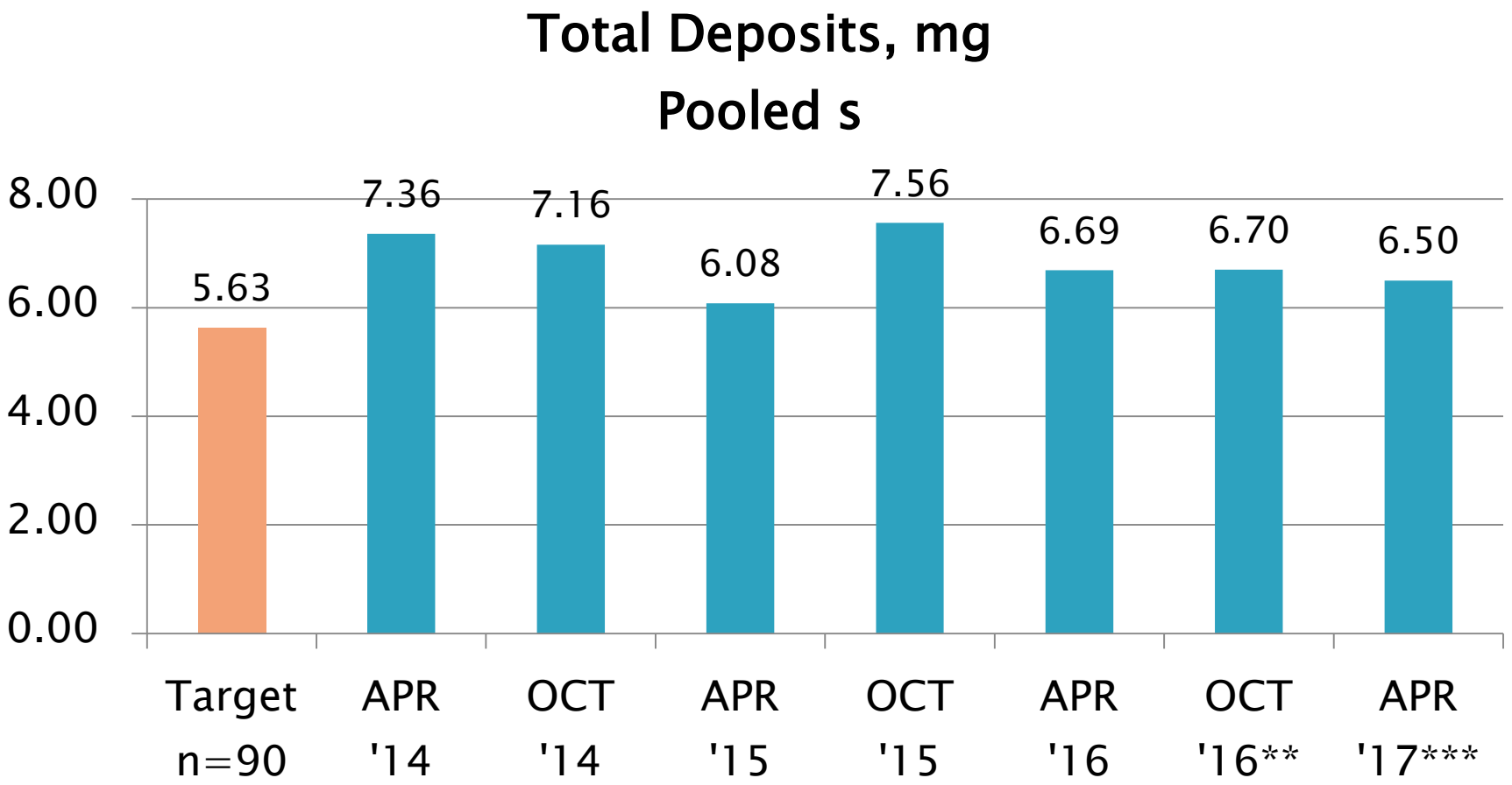
Total Deposits, mg	n	df	Pooled s	Mean Δ/s
Current Targets 7/31/2006	90	87	5.63	-----
10/1/14 through 3/31/15*	94	92	6.60	0.19
10/1/14 through 3/31/15*	90	88	6.08	0.04
4/1/15 through 9/30/15	84	82	7.56	0.39
10/1/15 through 3/31/16	84	82	6.69	0.29
4/1/16 through 9/30/16**	96	94	15.8	0.53
4/1/16 through 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

*Four severe OC tests from instrument G1 included and excluded

**Three severe OC tests from instrument P1 included and excluded

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

D7097 Precision Estimates



**Three severe OC tests from instrument P1 excluded

***Eight tests from instrument J2 excluded (failed to calibrate)

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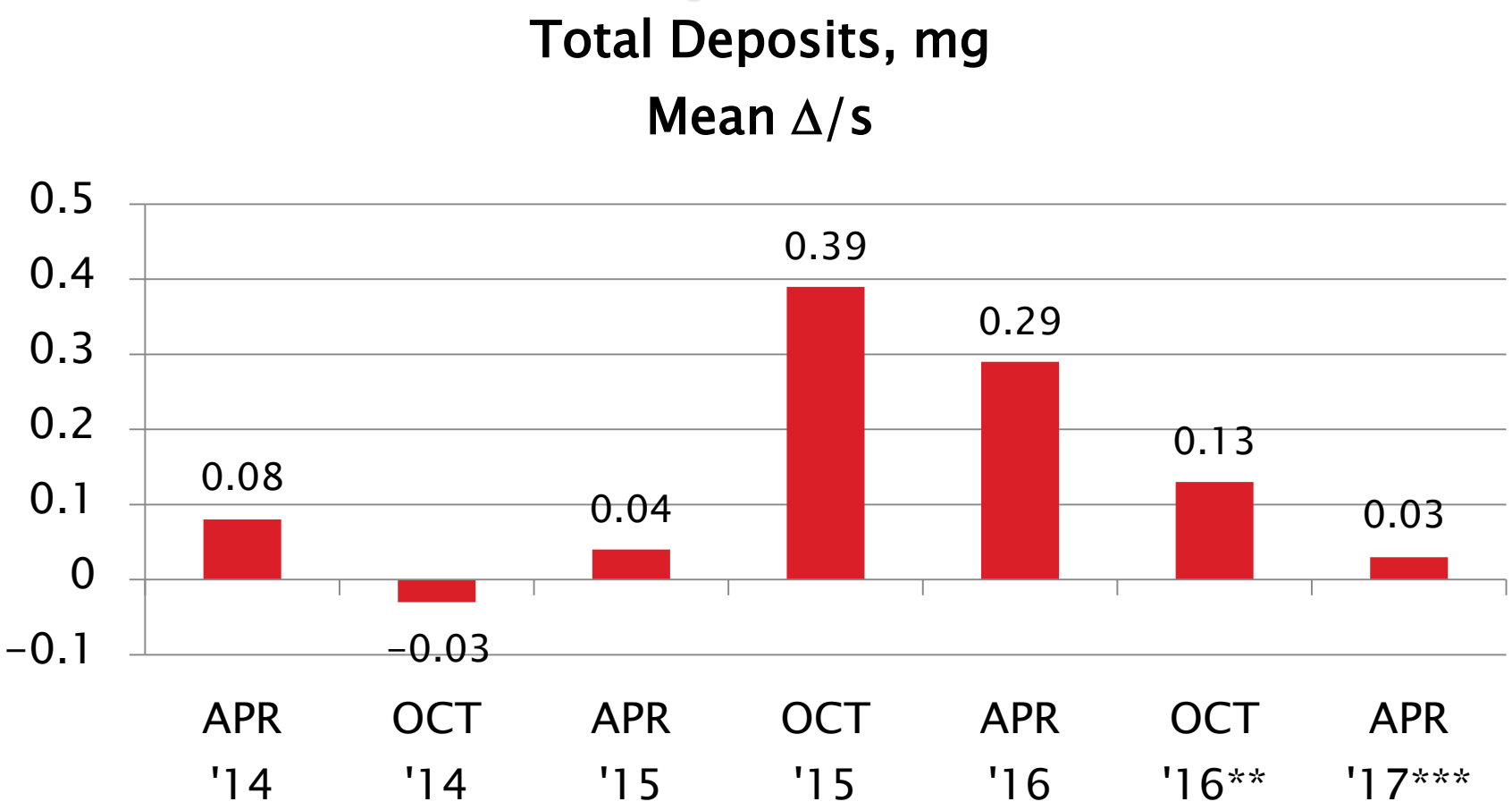
D7097 Severity Estimates



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

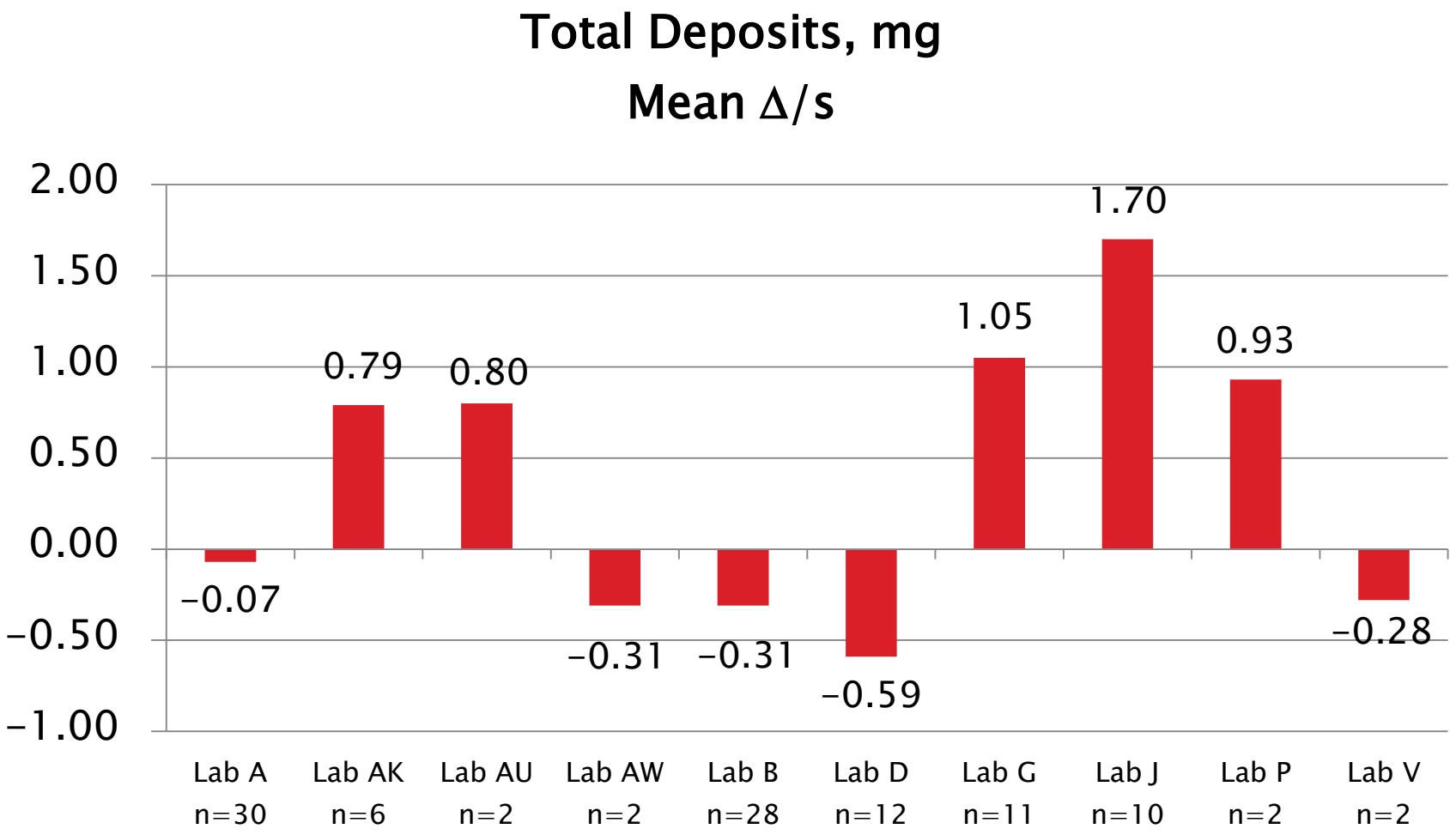
D7097: Deposits by MHT TEOST

Current Period Severity Estimates by Lab
Total Deposits, mg

Lab	n	Mean Δ/s	Lab	n	Mean Δ/s
Lab A	30	-0.07	Lab D	12	-0.59
Lab AK	6	0.79	Lab G	11	1.05
Lab AU	2	0.80	Lab J	10	1.70*
Lab AW	2	-0.31	Lab P	2	0.93
Lab B	28	-0.31	Lab V	2	-0.28

*Lab J Includes 4 failing sets of two-test calibrations

D7097 Lab Severity Estimates



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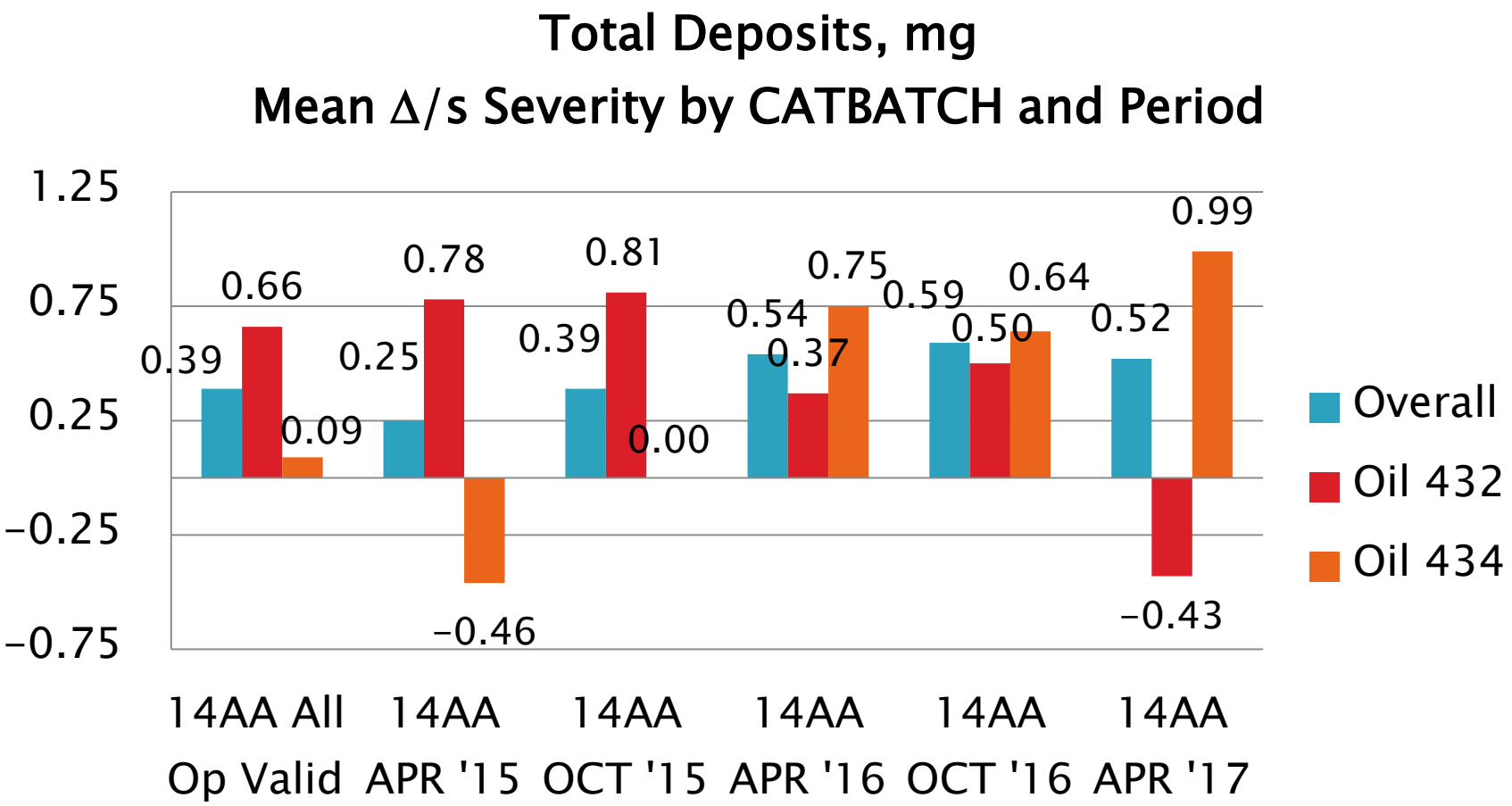
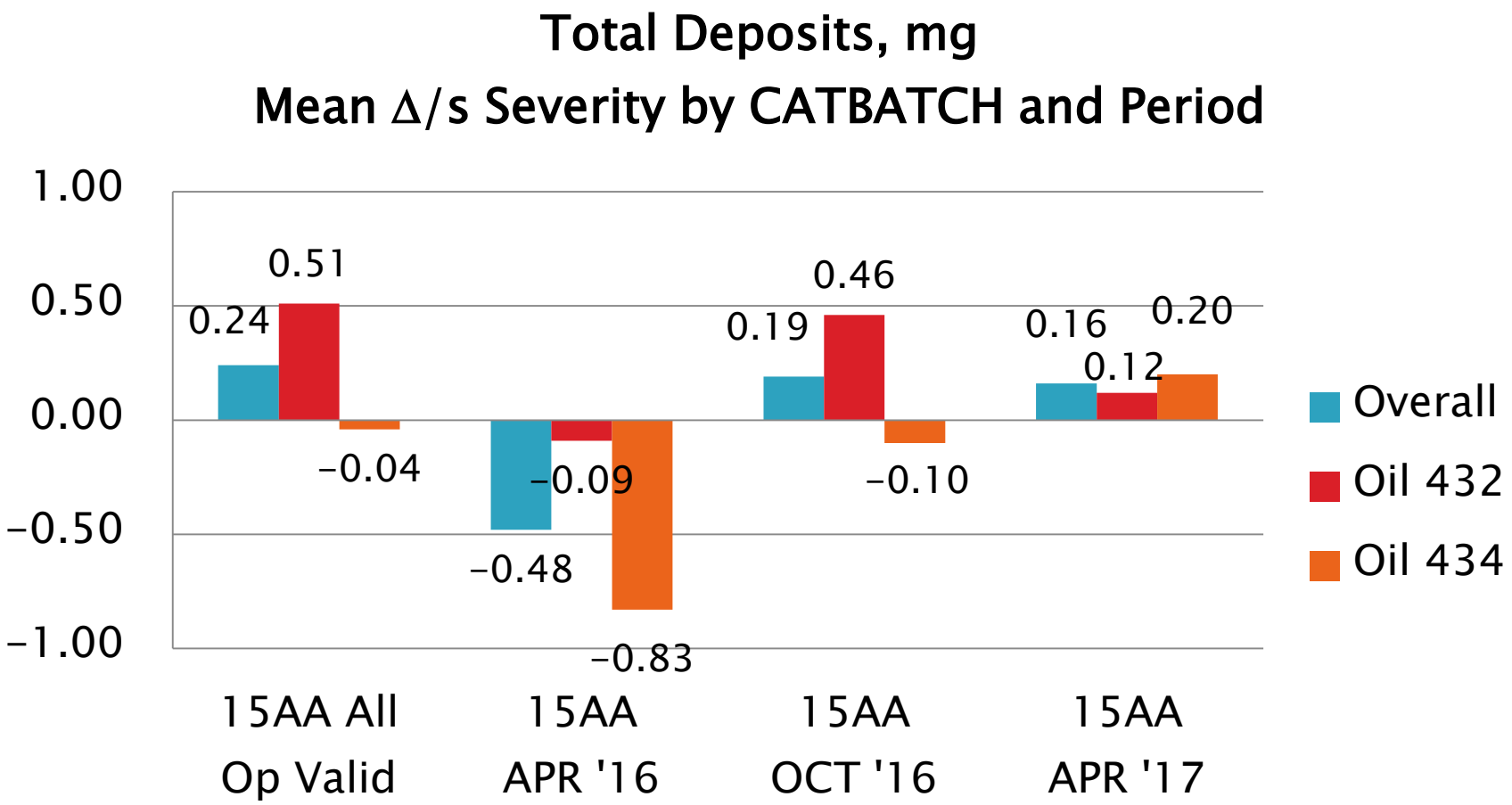
D7097: Deposits by MHT TEOST



D7097: Deposits by MHT TEOST



D7097: Deposits by MHT TEOST

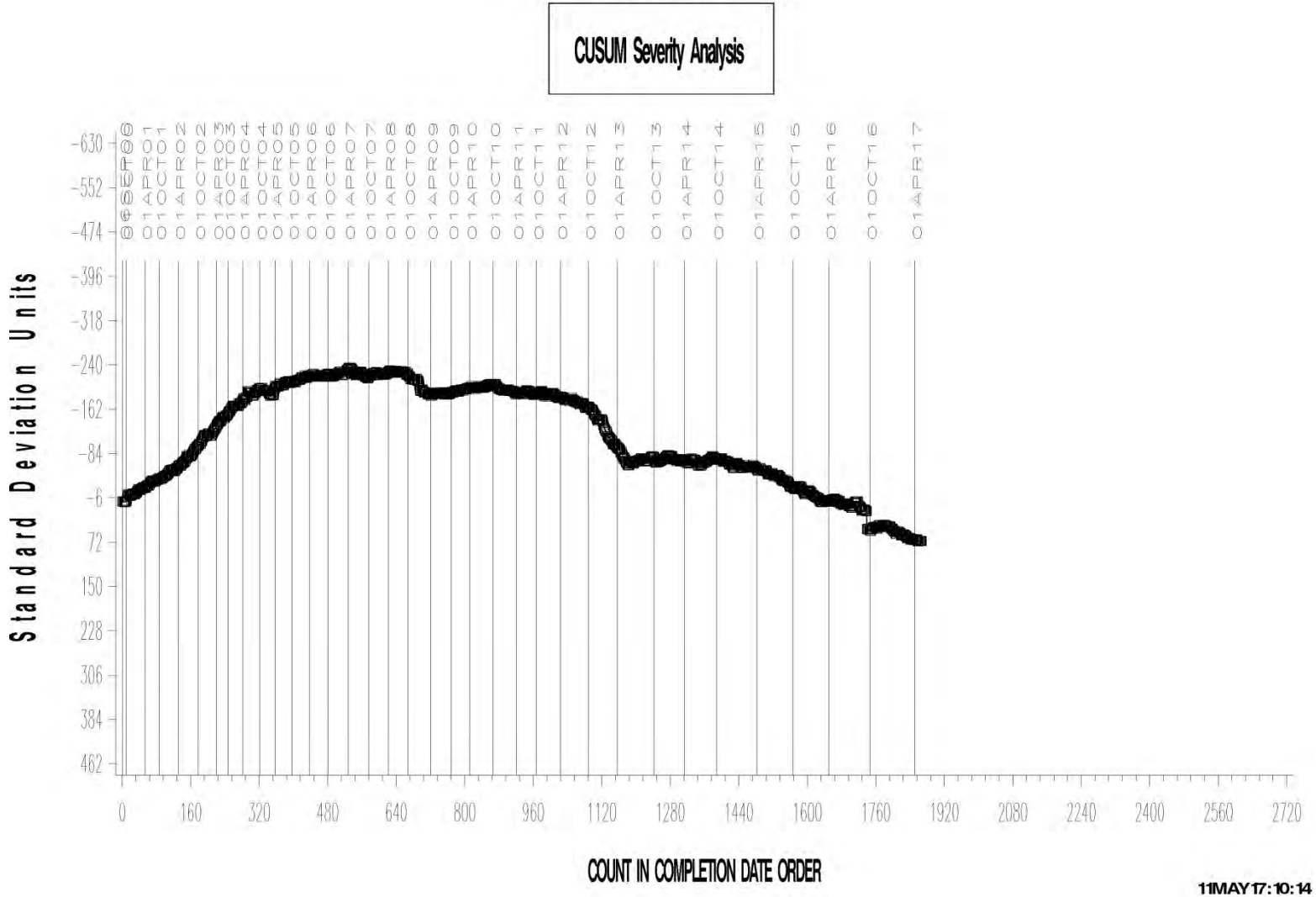
- Instrument J2 has four consecutive failing two-test sequence calibration attempts with four failing (OC) runs, two on each oil. Overall statistics in this report are shown with these eight tests included and excluded; the lab has not yet successfully re-calibrated the instrument.
  - Under prior calibration requirements, this instrument likely would have passed calibration on just one passing run. The new two-test requirements have appropriately flagged this instrument as statistically problematic.
- New end cap flask seals were added this period by test method update
- Precision (Pooled s) is somewhat better to prior period (with J2 excluded)
  - Remains less precise than target precision
- Performance (Mean Δ/s) is on target (-0.03 s) (with J2 excluded)
- All operationally valid tests this period report using Rod Batch L or M
- All operationally valid calibration tests this period report using Catalyst Batch 14AA (n=3) or 15AA (n=102)

D7097: Deposits by MHT TEOST

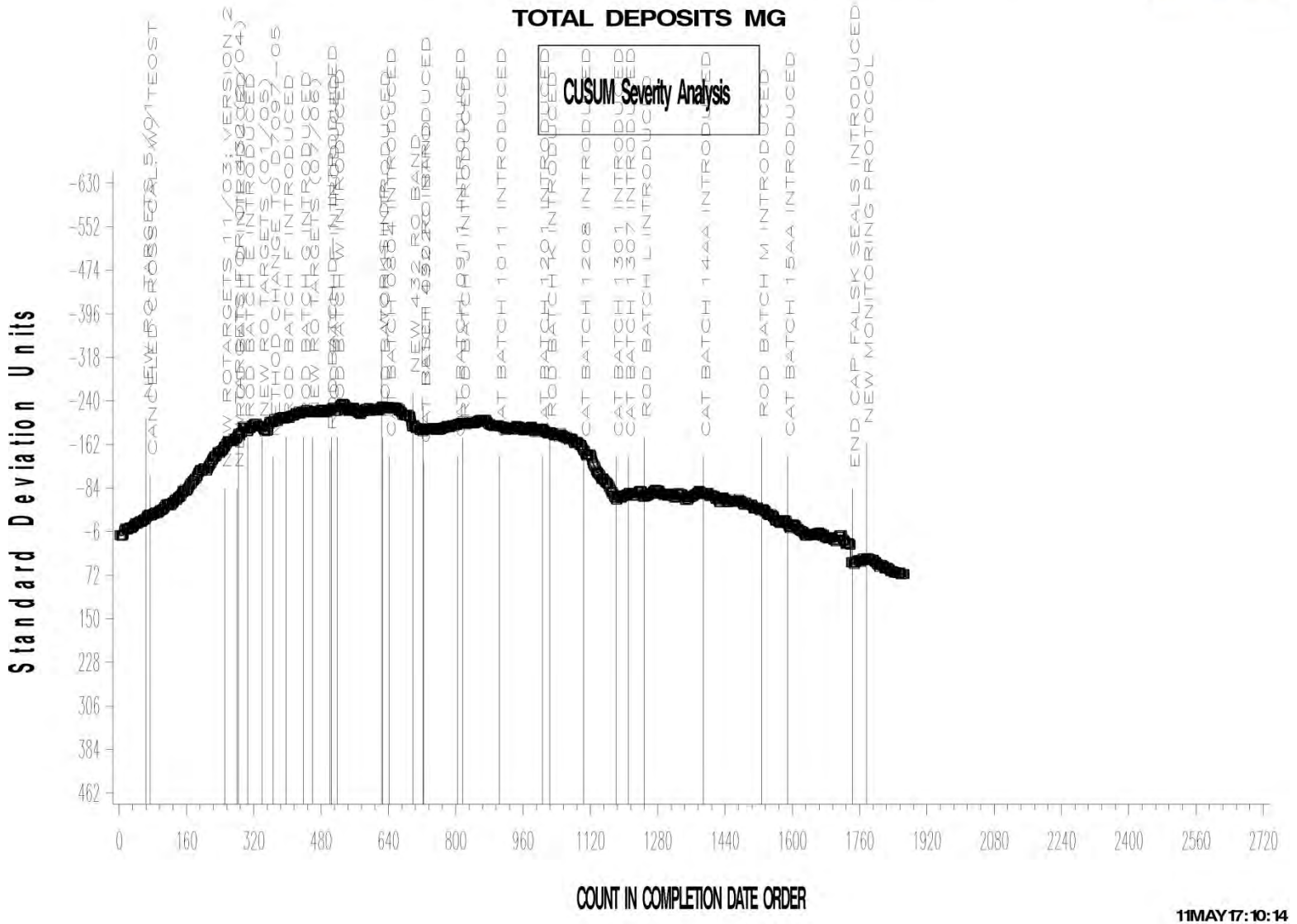
- CUSUM severity plot shows some leveling the past two periods (except for a single very severe result)
  - However, lab performance differences persist
- Precision on oil 434 has improved compared to last period, but still not near target precision, while precision on oil 432 is again much worse.
- Catalyst batch 15AA appears to have less of a bias on test results than prior catalyst batches, especially on severe oil 432

MHT—4 TEOST INDUSTRY OPERATIONALLY VALID DATA

TOTAL DEPOSITS MG



MHT—4 TEOST INDUSTRY OPERATIONALLY VALID DATA

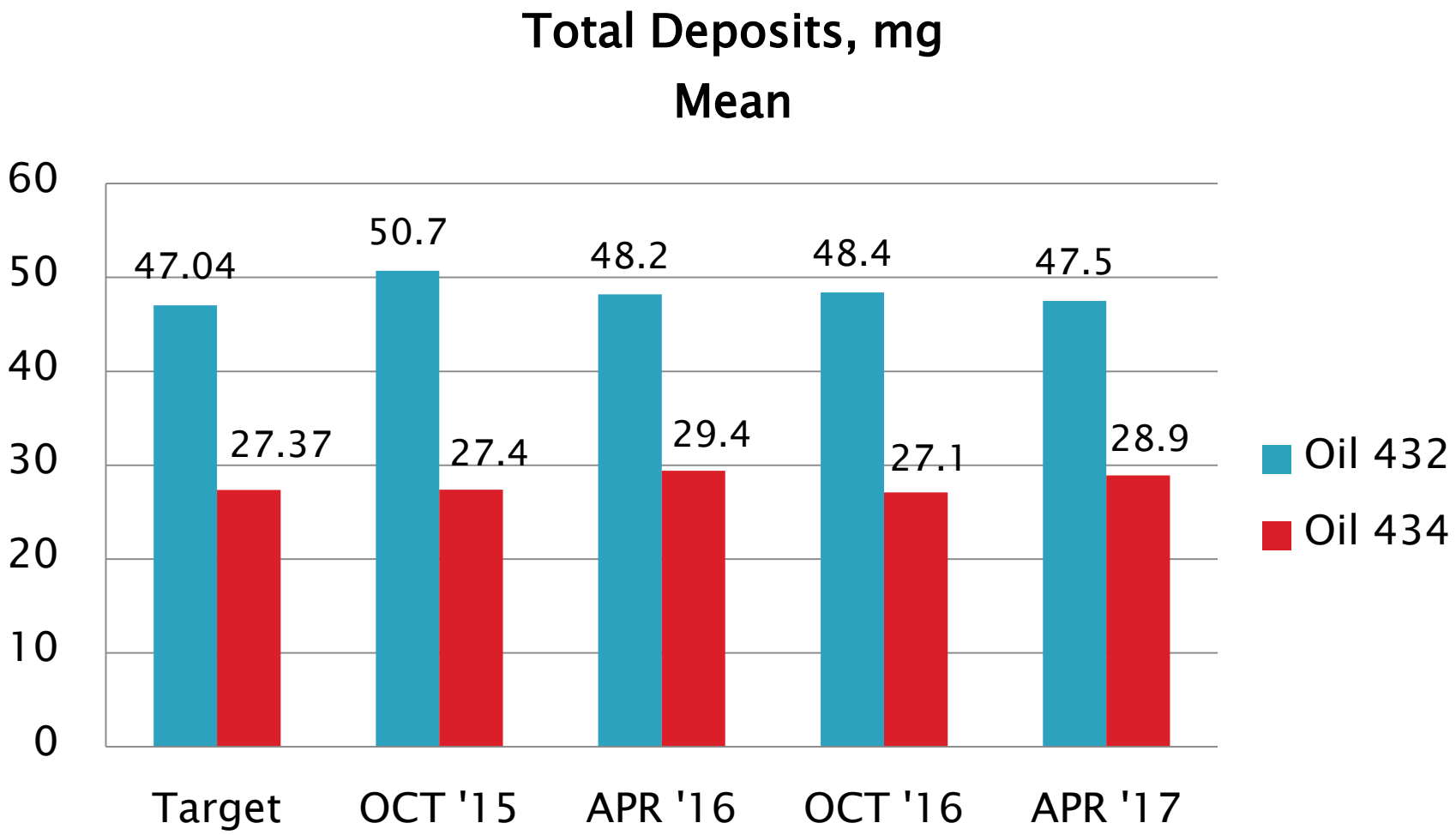


D7097 Performance by Oil

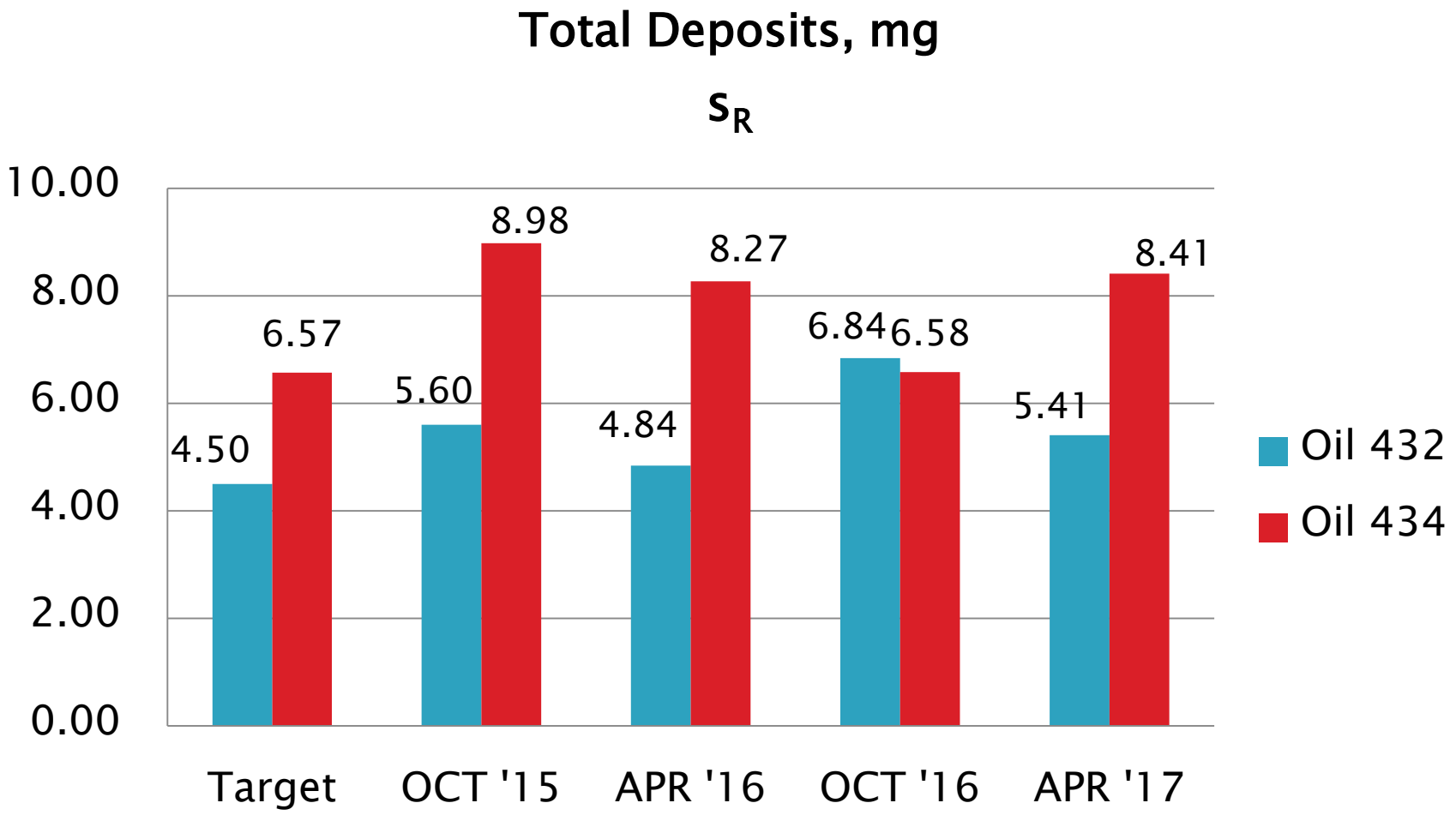
Total Deposits, mg
Performance by Oil

	Targets			10/1/15 – 3/31/16				4/1/16– 9/30/16				10/1/16 – 3/31/17			
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	44	48.2	4.84	0.27	45	48.4	6.84	0.31	51	47.5	5.41	0.11
434	30	27.37	6.57	40	29.4	8.27	0.31	48	27.1	6.58	-0.04	54	28.9	8.41	0.23

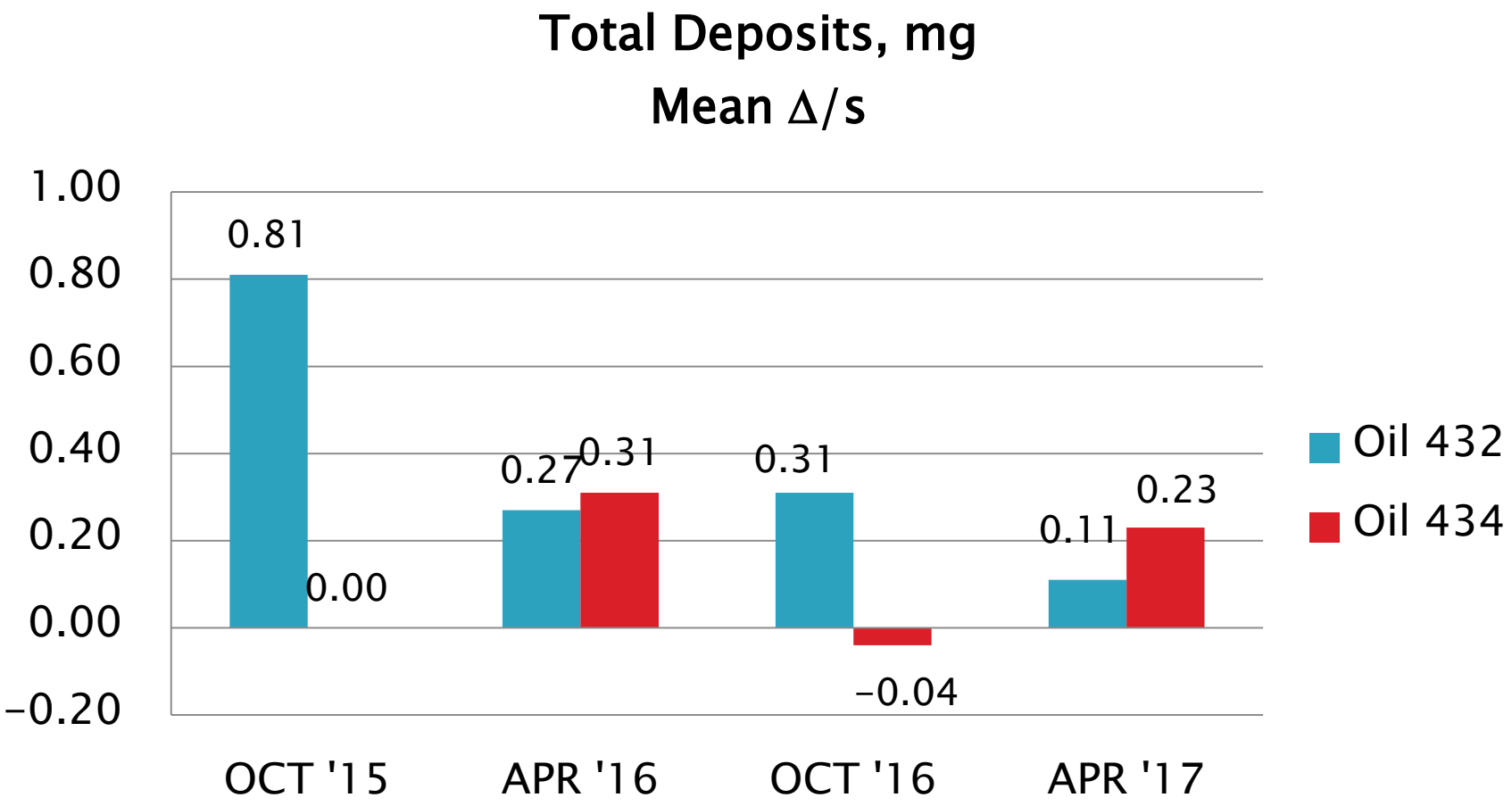
D7097 Performance by Oil



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	5
Failed Calibration Test	OC	0
Failed Discrimination Test	OS	1
Operationally Invalidated by Lab	LC, XC	0
Operationally Invalidated After Initially Reported as Valid	RS	1
Total		**21**

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

- One discrimination test failed statistically (OS) with a Foam Stability result > 0 ml (passed on retest). All other discrimination runs reported this period could discriminate oil 66 as a GF-5/SN failing oil for Foam Tendency.

- One discrimination test initially failed with a mild foam tendency, later found to have an air leak (validity RS; passed on retest).

- No TMC technical updates issued this period

D6082: High Temperature Foam

Period Precision and Severity Estimates Oil 1007

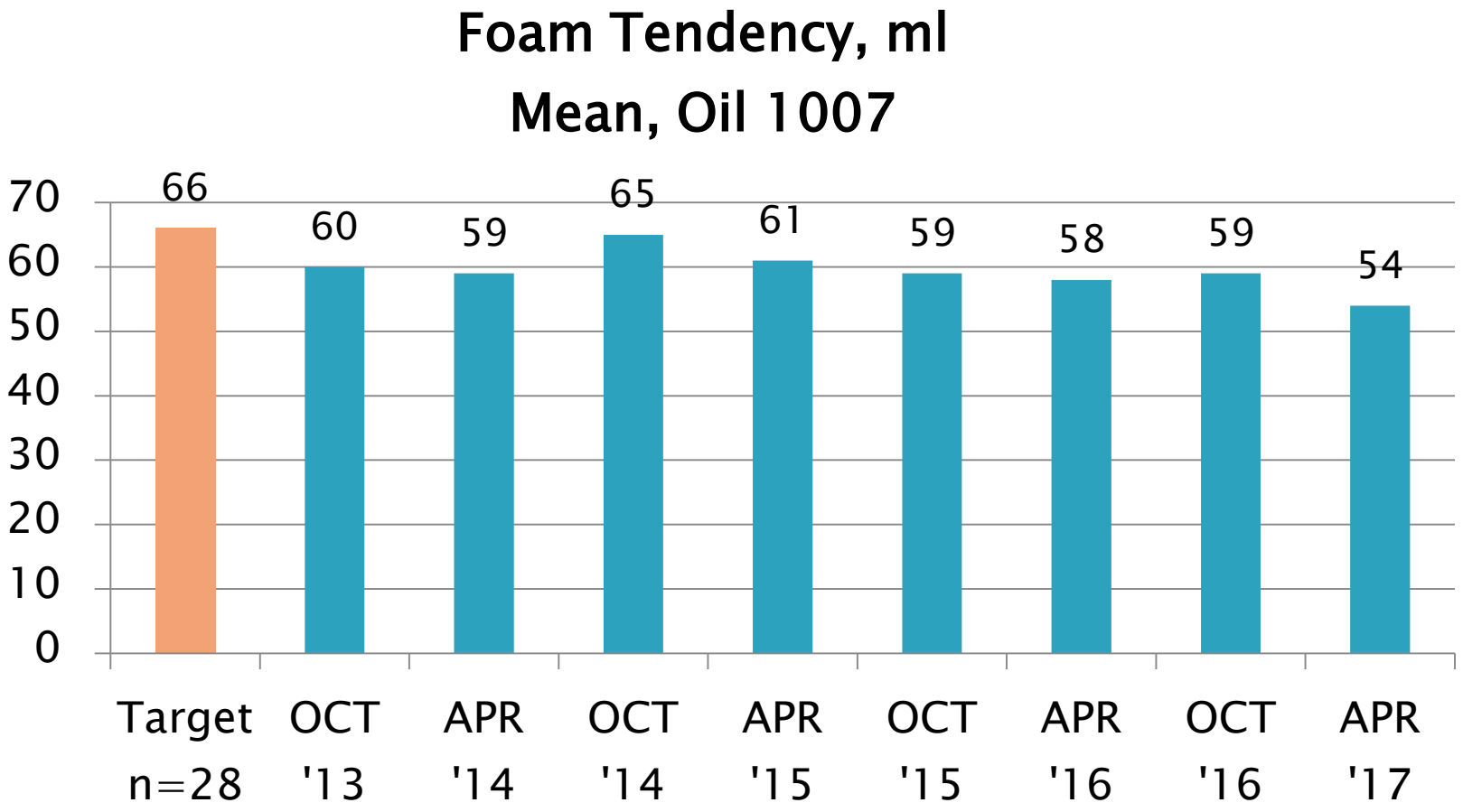
Foam Tendency, ml	n	Mean	Pooled s	Mean Δ/s
Current Targets	28	65.71	19.28	-----
4/1/13 through 9/30/13	9	60	7	-0.32
10/1/13 through 3/31/14	11	59	8	-0.39
4/1/14 through 9/30/14	11	65	22	-0.05
10/1/14 through 3/31/15	10	61	12	-0.26
4/1/15 through 9/30/15	11	59	16	-0.36
10/1/15 through 3/31/16	8	58	10	-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

D6082: High Temperature Foam

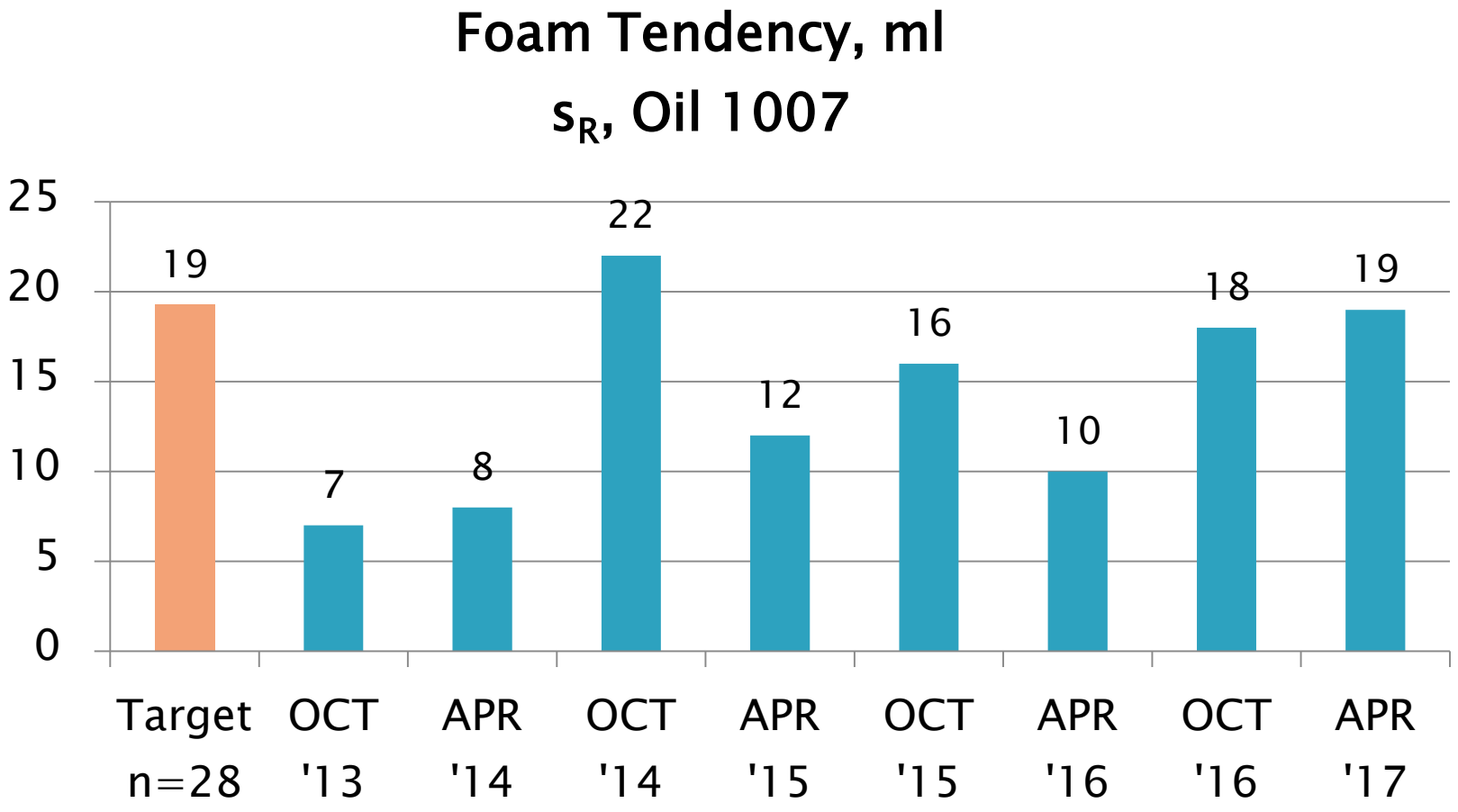
Period Precision and Severity Estimates Oil 1007

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

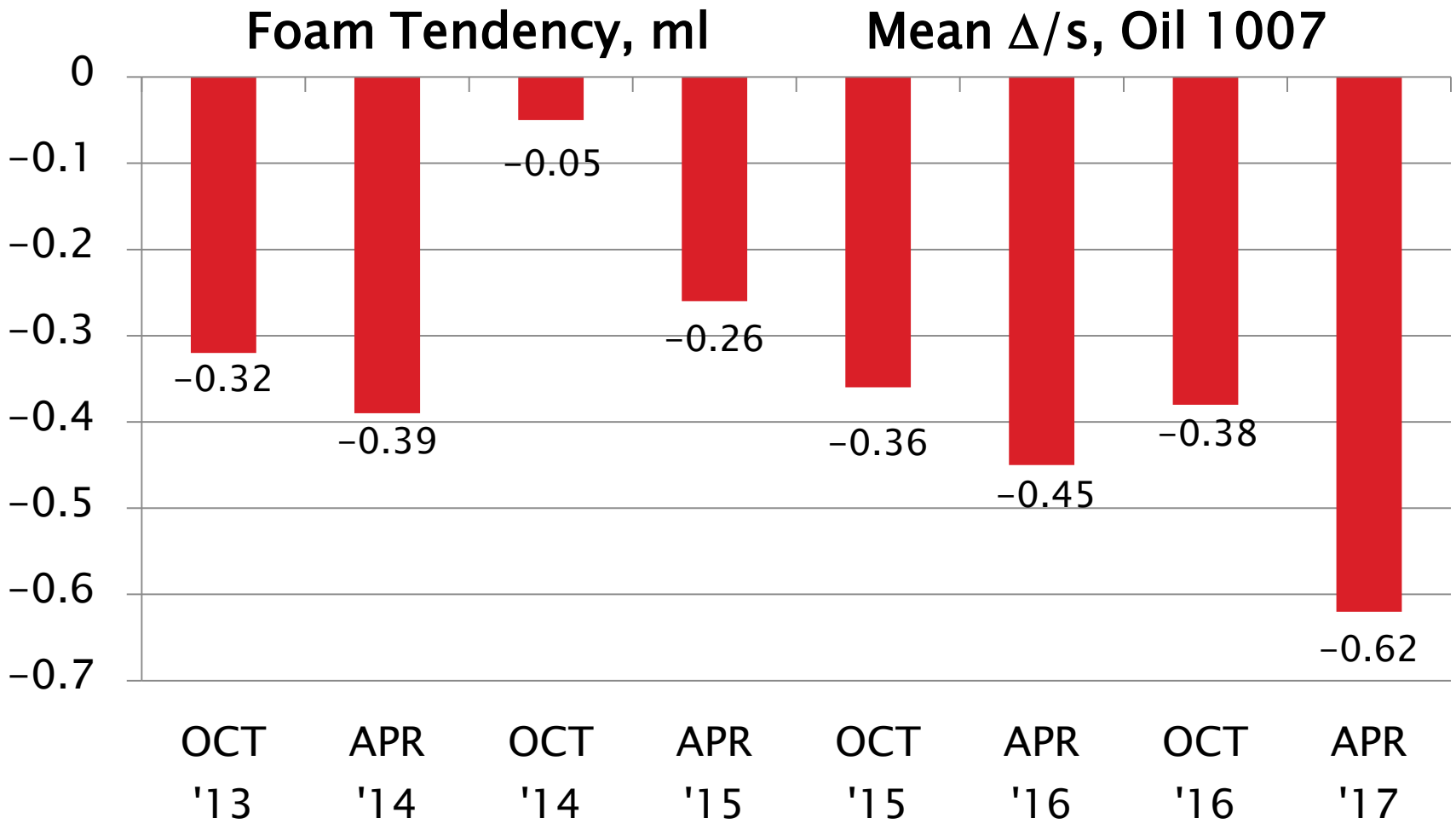
D6082: High Temperature Foam



D6082: High Temperature Foam



D6082: High Temperature Foam

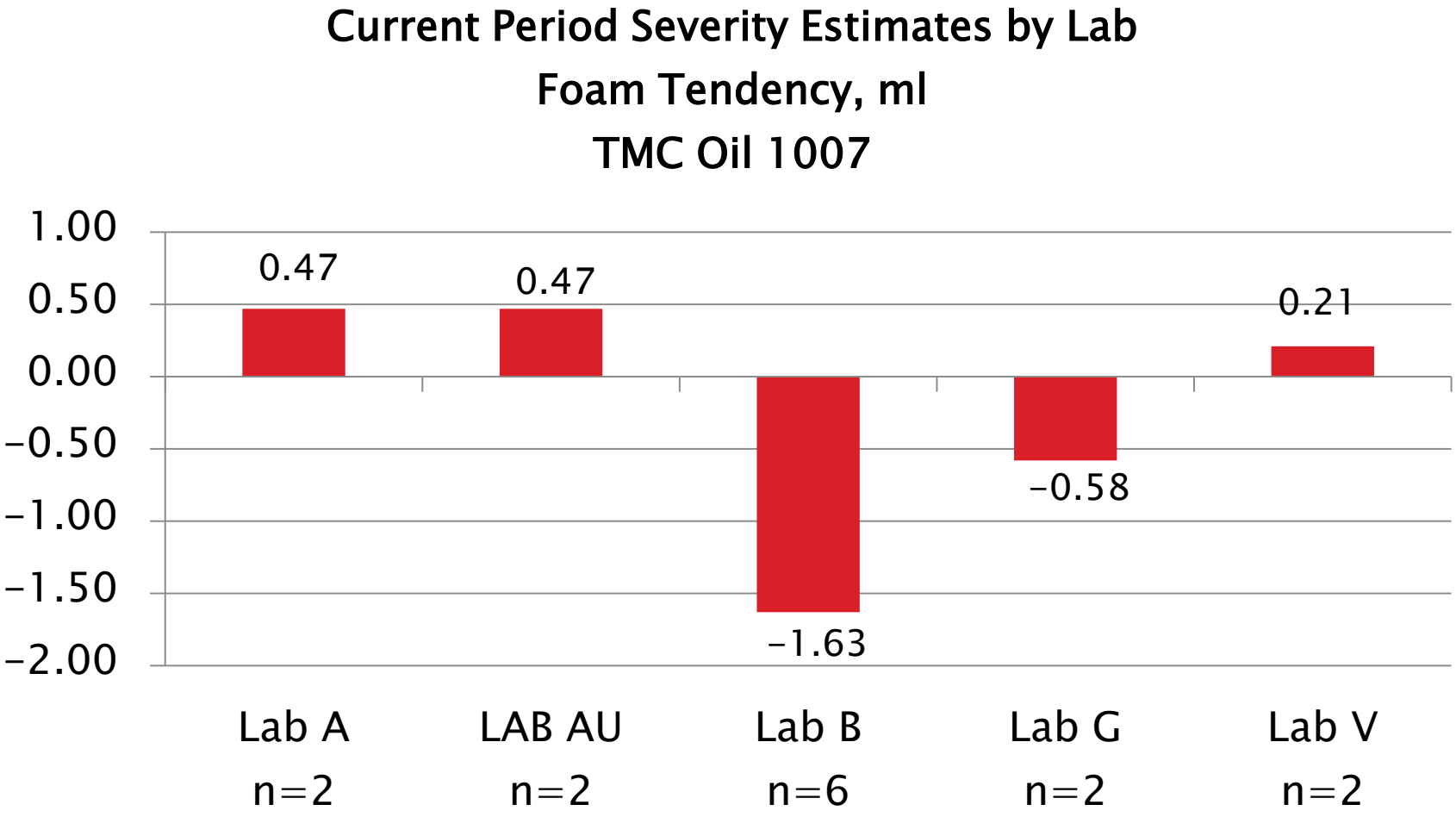


D6082: High Temperature Foam

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

	n	Mean Δ/s
Lab A	2	0.47
Lab AU	2	0.47
Lab B	6	-1.63
Lab G	2	-0.58
Lab V	2	0.21

D6082: High Temperature Foam



D6082: High Temperature Foam

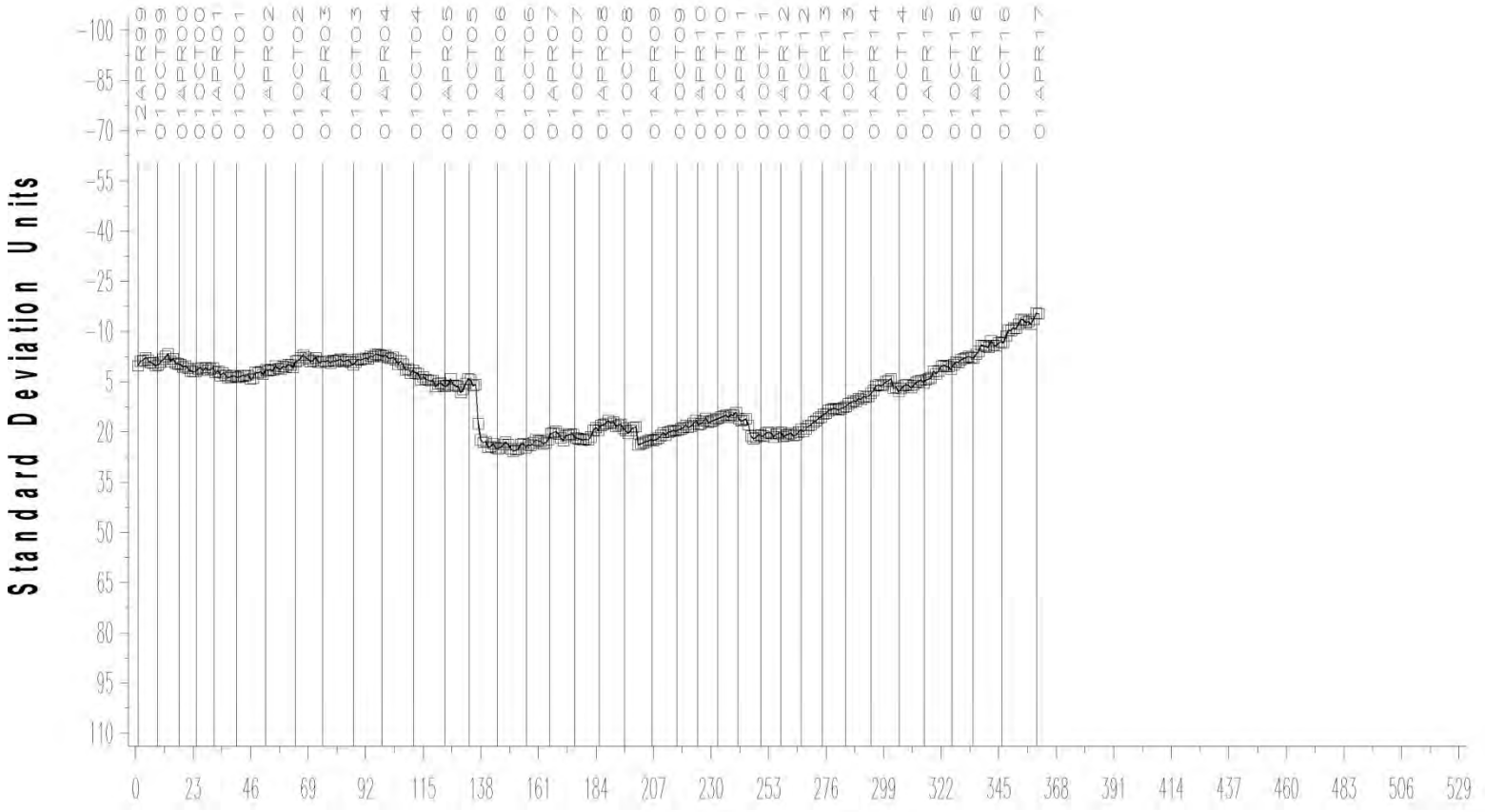
- Foam Tendency Precision (Pooled s) is comparable to prior period
  - Comparable to target precision
- Performance (Mean Δ/s) is -0.62 s mild
  - Most mild period since at least October 2013
  - Attributable mostly to Lab B (two instruments, six tests, all between -1.3 and -1.9 s mild)
- No non-zero occurrences of Foam Stability (on operationally valid tests)
- All but one operationally valid discrimination runs demonstrated acceptable discrimination, the one fail passed on retest.

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	7
Failed Calibration Test	OC	0
Operationally Invalidated by Lab	LC, XC	0
Operationally Invalidated After Initially Reported as Valid	RC	0
Total		**7**

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

D874: Sulfated Ash

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

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

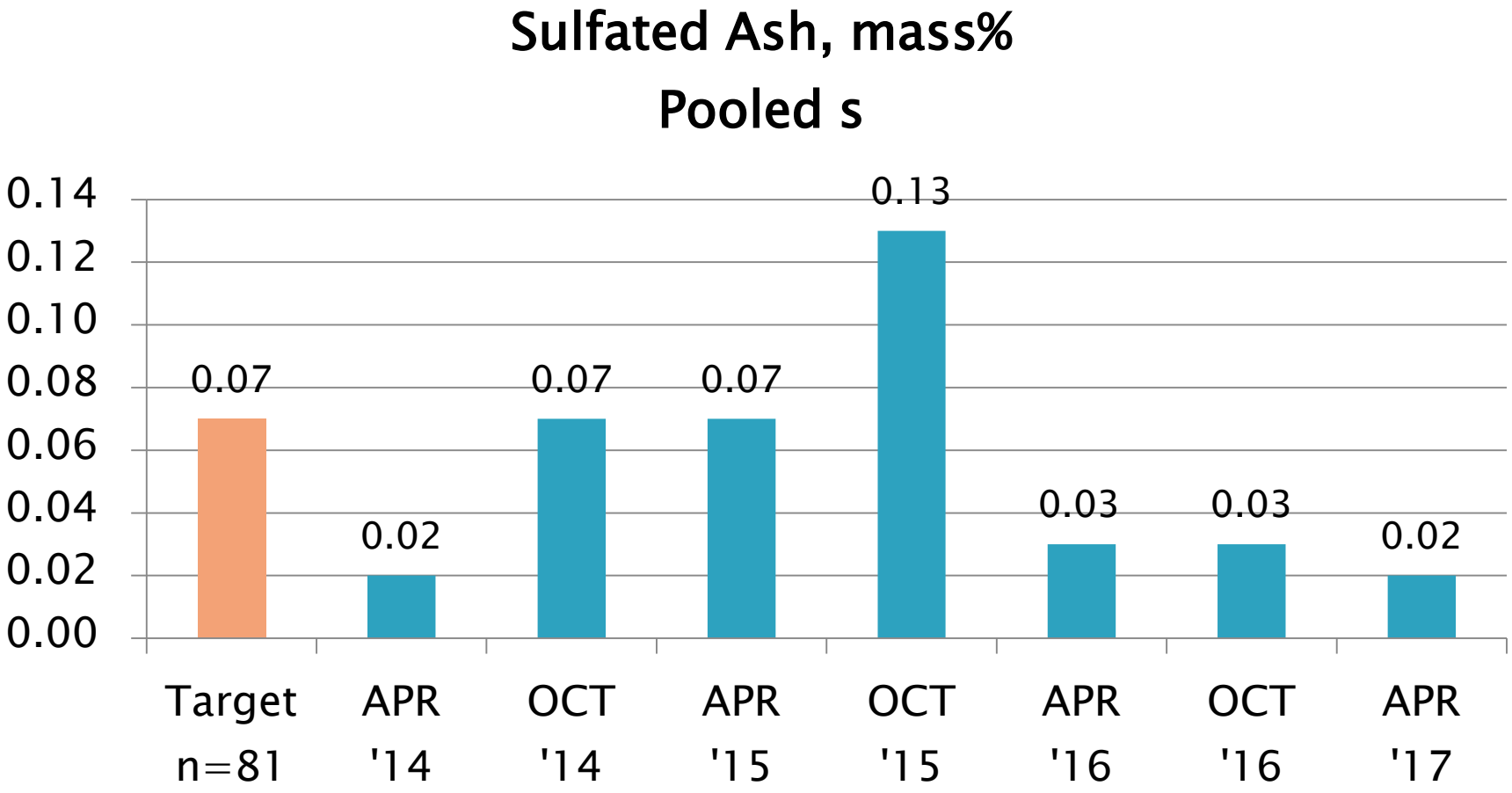
D874: Sulfated Ash

Period Precision and Severity Estimates

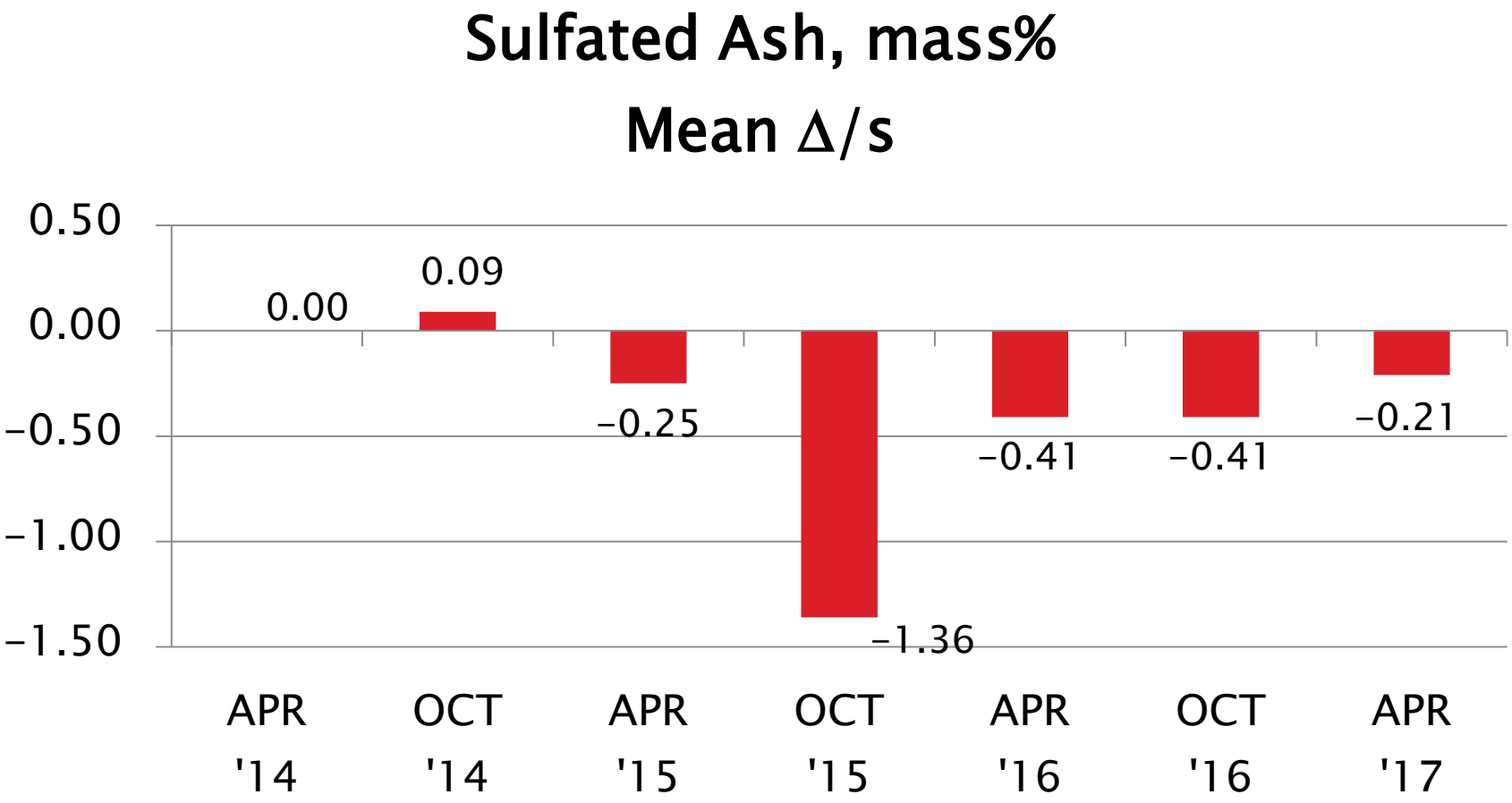
Total Deposits, mg	n	df	Pooled s	Mean Δ/s
Current Targets	81	78	0.07	-----
10/1/13 through 3/31/14	5	2	0.02	0.00
4/1/14 through 9/30/14	6	3	0.07	0.09
10/1/14 through 3/31/15	6	4	0.07	-0.25
4/1/15 through 9/30/15* 4/1/15 through 9/30/15*	8 7	5 4	0.13 0.05	-1.36 -0.36
10/1/15 through 3/31/16	7	4	0.03	-0.41
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

*Period statistics with and without extreme result included

D874: Sulfated Ash



D874: Sulfated Ash

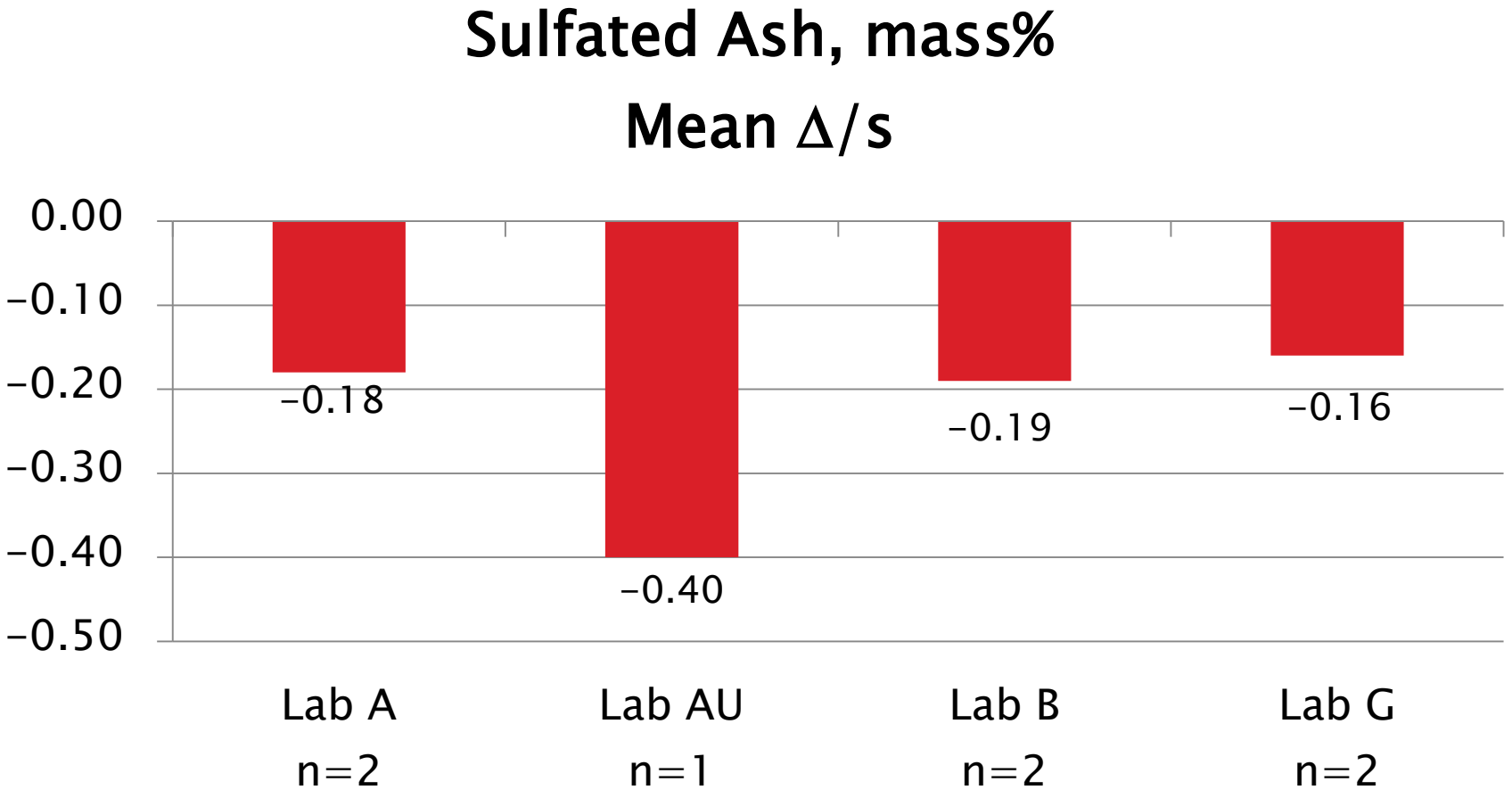


D874: Sulfated Ash

Current Period Severity Estimates by Lab
Sulfated Ash, mass%

	n	Mean Δ/s
Lab A	2	-0.18
Lab AU	1	-0.40
Lab B	2	-0.19
Lab G	2	-0.16

D874: Sulfated Ash



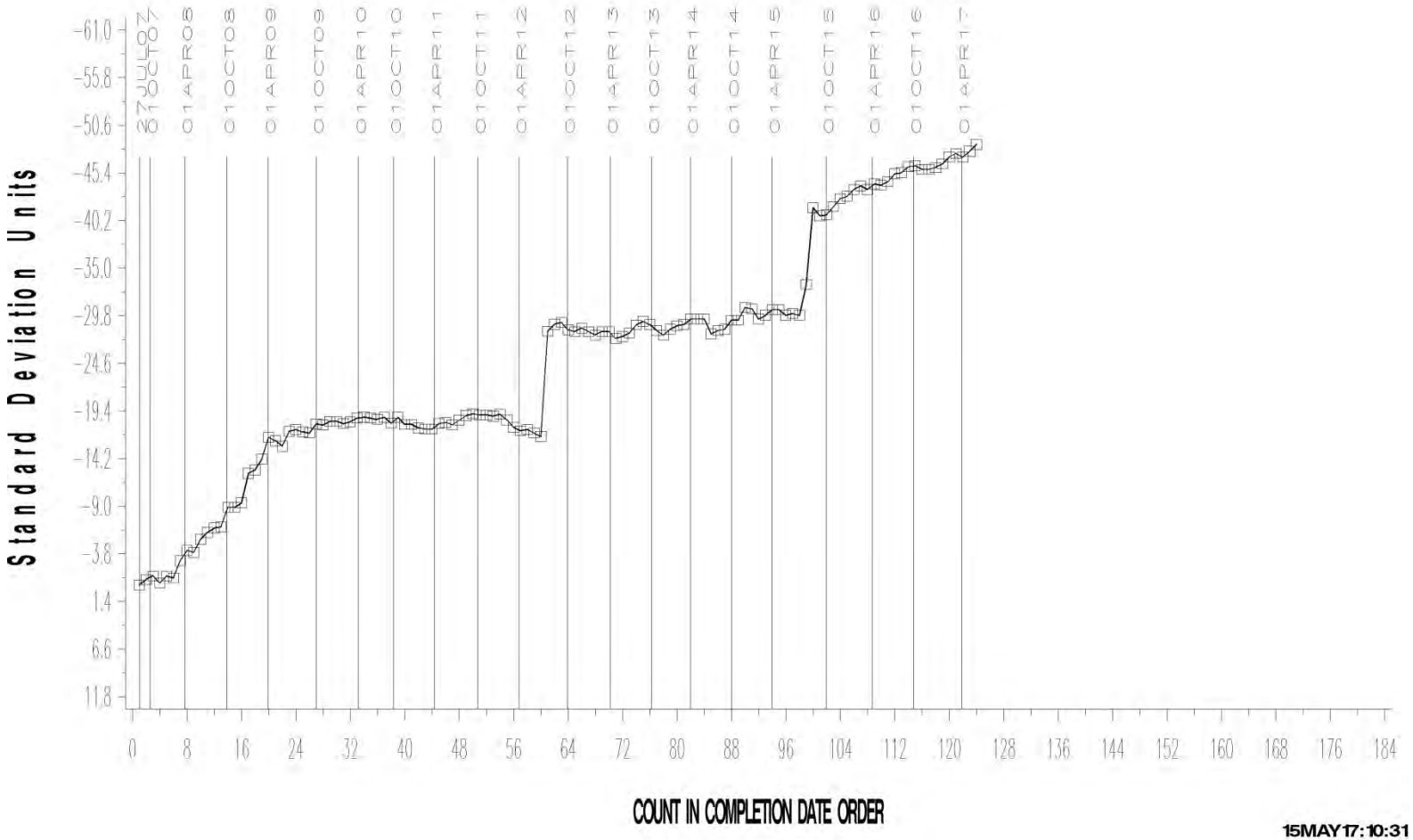
D874: Sulfated Ash

- Precision (Pooled s) is comparable to the prior period
  - More precise than target precision
- Performance (Mean Δ/s) is -0.21 s mild
  - All labs performing mild to some degree

D874 INDUSTRY OPERATIONALLY VALID DATA

TEST SAMPLE PERCENT SULFATED ASH

CUSUM Severity Analysis



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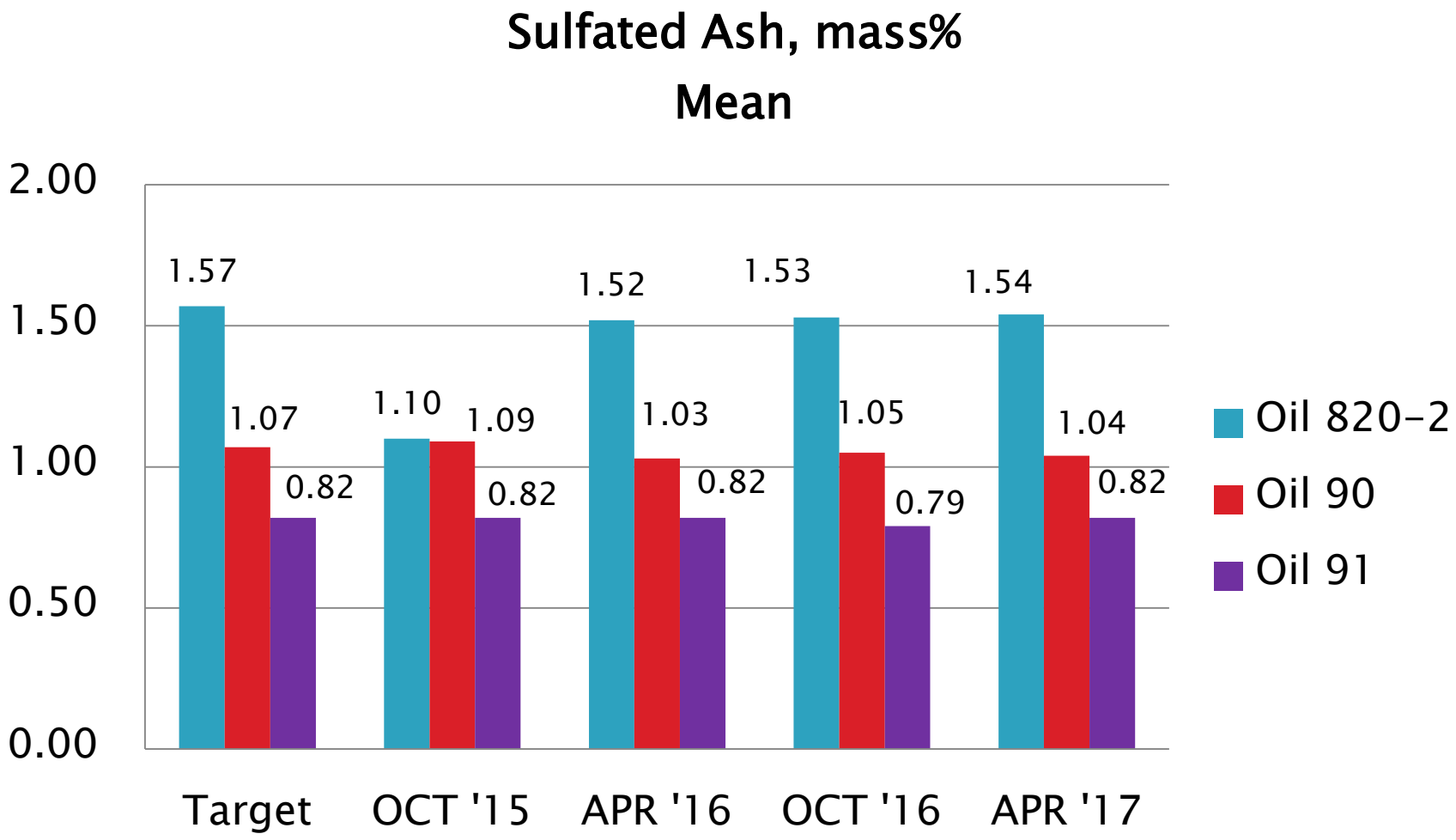
D874: Sulfated Ash

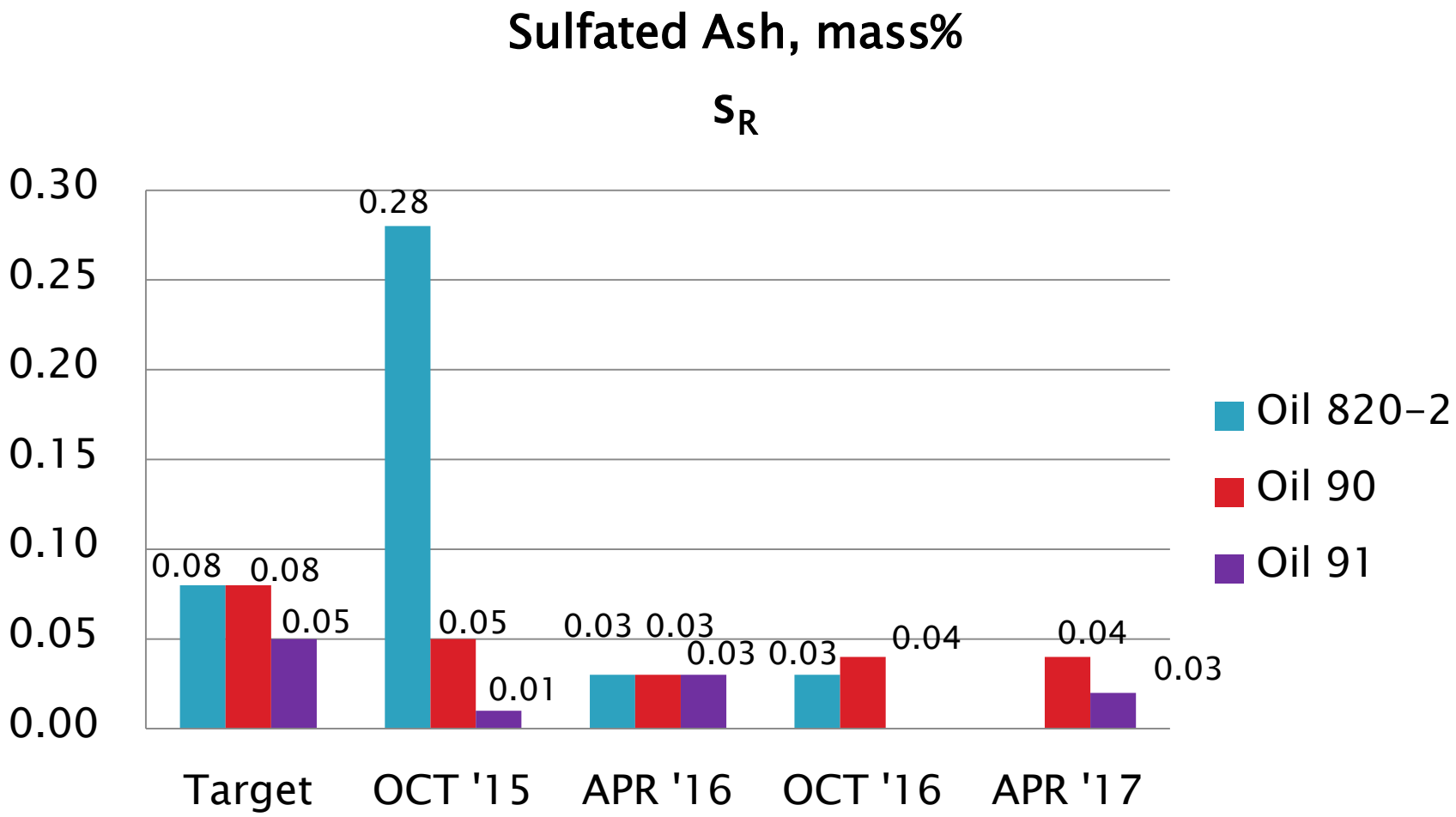
Performance by Oil
Sulfated Ash, mass%

	Targets			10/1/15 – 3/31/16				4/1/16 – 9/30/16				10/1/16 – 3/31/17			
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	1.52	0.03	-0.62	3	1.53	0.03	-0.46	1	1.54	---	-0.38
90	27	1.07	0.08	2	1.03	0.03	-0.50	2	1.05	0.04	-0.25	2	1.04	0.04	-0.44
91	27	0.82	0.05	2	0.82	0.03	0.00	1	0.79	---	-0.60	4	0.82	0.02	-0.05

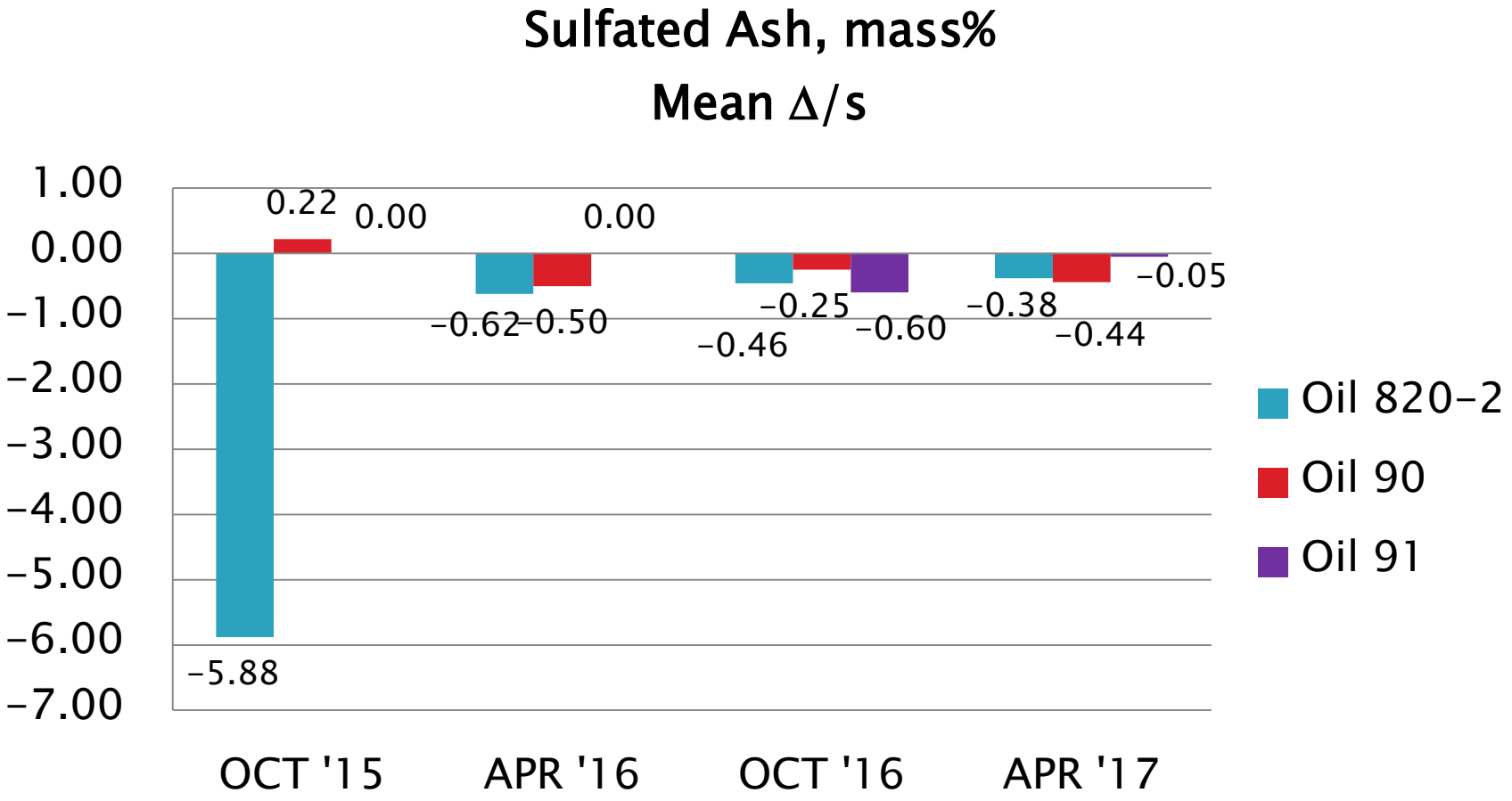
D874: Sulfated Ash



D874: Sulfated Ash



D874: Sulfated Ash



Return to Executive Summary

D7528: Oxidation by ROBO

Test Status	Validity Code	No. Tests
Acceptable Calibration Test	AC	65
Failed Calibration Test	OC	13
Operationally Invalidated by Lab	LC, XC	9
Operationally Invalidated After Initially Reported as Valid	RC	1
Rig Shakedown Runs	NN	3
New Oil Screening Donated Runs	AG	5
Total		**96**

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

D7528: Oxidation by ROBO

Operationally Invalid Tests

- 1 test unexplained high EOT volatiles (RC)
- 4 tests heater or heater control failure (XC)
- 1 test wrong vacuum control valve setting (LC)
- 3 tests NO_2 Flow Off-Spec (LC)
- 1 test sample completely oxidized before EOT (XC)

Other Tests

- 3 tests required pre-calibration shakedown runs on new rig
- 5 tests donated screener runs on proposed replacement reference oil 434-2

D7528: Oxidation by ROBO

Statistically Unacceptable Tests (OC)	No. Of Tests
Natural Log (MRV Viscosity) Mild	11
Natural Log (MRV Viscosity) Severe	2

- No technical memos were issued this period for ROBO.
  - As of this report, ROBO Information Letter 16-1 (March 11. 2016) changes have not yet been published in an updated D7528 Test Method.

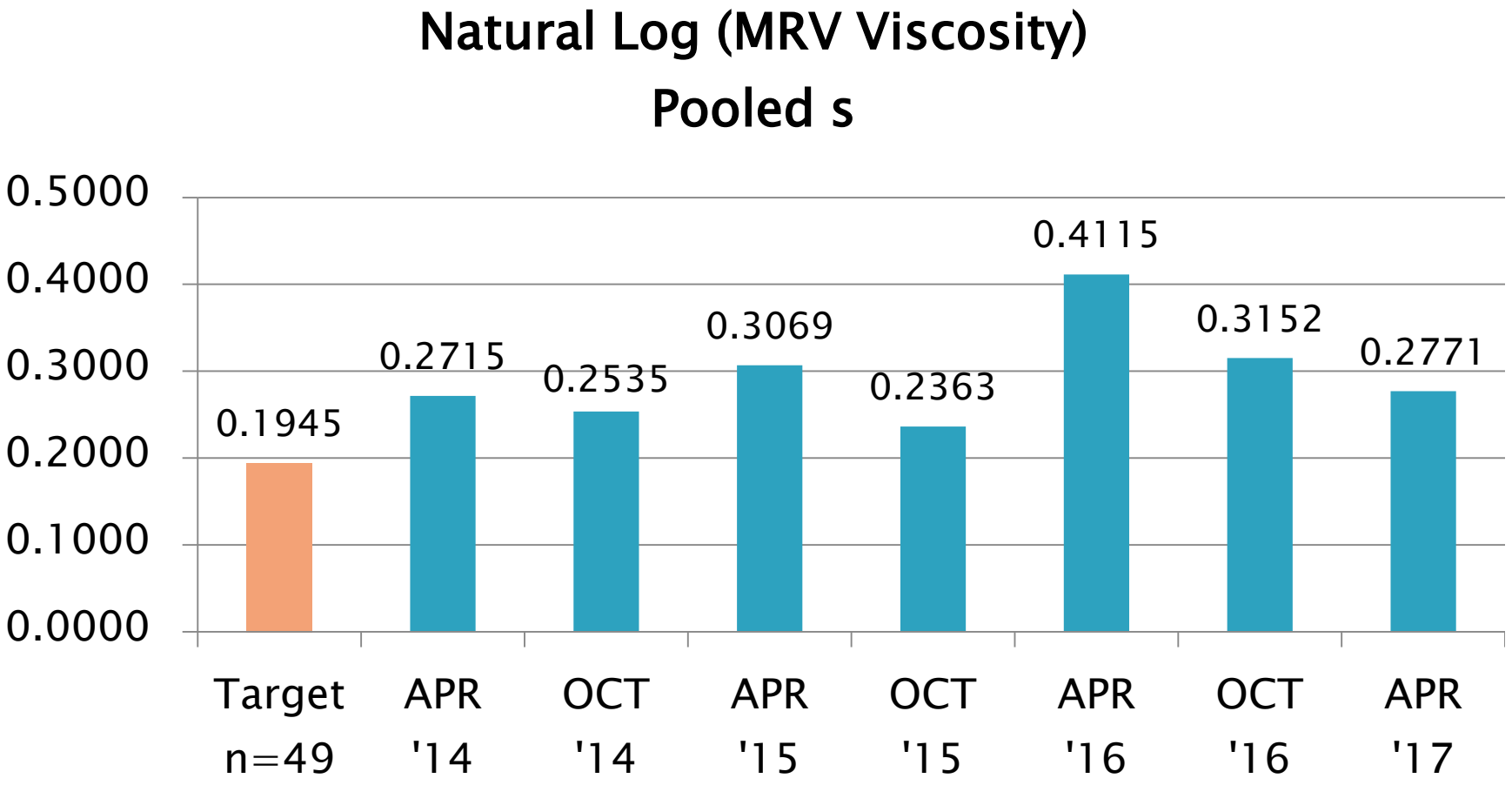
D7528: Oxidation by ROBO

Period Precision and Severity Estimates

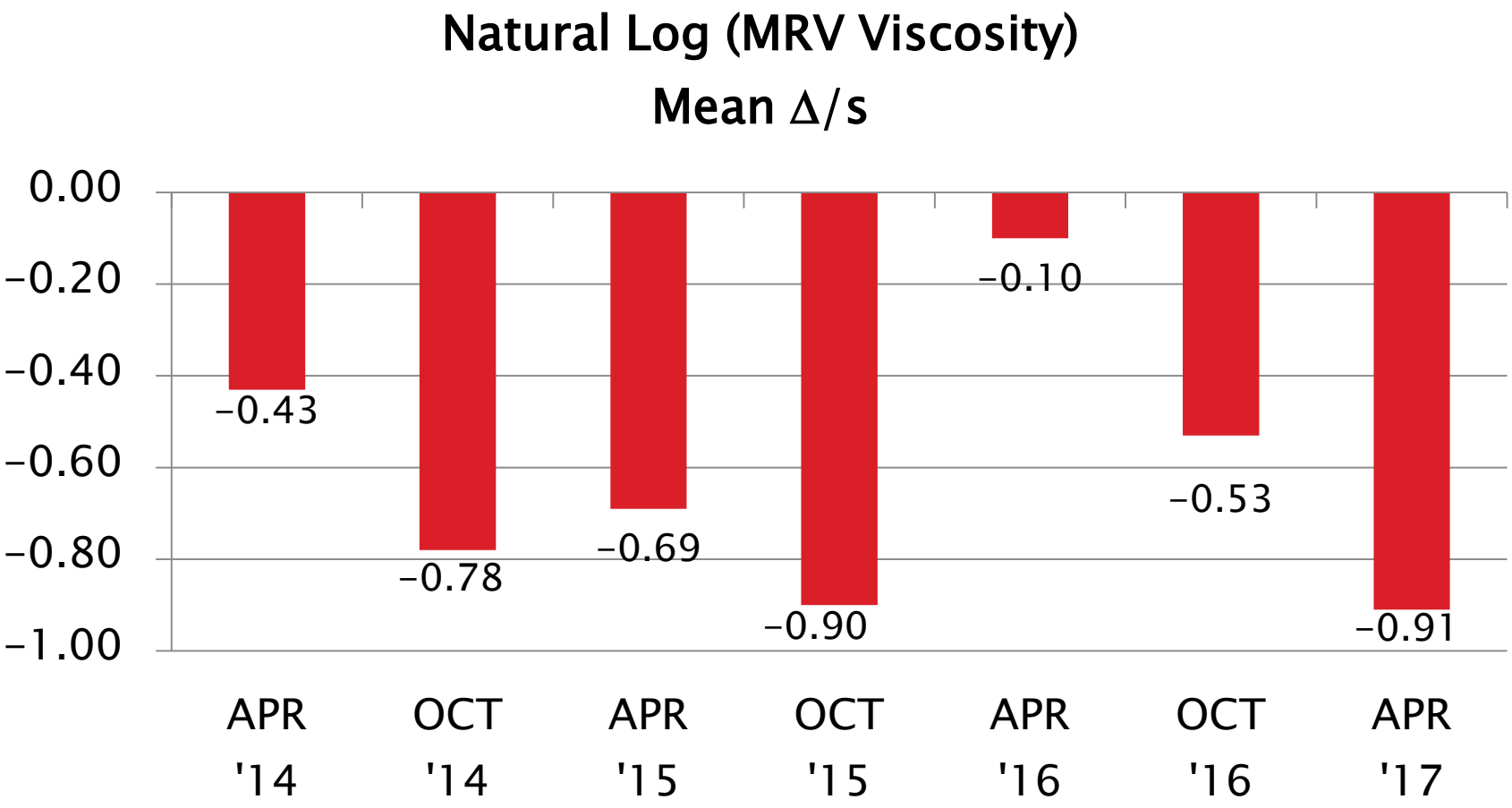
Natural Log (MRV Viscosity)	n	df	Pooled s	Mean Δ/s
Current Targets	49	46	0.1945	-----
10/1/13 through 3/31/14	85	82	0.2715	-0.43
4/1/14 through 9/30/14	83	80	0.2535	-0.78
10/1/14 through 3/31/15	97	94	0.3069	-0.69
4/1/15 through 9/30/15	85	82	0.2363	-0.90
10/1/15 through 3/31/16*	92	89	0.4115	-0.10
10/1/15 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

*Period statistics with and without extreme result included

D7528: Oxidation by ROBO



D7528: Oxidation by ROBO

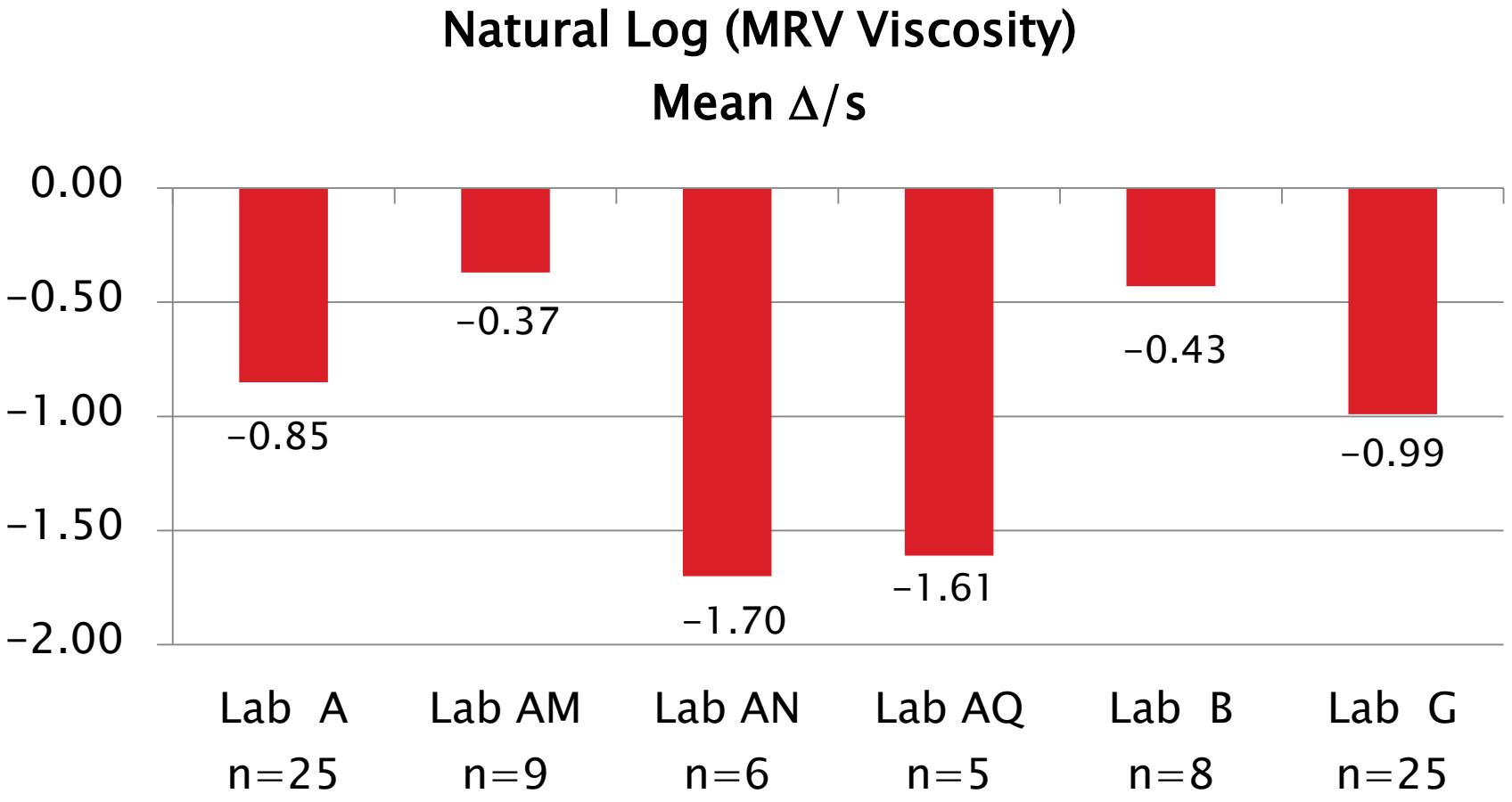


D7528: Oxidation by ROBO

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

	n	Mean Δ/s
Lab A	25	-0.85
Lab AM	9	-0.37
Lab AN	6	-1.70
Lab AQ	5	-1.61
Lab B	8	-0.43
Lab G	25	-0.99

D7528: Oxidation by ROBO



D7528: Oxidation by ROBO

- Precision (Pooled s) is more precise than the last two periods
  - Continues to be less precise than target precision
  - Seven tests on various rigs are between 3 and 5 s mild or severe this period (rig A1 @ 3.4 s, A1 @ -3.5 s, AN2A @ -3.9 s, AQ2 @ -4.5 s, G4 @ 4.4 s, G4 @ -3.3 s, G7 @ -3.2 s)
  - Rig G4 had 3 OC failing runs alternating with 3 AC passing runs this period
- Performance (Mean Δ/s) is -0.91 s mild with all labs mild and all three oils performing more than -0.8 s mild

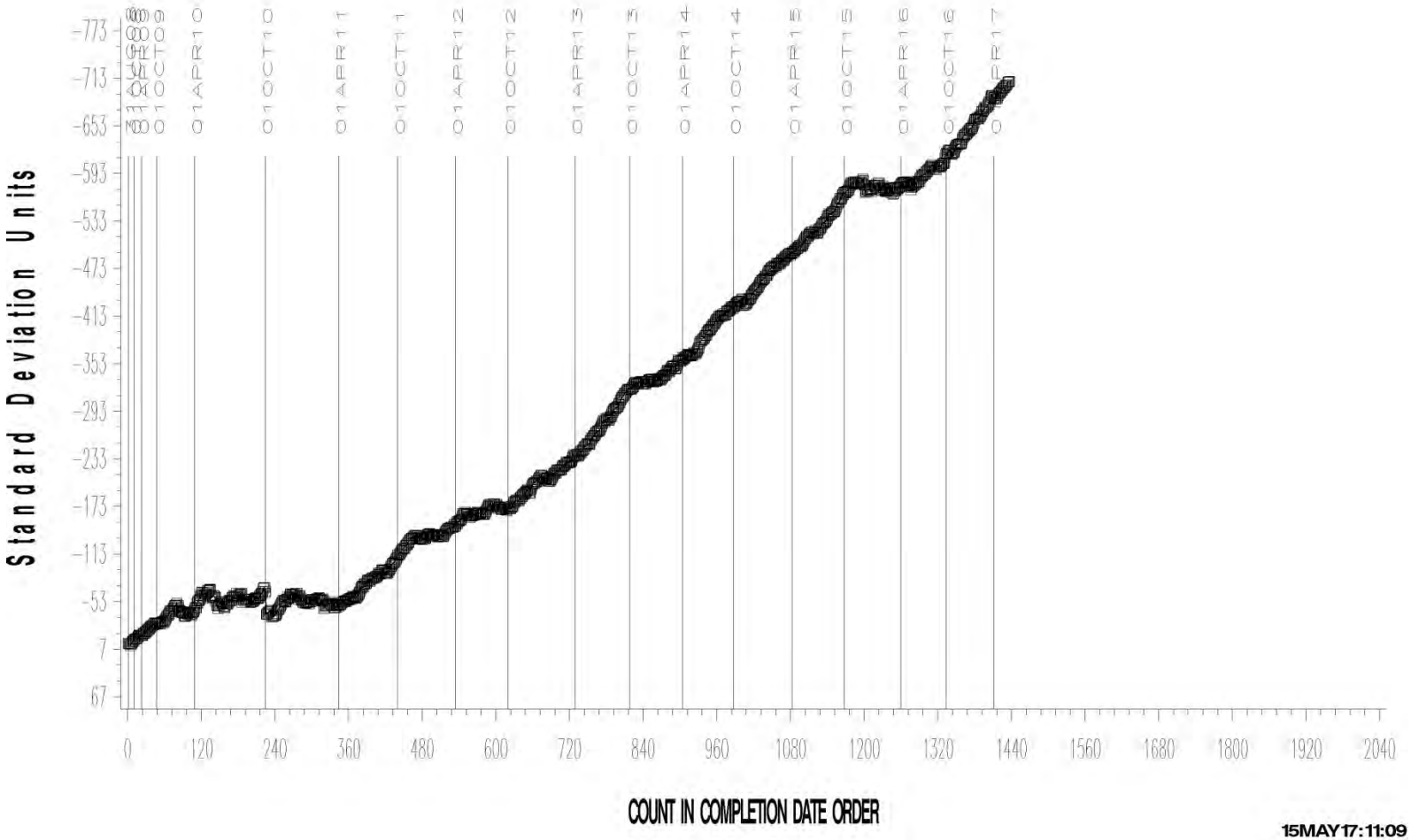
D7528: Oxidation by ROBO

- Precision on oil 434-1 has improved somewhat, but 435-1 continues to be especially imprecise
- 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.
- Oil 434-1 is nearly depleted, a round robin has been started on proposed replacement oil 434-2.
  - **There is no longer enough 434-1 to meet the current calibration or pre-calibration shakedown requirements.**

ROBO TEST INDUSTRY OPERATIONALLY VALID DATA

AGED OIL MRV APPARENT VISCOSITY

CUSUM Severity Analysis



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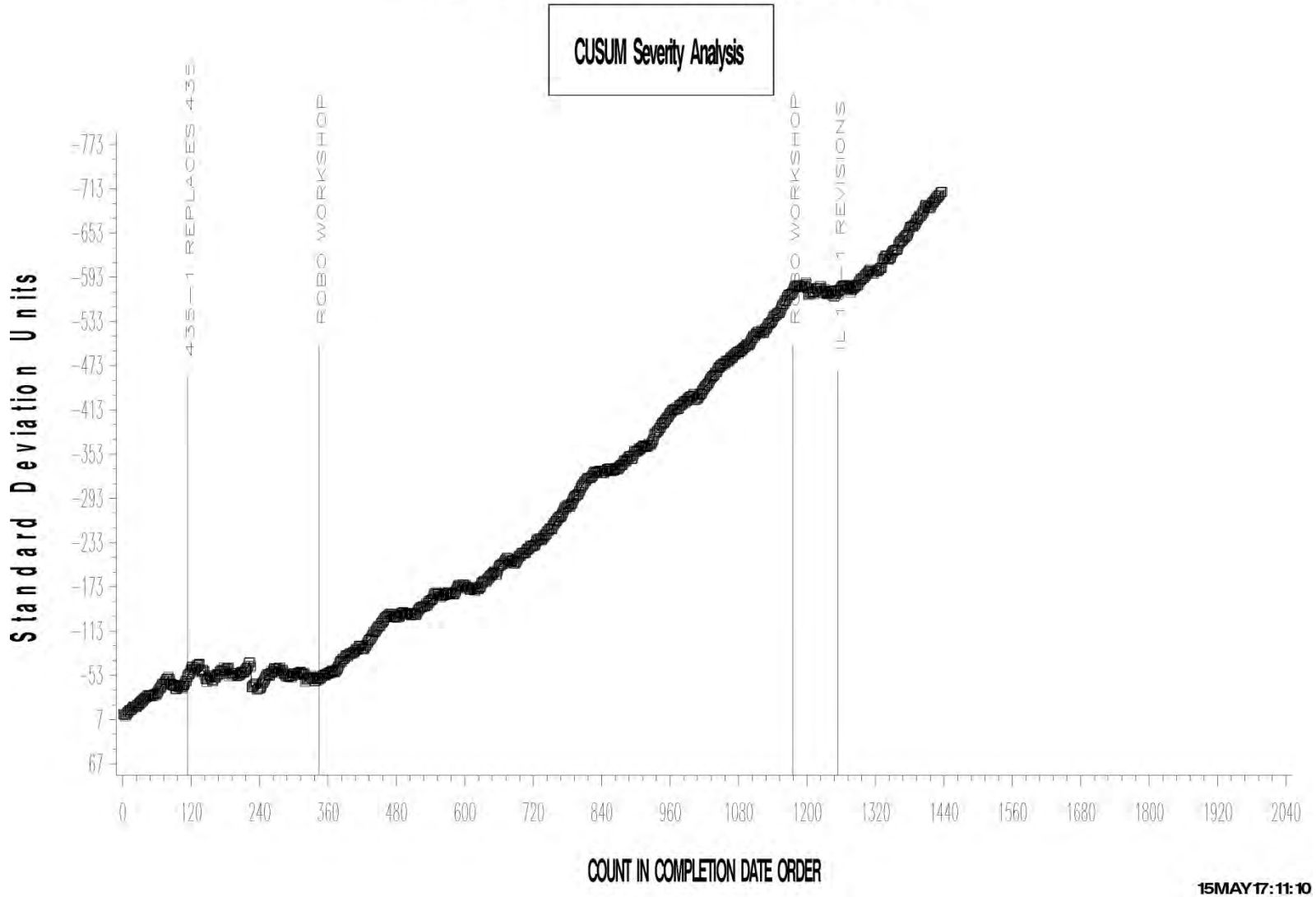
Test Monitoring Center
http://astmtmc.cmu.edu

ROBO TEST INDUSTRY OPERATIONALLY VALID DATA

AGED OIL MRV APPARENT VISCOSITY



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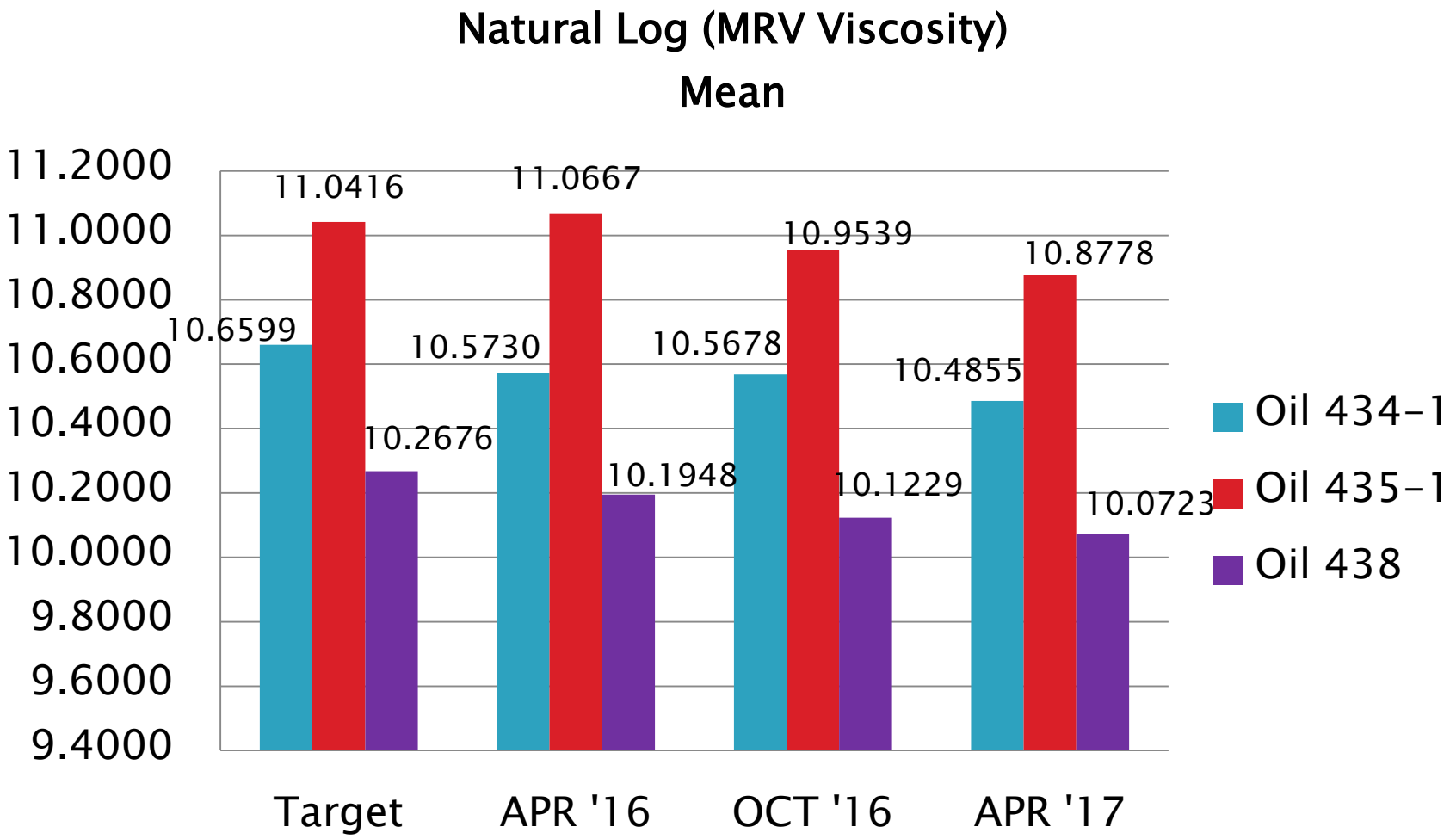
D7528: Oxidation by ROBO

Performance by Oil
Natural Log (MRV Viscosity)

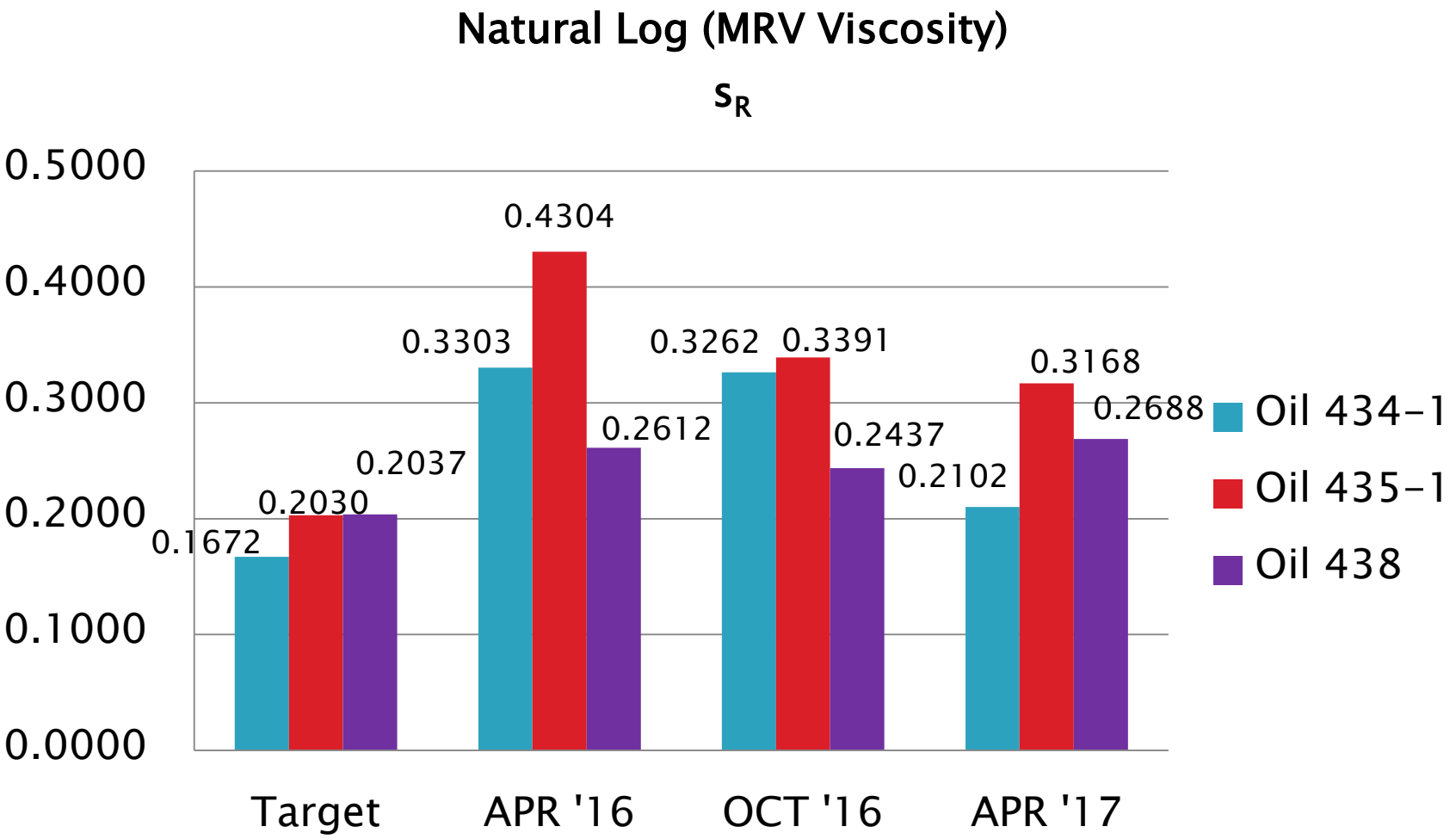
	Targets			10/1/15 - 3/31/16				4/1/15 - 9/30/15				10/1/16 - 3/31/17			
Oil Code	n	Mean	s_R	n	Mean	s_R	Mean Δ/s	n	Mean	s_R	Mean Δ/s	n	Mean	s_R	Mean Δ/s
434-1	13	10.6599	0.1672	31	10.5730	0.3303	-0.52	20	10.5678	0.3262	-0.55	23	10.4855	0.2102	-1.04
435-1	22	11.0416	0.2030	40*	11.0667	0.4304	0.12	36	10.9539	0.3391	-0.43	38	10.8778	0.3168	-0.81
438	14	10.2676	0.2037	20	10.1948	0.2612	-0.36	18	10.1229	0.2437	-0.71	17	10.0723	0.2688	-0.96

*Extreme (9 s) result excluded

D7528: Oxidation by ROBO



D7528: Oxidation by ROBO



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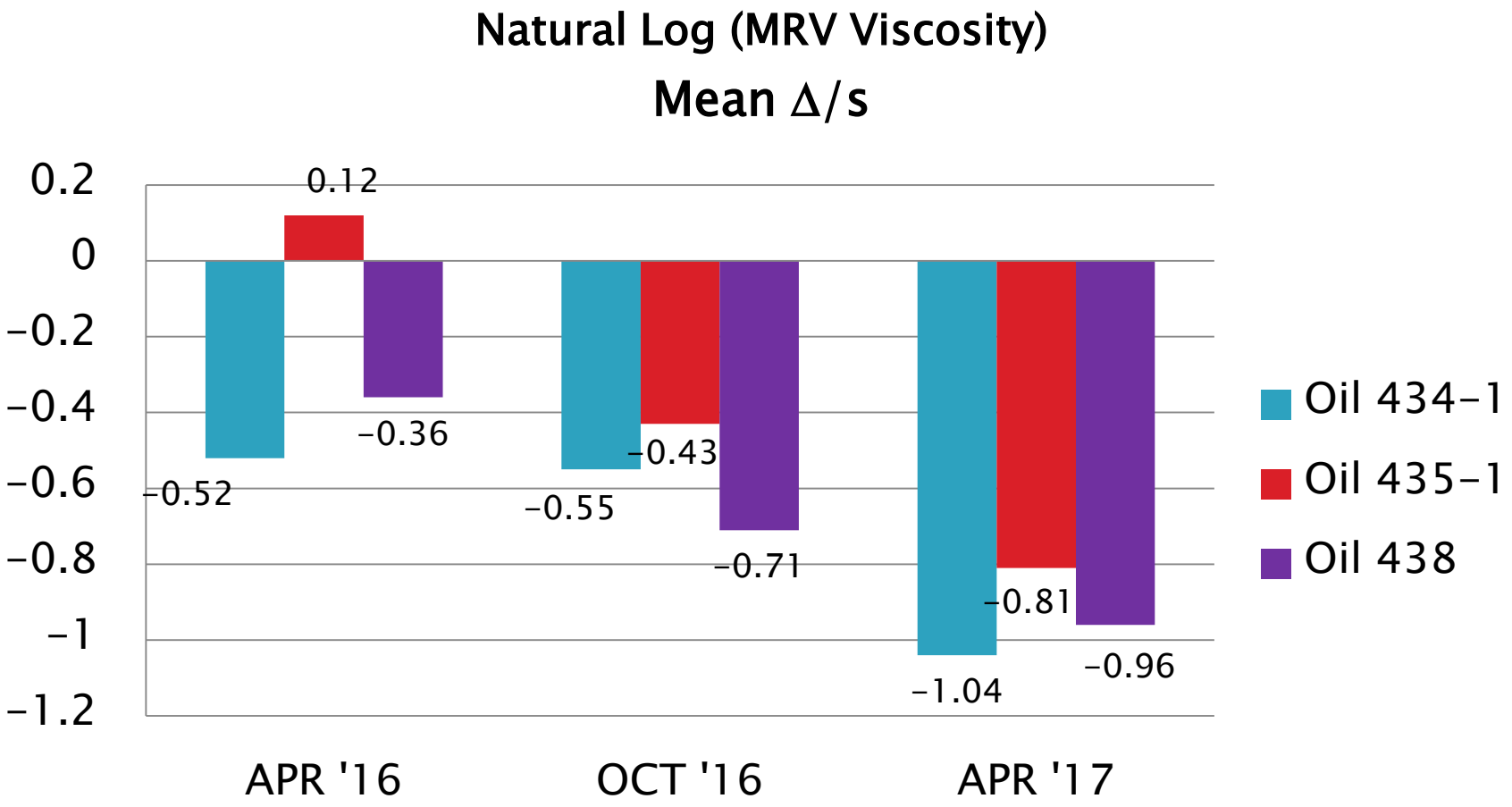
D7528: Oxidation by ROBO



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 3/31/2017

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	0.7	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	108.2	0.6
434	2003	MTEOS	2.6	0.6
75	2010	TEOST	2.2	1.6
75-1	2016	TEOST (proposed)	9.3	0.7
435-2*	2010	TEOST	43.3	1.0
434-1	2008	ROBO	4 SAMPLES	----
434-2*	2014	ROBO (proposed)	29.4	----
435-1	2008	ROBO	445.5	8.6
438*	2003	ROBO	2.6	4.5

*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	5.5	3.5
66	2002	D6082	84.4	3.6
820-2	2001	D874	10.1	0.1
90	2005	D874	23.3	2.2
91	2006	D874	3.9	0.1

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	121.2	10.0
HMB	2002	H&M	124.7	10.0
HMC	2003	H&M	111.4	10.0
HMD	2002	H&M	118.9	10.0
HME	2002	H&M	105.2	10.0
HMF	2002	H&M	127.7	10.0

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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