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

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

October 2015

B0.07 Bench Testing Executive Summary

- D6417 (Volatility by GC)
  - Less precise than last period and target precision
    - Comparable to last period and to target with extreme result excluded (-5.1 s)
  - Performance (Mean Δ/s) is -0.36 s mild
    - Nearly on-target with extreme result excluded
  - CUSUM plot shows overall on-target performance this period except for shift from single extreme result.

B0.07 Bench Testing Executive Summary

- D5800 (Volatility by Noack)
- Precision (Pooled s) is more precise than prior period
  - Less precise than target precision
- Performance (Mean Δ/s) is 1.04 s severe, significantly more severe than any period since at least April 2010
- Fail rate of operationally valid tests (AC & OC) is 20% compared to 27% last report period, and 36% prior to that
- Severity plot shows unexplained long-term severe trend since 01JUL06 timeline with only a modest decrease in severity following the introduction of the new reference oils (on 2013-09-17), but a substantial increase in severity for this period, and with comparable to worse overall precision.

B0.07 Bench Testing Executive Summary

- D5800 (Volatility by Noack)
  - Reference oils VOLC12 and VOLD12 each performing more than 1 s mild this period
  - Four technical updates were issued by the TMC this period.

B0.07 Bench Testing Executive Summary

- D5133 (Gelation Index)
  - Precision (Pooled s) is less precise than prior period
    - More precise than target precision
  - Performance (Mean Δ/s) is -0.17 s mild

B0.07 Bench Testing Executive Summary

- D6335 (TEOST-33C)
  - Precision (Pooled s) is less precise than prior period
    - Less precise than target precision
  - Performance (Mean Δ/s) is -0.11 s mild

- D7097 (MHT-4 TEOST)
  - Precision (Pooled s) is less precise than prior period
    - Less precise than target precision
  - Performance (Mean Δ/s) is 0.39 s severe
    - Significant lab performance differences persist
    - Catalyst affects on oil severity are indicated

B0.07 Bench Testing Executive Summary

- D6082 (High Temperature Foam)
  - Foam Tendency Precision (Pooled s) is less precise than prior period
    - More precise than target precision
  - Performance (Mean Δ/s) is -0.36 s mild
  - No non-zero occurrences of Foam Stability (as expected)
  - All operationally valid discrimination runs demonstrated acceptable discrimination

- D874 (Sulfated Ash)
  - Precision (Pooled s) is less precise than the prior period
    - Less precise than target precision
    - More precise on both with -8.4 s mild result excluded
  - Performance (Mean Δ/s) is -1.36 s mild
    - -0.36 s mild with extreme mild result excluded

B0.07 Bench Testing Executive Summary

- D7528 (ROBO)
  - 24% fail rate for operationally valid tests
  - Precision (Pooled s) is more precise than prior period
    - Continues to be less precise than target precision
  - Performance (Mean Δ/s) is -0.90 s mild
    - Two labs, A and B, more than -1 s mild, overall; with each lab contributing 20 or more tests for the period
    - Oil 434 performing -1.32 s mild for period
  - CUSUM Severity Plot shows an ongoing overall mild trend since the 01APR11 timeline

Calibrated Labs and Stands*

Test	Labs	Stands
D6417	4	5
D5800	9	21
D5133 (GI)	3	5
D6335 (TEOST)	5	5
D7097 (MTEOS)	8	24
D6082	2	3
D874	3	--
D7528 (ROBO)	6	11

*As of 9/30/2015

D02.B0.07
TMC Monitored Tests

- April 1, 2015 –
  September 30, 2015

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D6417: Estimation of Engine Oil Volatility by Capillary GC

Test Status	Validity Code	No. Tests
Acceptable Calibration Test	AC	14
Failed Calibration Test	OC	2
Operationally Invalidated by Lab	LC, XC	0
Operationally Invalidated After Initially Reported as Valid	RC	0
Excluded For Other Reasons	NN	1
Total		**17**

Number of Labs Reporting Data: 5
Fail Rate of Operationally Valid Tests: 12%

D6417: Estimation of Engine Oil Volatility by Capillary GC

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

- One instrument diagnostic shakedown run (NN) following a mild fail result.

- One TMC technical update was issued this period:
  - Memo 15-029, July 31, 2015: Updated Test Method D6417-15

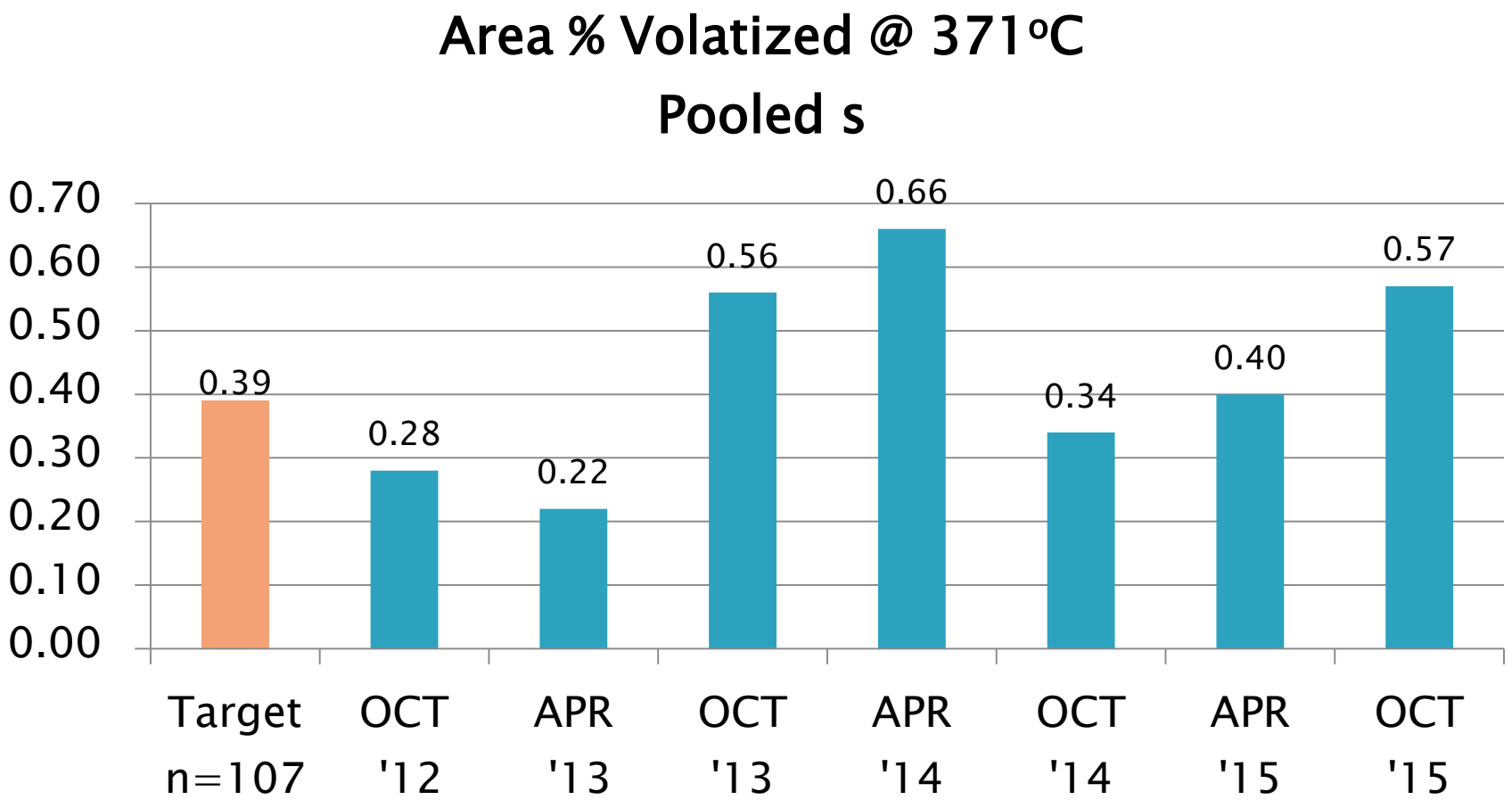
D6417: Estimation of Engine Oil Volatility by Capillary GC

Period Precision and Severity Estimates

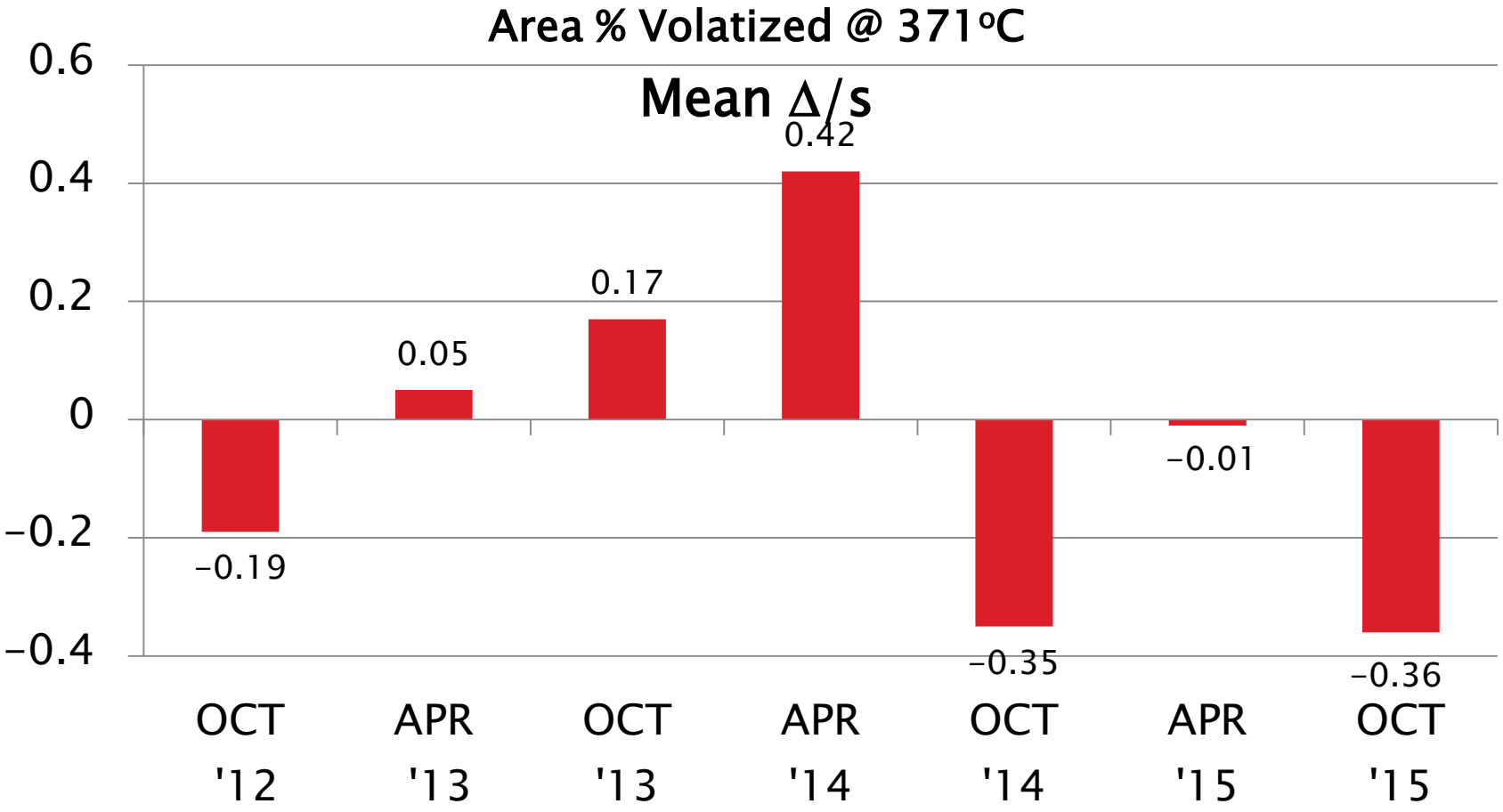
Area % Volatized @ 371°C	n	df	Pooled s	Mean Δ/s
Initial Selected Oils from RR	54	51	0.39	-----
10/1/12 through 3/31/13	14	11	0.22	0.05
4/1/13 through 9/30/13	17	14	0.56	0.17
10/1/13 through 3/31/14	15	12	0.66	0.42
4/1/14 through 9/30/14	15	12	0.34	-0.35
10/1/14 through 3/31/15	14	11	0.40	-0.01
4/1/15 through 9/30/15*	16	13	0.57	-0.36
4/1/15 through 9/30/15*	15	12	0.42	-0.04

*Extreme OC result included and excluded

D6417 Precision Estimates



D6417 Severity Estimates



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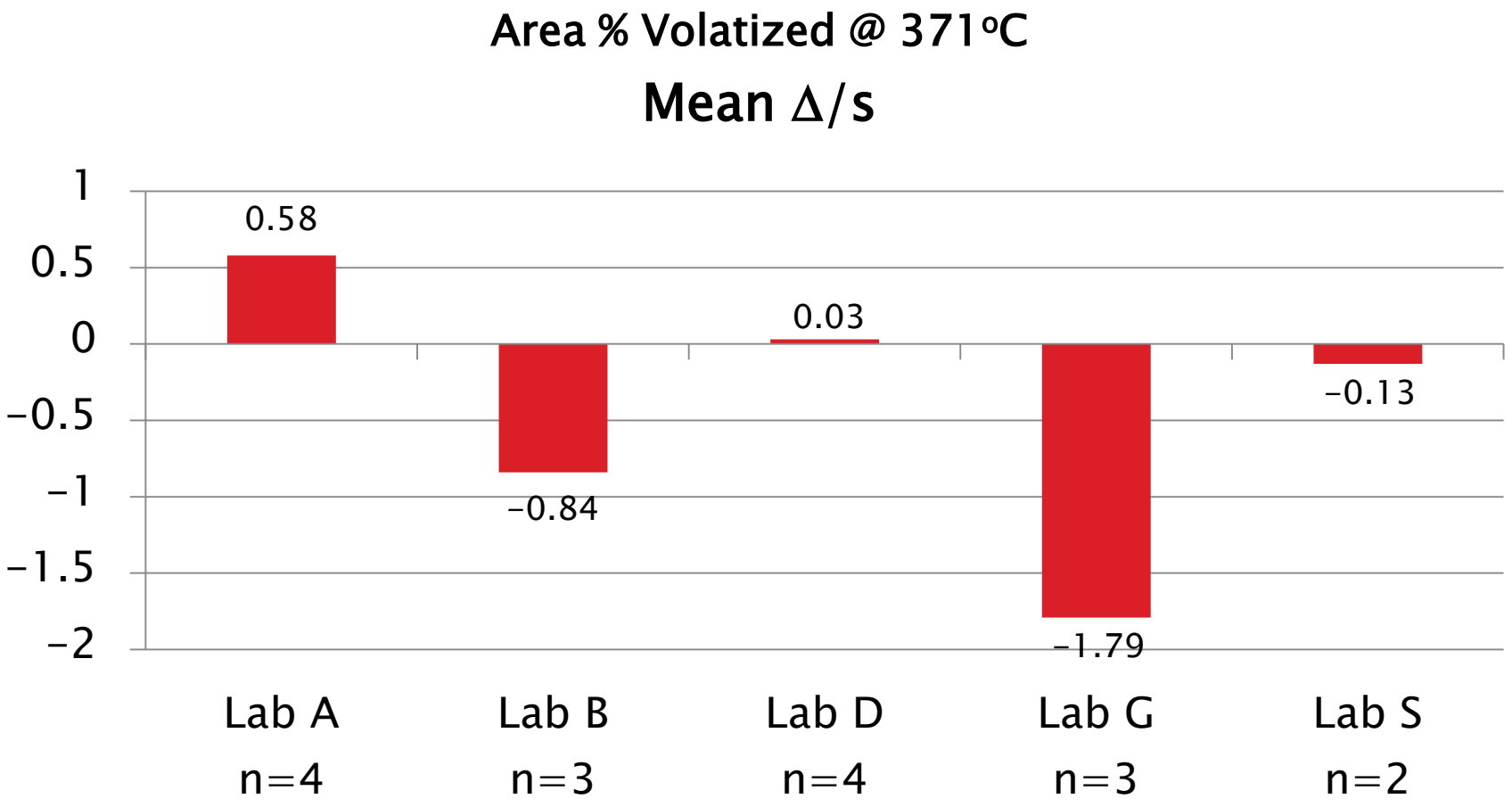
D6417: Estimation of Engine Oil Volatility by Capillary GC

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

	n	Mean Δ/s
Lab A	4	0.58
Lab B	3	-0.84
Lab D	4	0.03
Lab G	3	-1.79
Lab S	2	-0.13

D6417 Lab Severity Estimates



D6417: Estimation of Engine Oil Volatility by Capillary GC

- One result this period -5.1 s mild, reported as operationally valid (Instrument G3, Oil 55); statistics table shown with result included and excluded.

- Precision (Pooled s) is less precise than last period
  - Less precise than target precision
  - Comparable to last period and to target with extreme result excluded

- Performance (Mean Δ/s) is -0.36 s mild
  - Nearly on-target with extreme result excluded

- CUSUM plot shows overall on-target performance this period except for shift from single extreme result.

D6417 VOLATILITY BY GC INDUSTRY OPERATIONALLY VALID DATA

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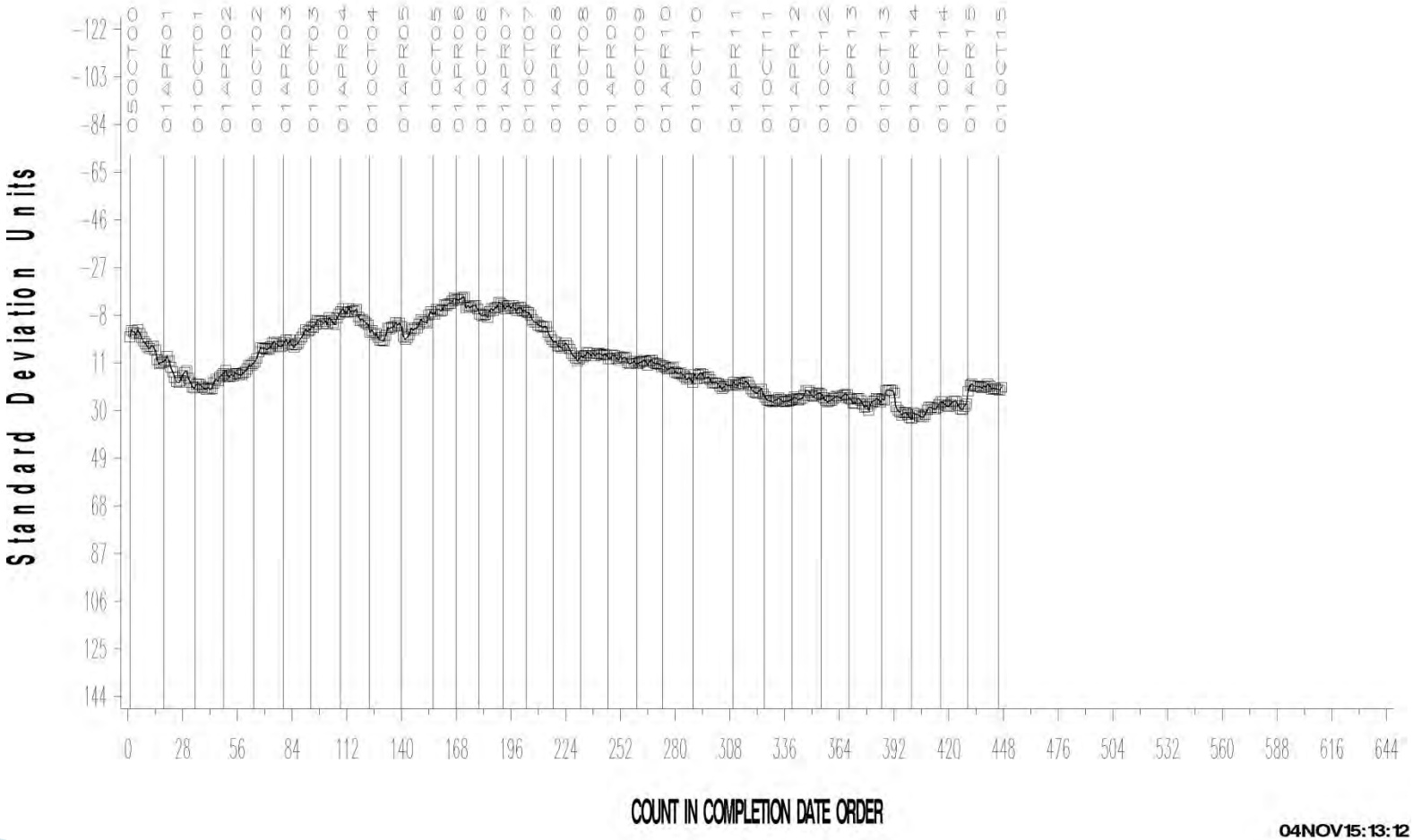
SAMPLE AREA % VOLATIZED

CUSUM Severity Analysis



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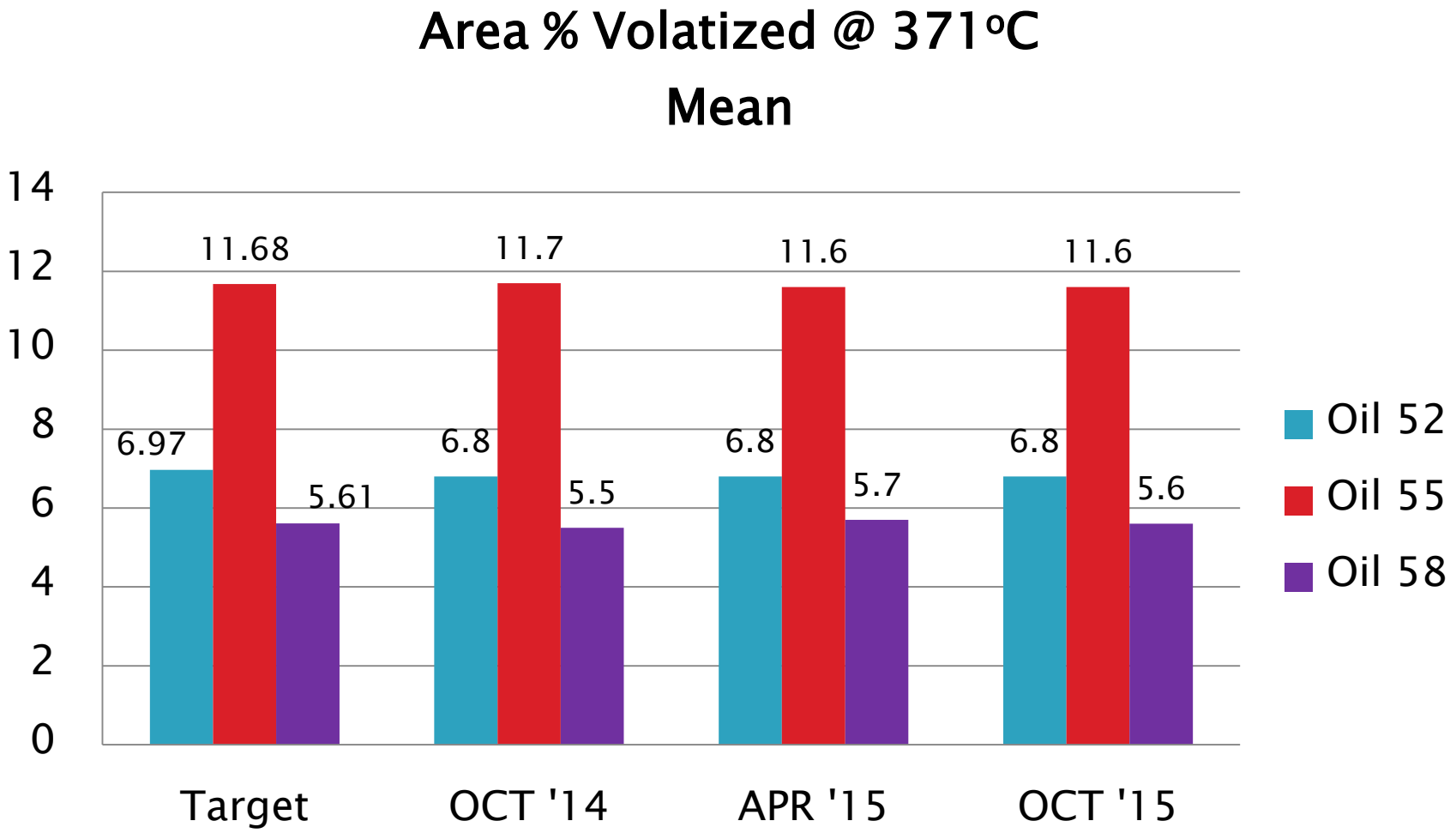
D6417: Estimation of Engine Oil Volatility by Capillary GC

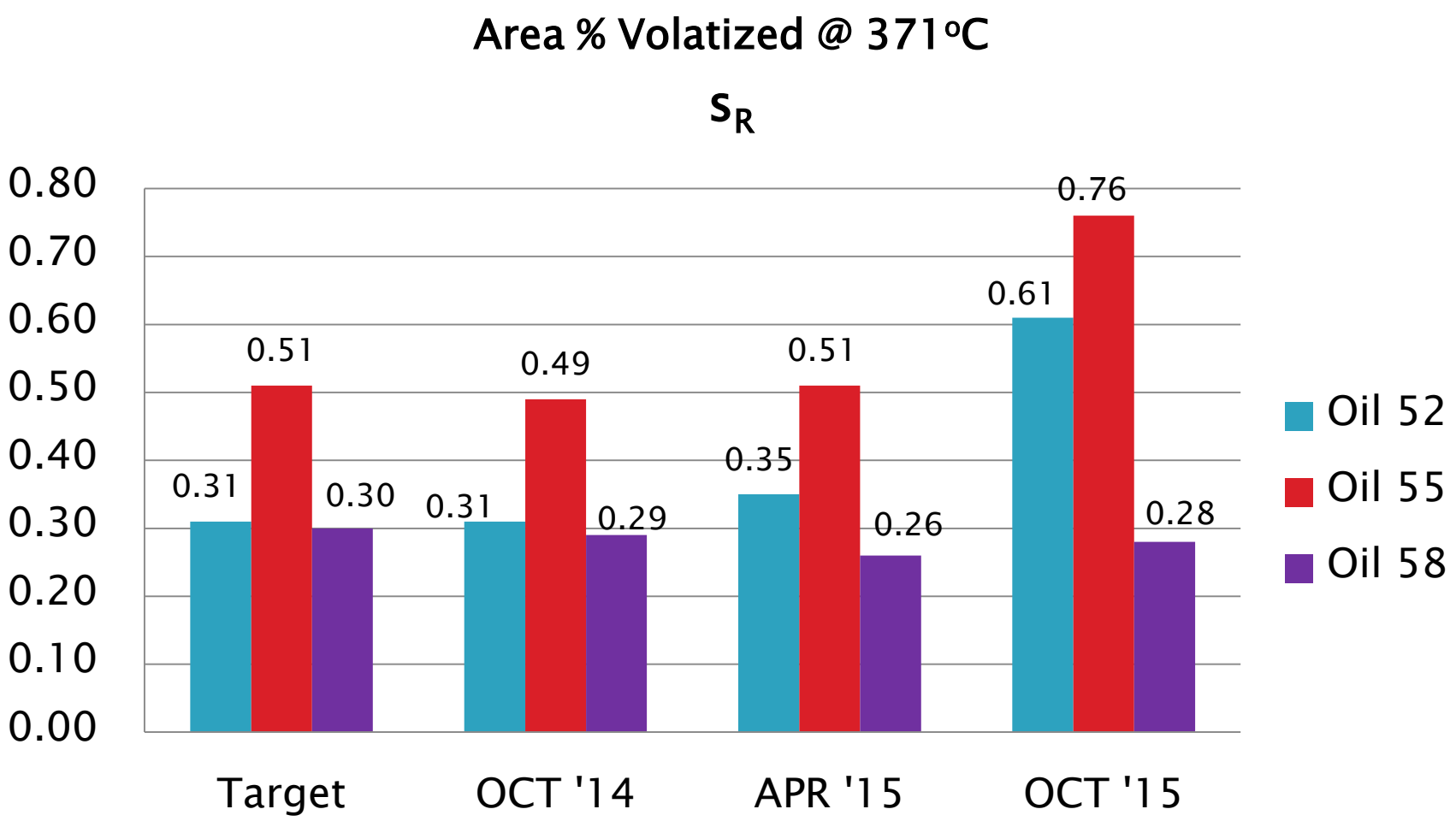
Area % Volatized @ 371°C
Performance by Oil

	Targets			4/1/14 - 9/30/14				10/1/14 - 3/31/15				4/1/15 - 9/30/15			
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	8	6.8	0.31	-0.47	2	6.8	0.35	-0.39	7	6.8	0.61	-0.69
55	18	11.68	0.51	3	11.7	0.49	-0.03	6	11.6	0.51	-0.09	4	11.6	0.76	-0.11
58	18	5.61	0.30	4	5.5	0.29	-0.37	6	5.7	0.26	0.19	5	5.6	0.28	-0.10

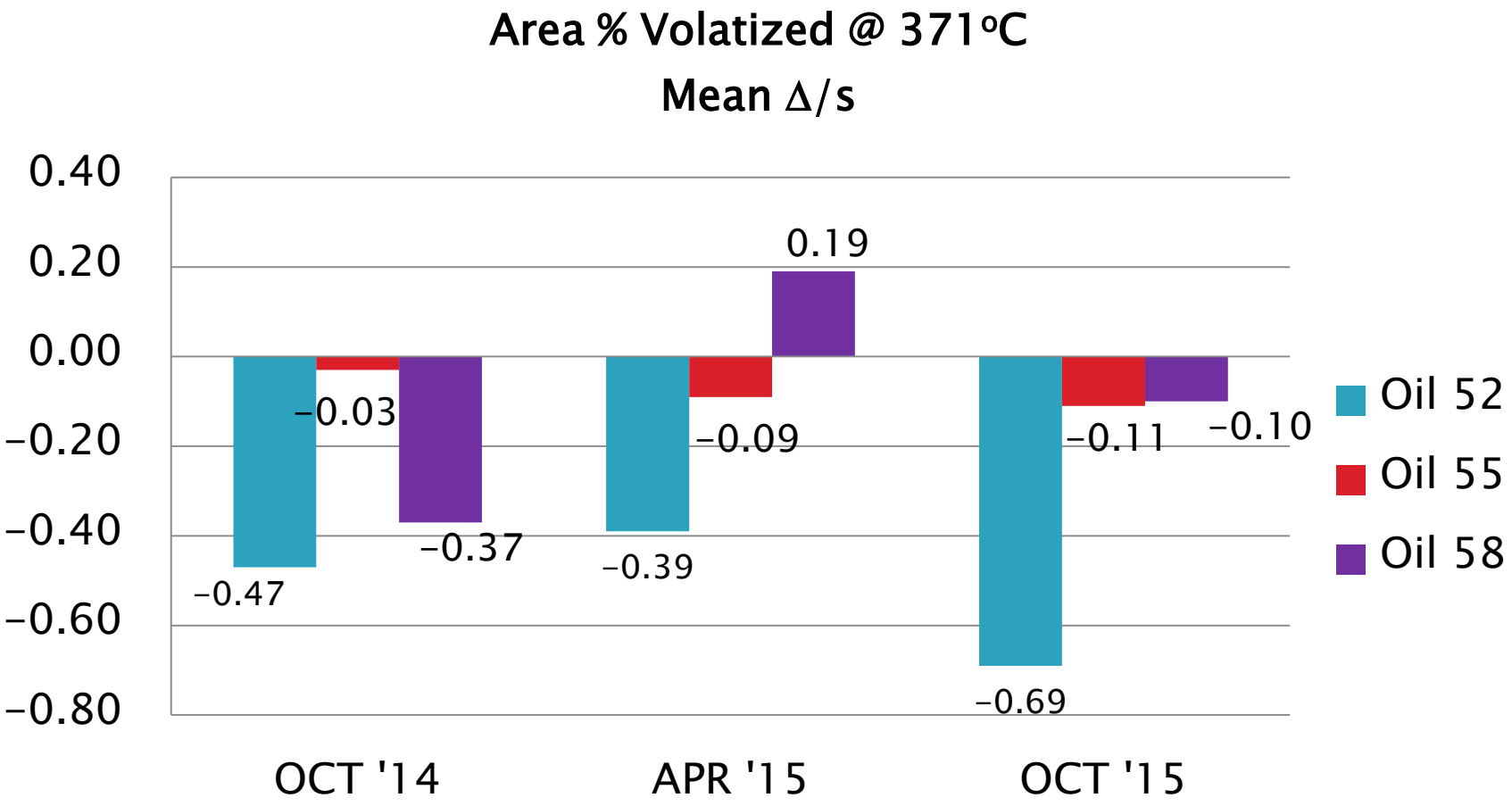
D6417 Performance by Oil



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	44
Failed Calibration Test	OC	11
Operationally Invalidated by Lab	LC, XC	0
Operationally Invalidated After Initially Reported as Valid	RC	1
Donated Round Robin (PC11)	AG	48
Excluded For Other Reasons	NN	4
Total		**108**

Number of Labs Reporting Data: 9
Fail Rate of Operationally Valid Tests: 20%

D5800: Evaporation Loss of Lubricating Oil by Noack Method

Statistically Unacceptable Tests (OC)	No. Of Tests
Evaporation Loss Mild	1
Evaporation Loss Severe	10

- Failing results are across multiple labs, instruments and oils.
  - Apparatus A8 (model NCK25G) contributed three severe fails this period, the most from one instrument; two consecutive on VOLC12 and one later on VOLD12.

- Number of operationally valid results reported by oil:
  - VOLC12: 18 AC, 7 OC (1 mild, 6 severe)
  - VOLD12: 14 AC, 2 OC (both severe)
  - VOLE12: 12 AC, 2 OC (both severe)

D5800: Evaporation Loss of Lubricating Oil by Noack Method

- Not included in period statistics:
  - Lab used non-approved daily calibration oil (operationally invalid, RC)
  - Lab G ran four non-blind instrument shakedown runs (NN) on two instruments to troubleshoot instrument problems following failing calibration runs on both instruments.
  - PC11 round robin (48 tests, validity AG) to estimate variability on HD category oils PC11C and PC11E

D5800: Evaporation Loss of Lubricating Oil by Noack Method

- Four technical updates were issued this report period:
  - Memo 15-005, March 10, 2015, Mandatory Daily QC Check Sample
    - TMC Oil VOLD14 was selected by panel for use as a mandatory daily QC check sample for D5800 procedures B & C for TMC monitored labs, effective May 1, 2015.
  - Report Packet Revision Notice D5800-20150224, issued April 15, 2015
    - Added field FIRMWARE to data dictionary, effective May 15, 2015
  - Memo 15-021, May 29, 2015, Updated Test Method D5800-15 (superseded by memo 15-028)
  - Memo 15-028, July 31, 2015, Updated Test Method D5800-15a

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 10/1/2013	78	75	0.50	-----
4/1/12 through 9/30/12	33	30	0.67	0.56
10/1/12 through 3/31/13	33	30	0.79	0.43
4/1/13 through 9/30/13	30	27	0.72	0.58
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*	55	52	0.67	1.04
4/1/15 through 9/30/15*	54	51	0.61	0.95

*Extreme OC result included and excluded

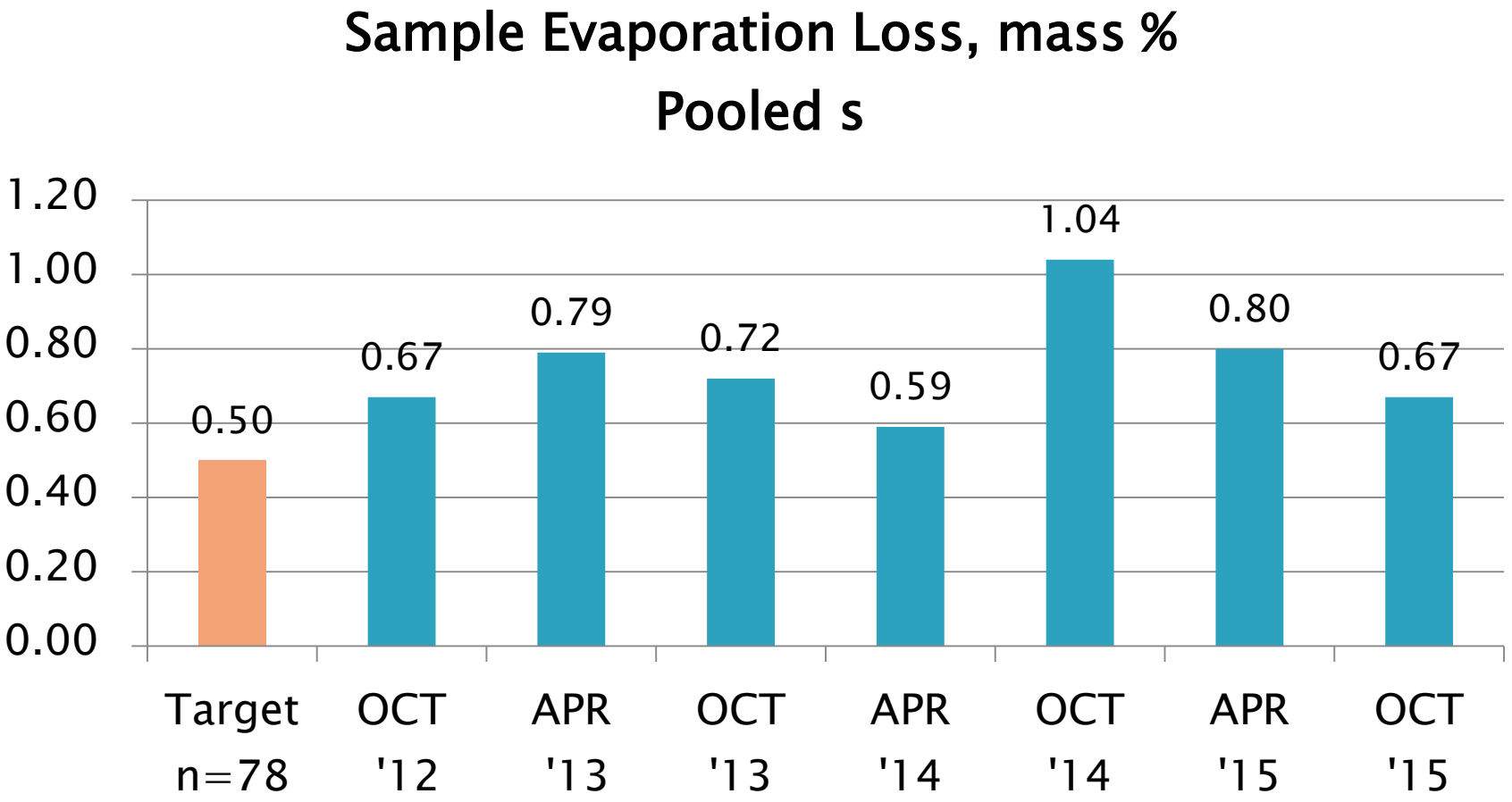
D5800: Evaporation Loss of Lubricating Oil by Noack Method

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

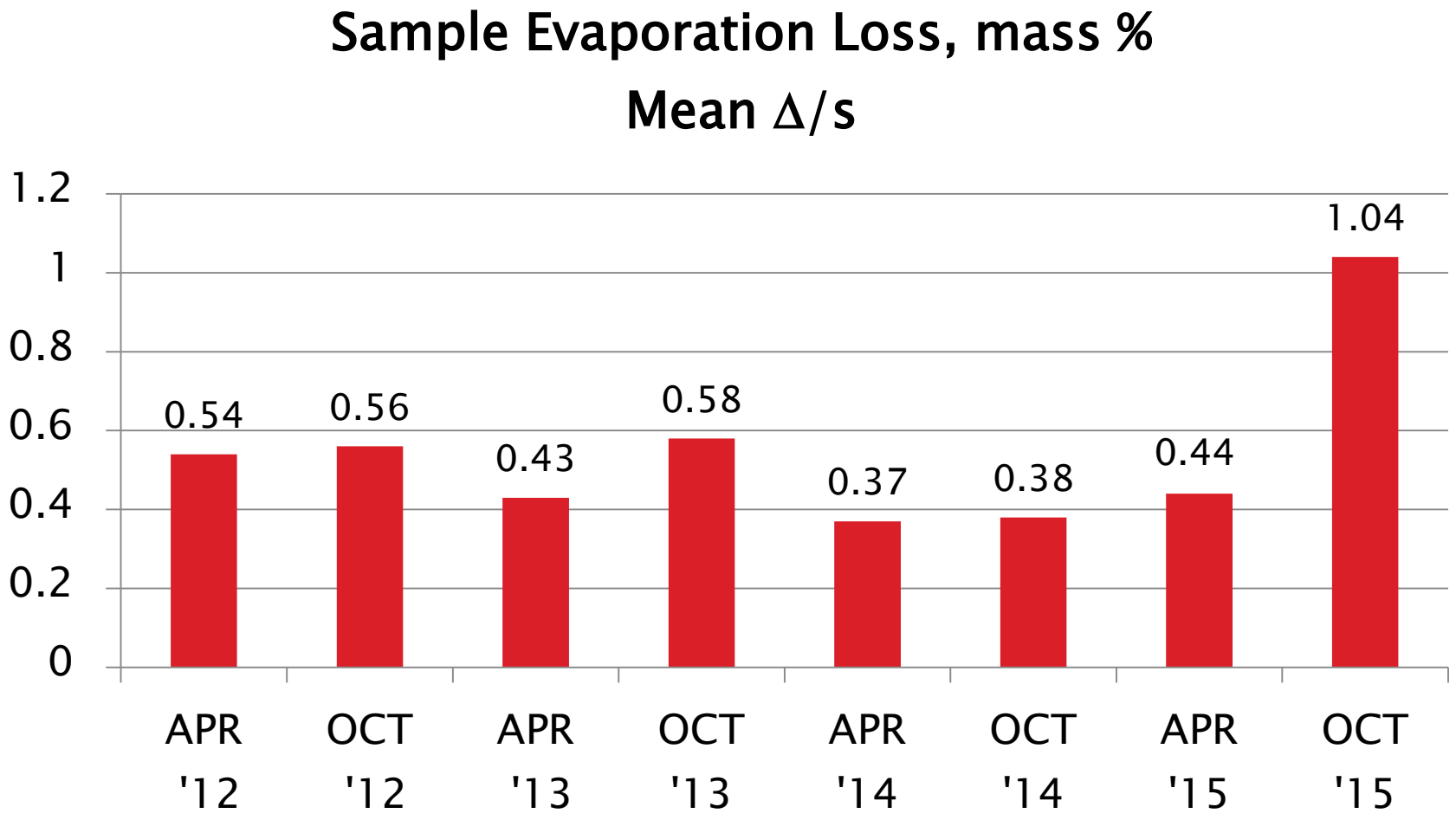
	n	df	Pooled s	Mean Δ/s
Procedure B	49	46	0.62	1.19
Procedure C	6	3	0.95	-0.19

Model	n	df	Pooled s	Mean Δ/s
NCK2	10	7	0.42	1.15
NCK25G	39	36	0.66	1.21
SVT1	6	3	0.95	-0.19

D5800 Precision Estimates



D5800 Severity Estimates

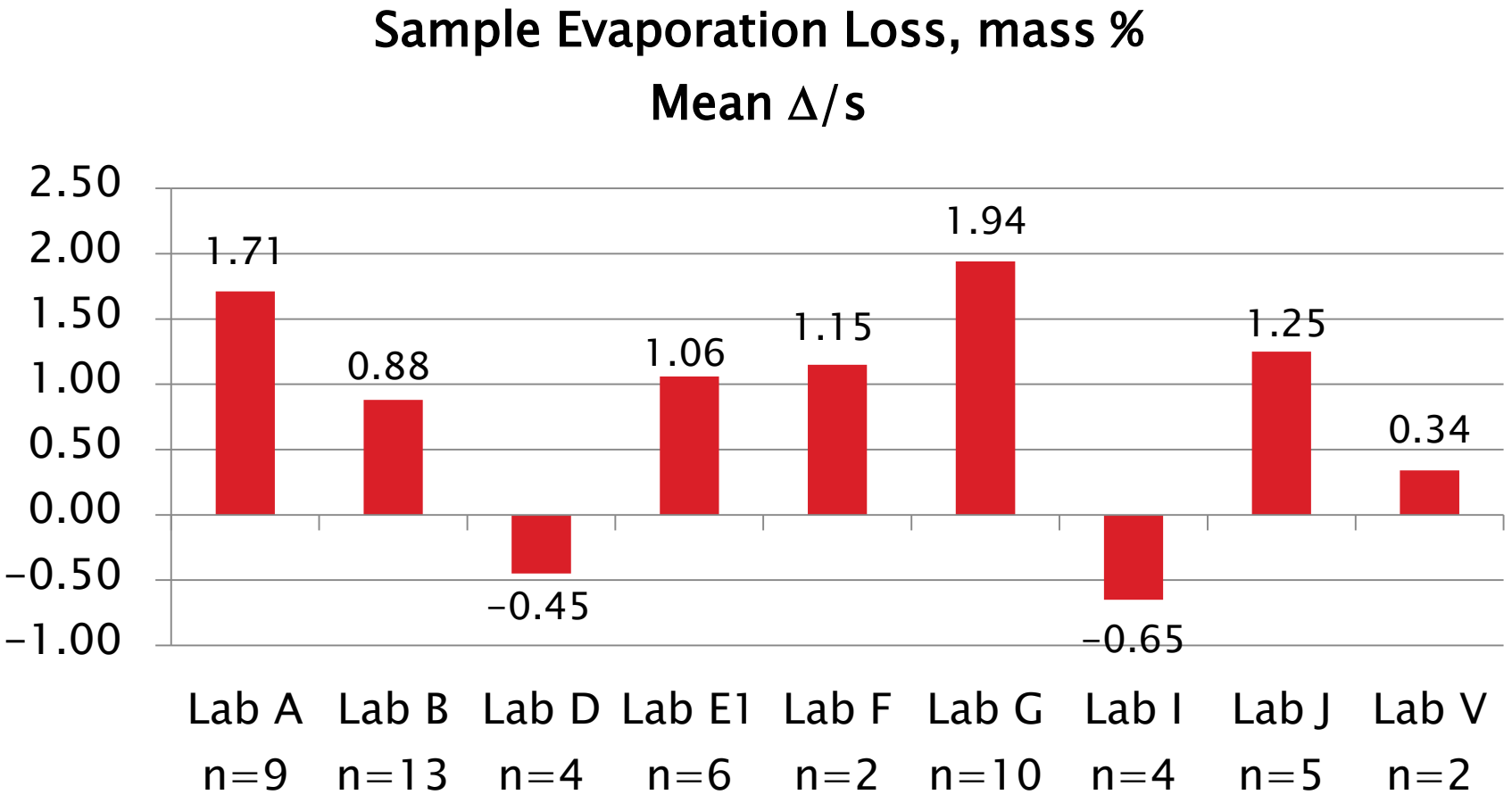


D5800: Evaporation Loss of Lubricating Oil by Noack Method

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

	n	Mean Δ/s
Lab A	9	1.71
Lab B	13	0.88
Lab D	4	-0.45
Lab E1	6	1.06
Lab F	2	1.15
Lab G	10	1.94
Lab I	4	-0.65
Lab J	5	1.25
Lab V	2	0.34

D5800 Lab Severity Estimates



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D5800: Evaporation Loss of Lubricating Oil by Noack Method

- Precision (Pooled s), at 0.67 mass %, is more precise than prior period (0.8 mass %) but still less precise compared to the target precision (0.50 mass %).
- Performance (Mean Δ/s) is 1.04 s severe, significantly more severe than any period since at least April 2010 (the prior most severe period since was October 2011 at 0.77 s severe).
- Fail rate of operationally valid tests (AC & OC) is 20% compared to 27% last report period, and 36% prior to that.
- Severity plot shows unexplained long-term severe trend since 01JUL06 timeline with only a modest decrease in severity following the introduction of the new reference oils (on 2013-09-17), but a substantial increase in severity for this period, and with comparable to worse overall precision.

D5800: Evaporation Loss of Lubricating Oil by Noack Method

- Breakdown of tests reported this period by severity of results:
  - 7 tests between 2 and 3 s severe of targets (two pass on acceptance bands due to rounding), includes all three instrument models
  - 3 tests between 3 and 4 s severe, models NCK25G and NCK2
  - 1 test 4.8 s severe (lab-instrument G-6, model NCK25G)
  - 1 test 6.3 s severe (lab-instrument B-10, model NCK25G; period statistics table in this report shown with this result included and excluded for comparison)
  - 1 test -3.2 s mild, model SVT1

D5800 VOLATILITY BY NOACK INDUSTRY OPERATIONALLY VALID DATA

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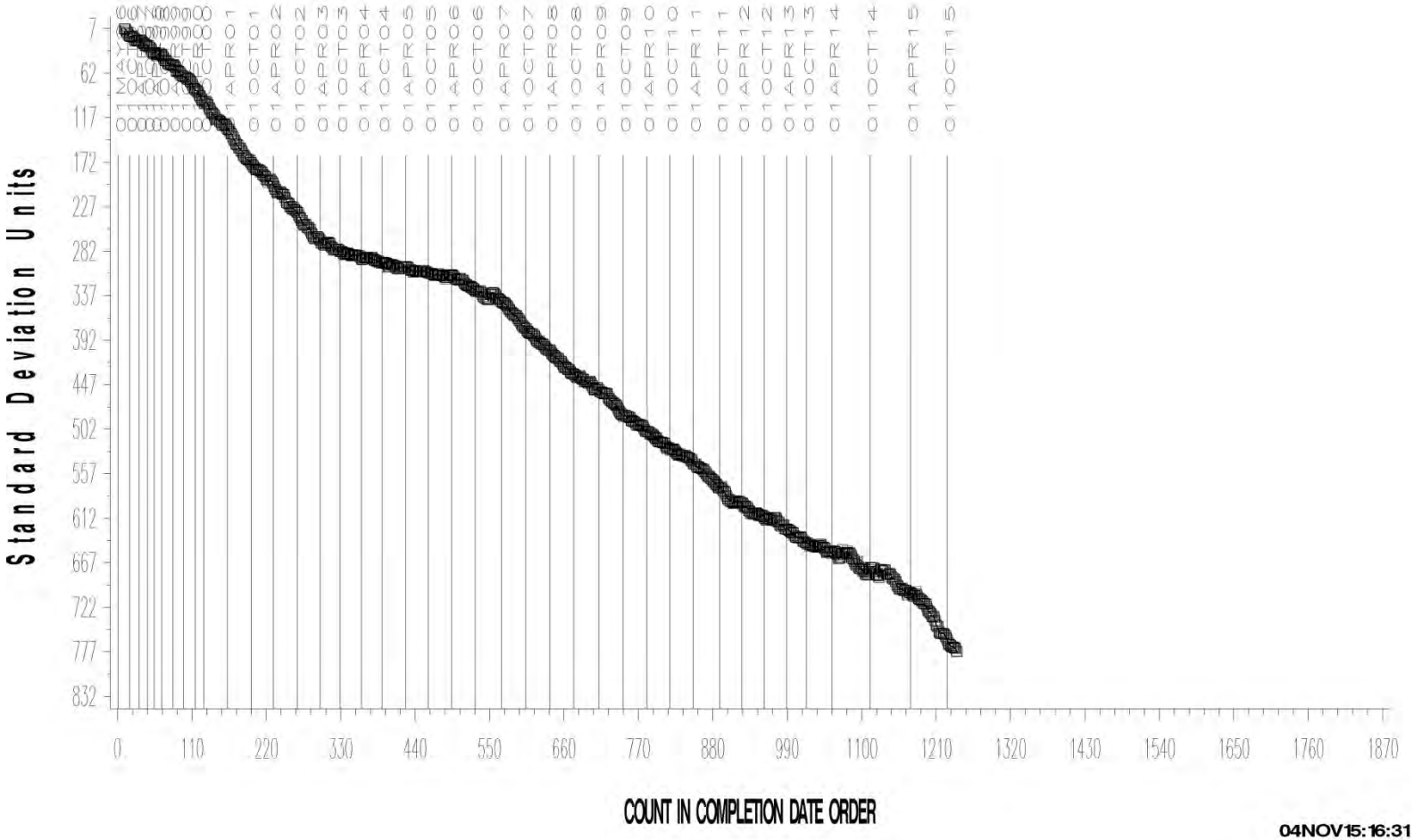
EVAPORATION LOSS, MASS%

CUSUM Severity Analysis



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D5800 VOLATILITY BY NOACK INDUSTRY OPERATIONALLY VALID DATA

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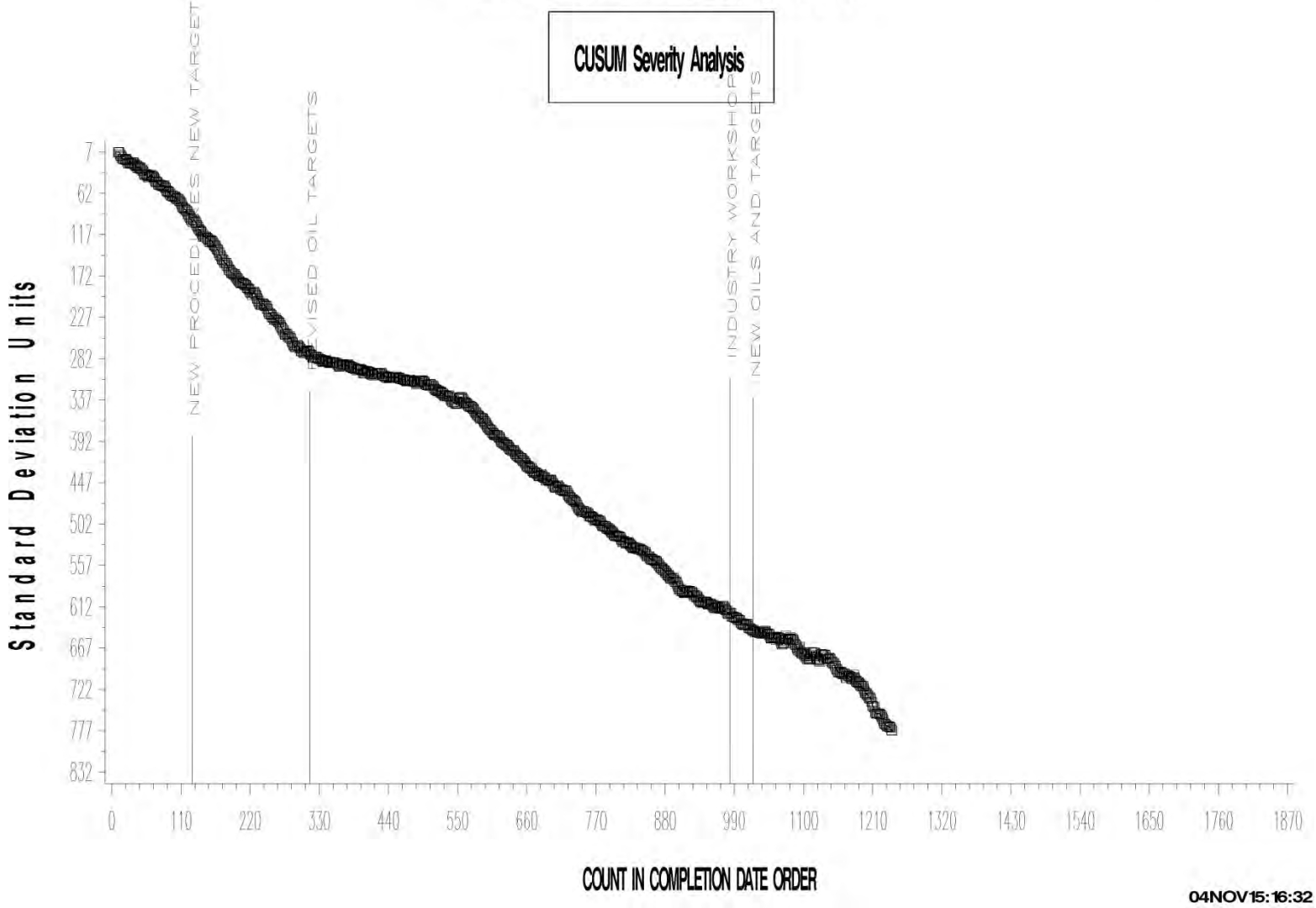
EVAPORATION LOSS, MASS%



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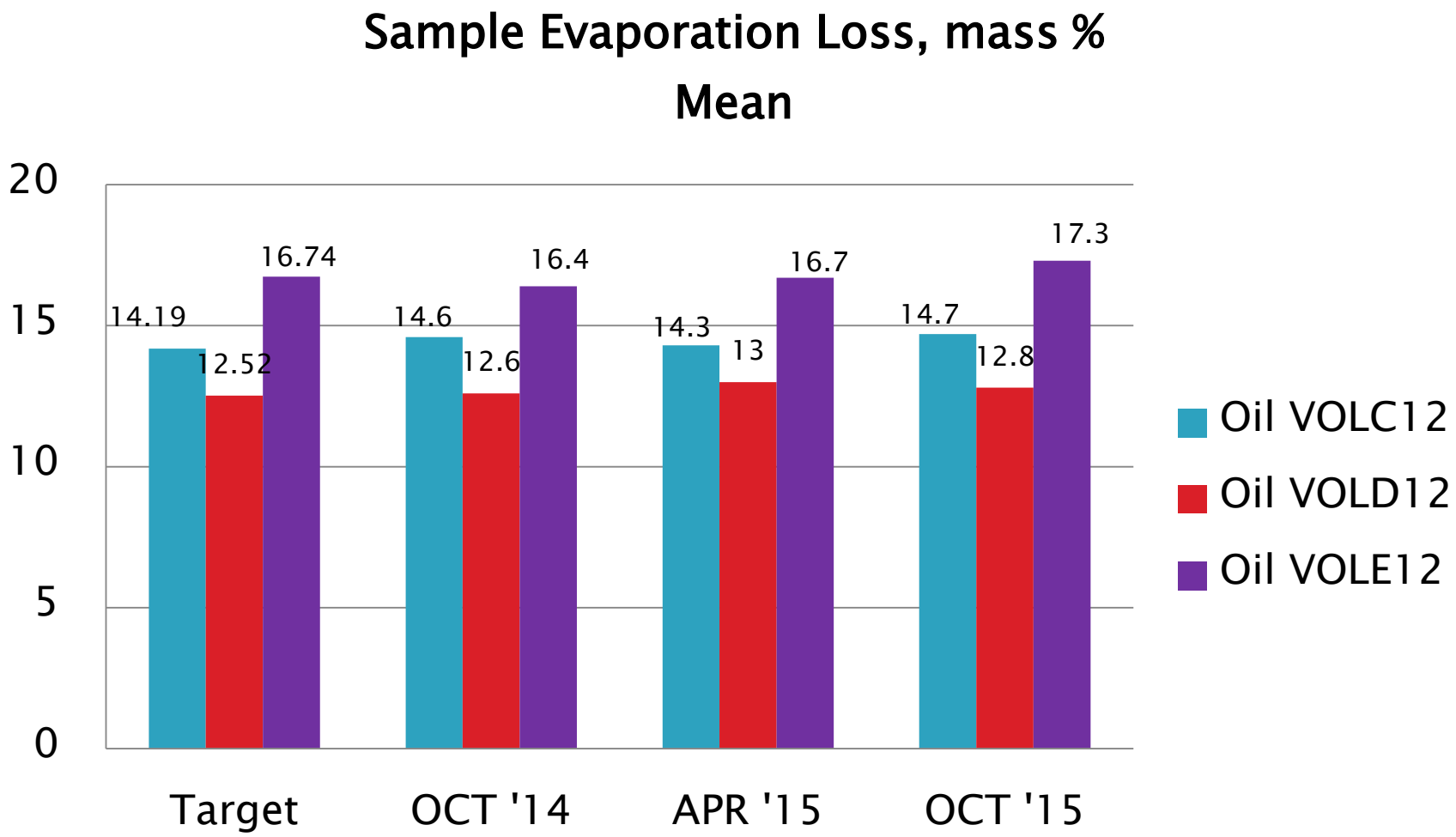
D5800: Evaporation Loss of Lubricating Oil by Noack Method

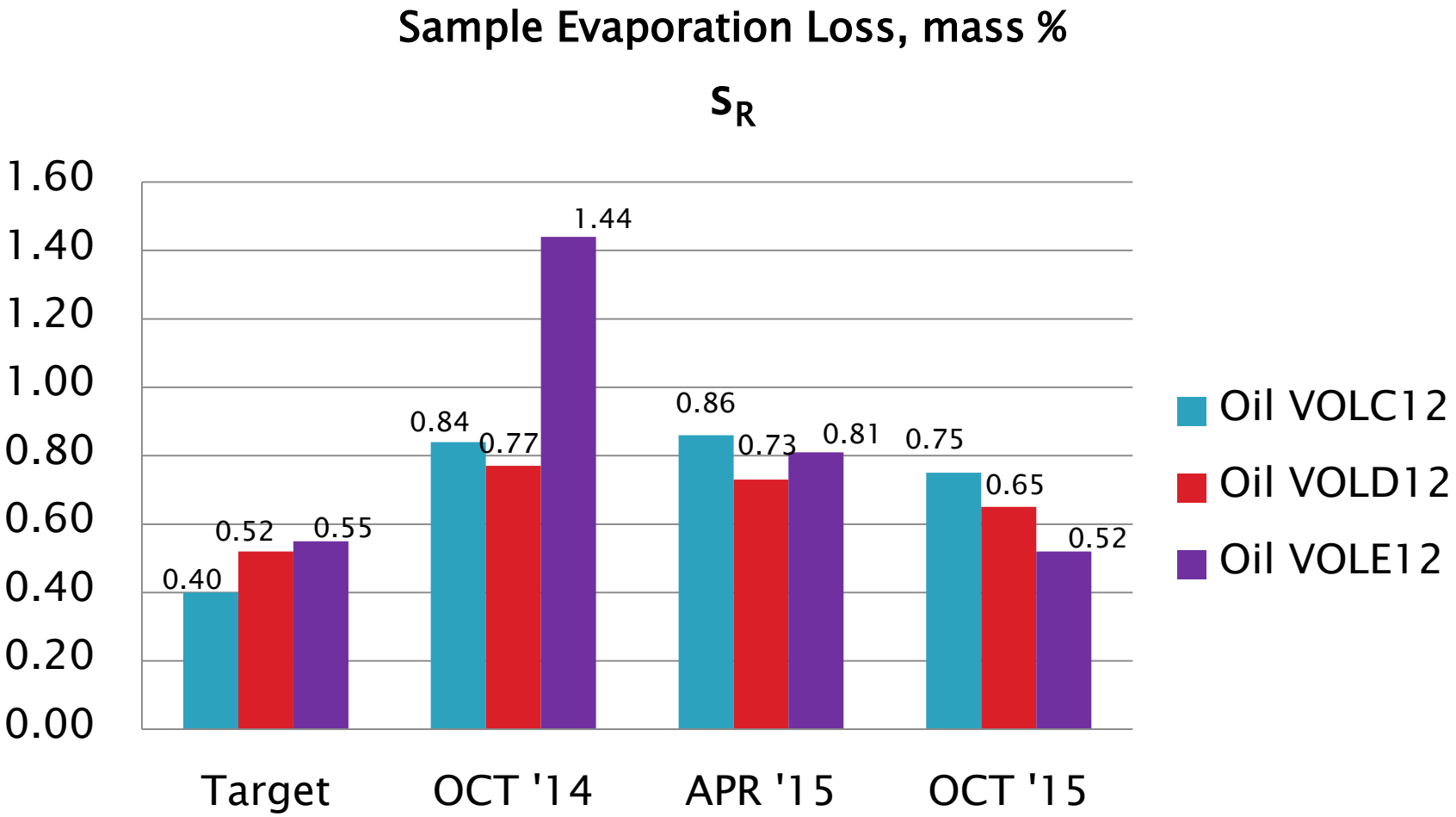
Sample Evaporation Loss, mass %
Performance by Oil

	Targets			4/1/134– 9/30/14				10/1/14 – 3/31/15				4/1/135– 9/30/15			
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	0.40	26	14.6	0.84	1.05	21	14.3	0.86	0.33	25	14.7	0.75	1.32
VOLD12	27	12.52	0.52	13	12.6	0.77	0.21	21	13.0	0.73	0.93	16	12.8	0.65	0.57
VOLE12	27	16.74	0.55	16	16.4	1.44	-0.58	18	16.7	0.81	0.00	14	17.3	0.52	1.10

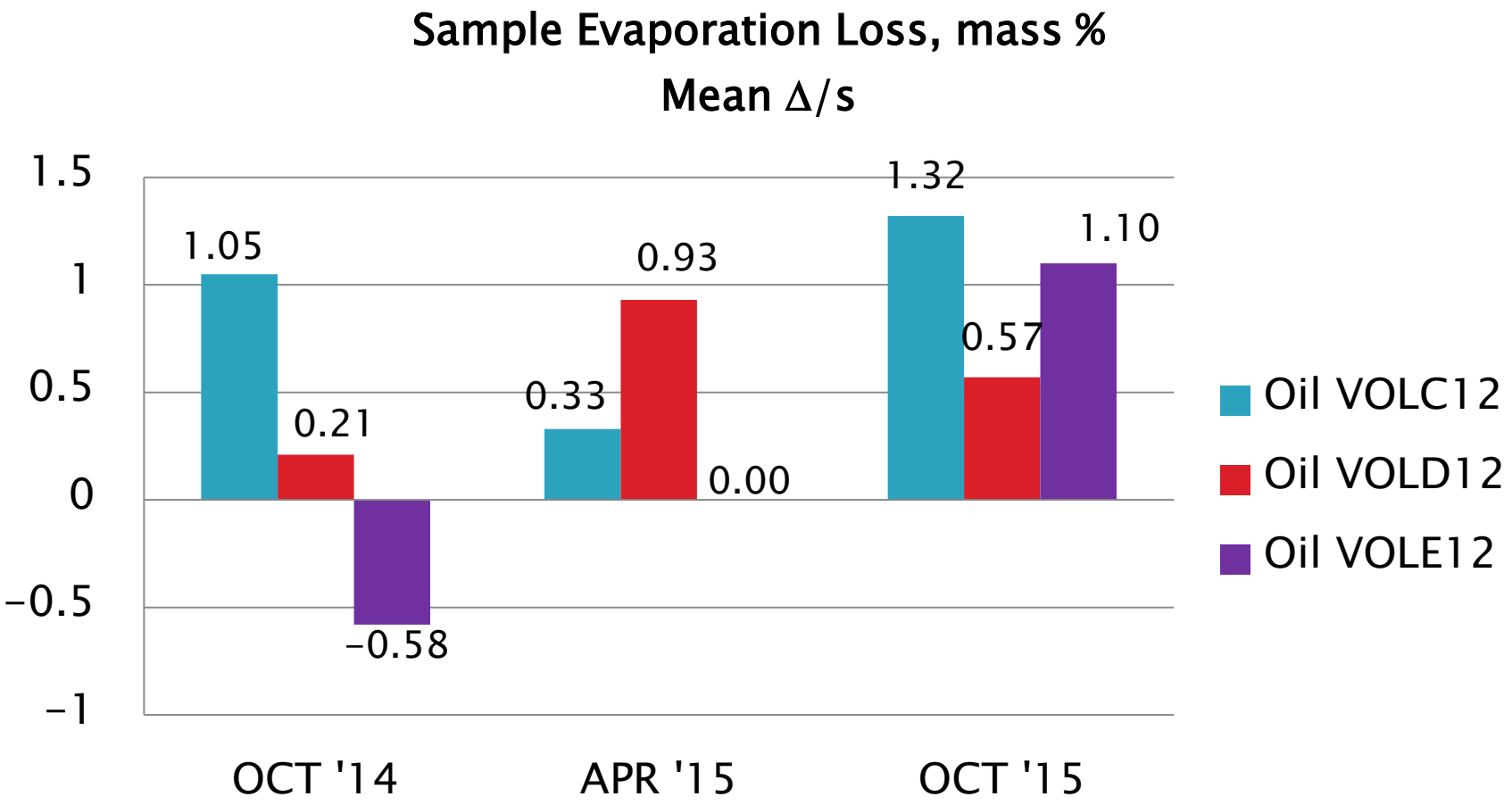
D5800 Performance by Oil



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	31
Failed Calibration Test	OC	3
Operationally Invalidated by Lab	LC, XC	0
Operationally Invalidated After Initially Reported as Valid	RC	0
Instrument Shakedown	NN, MC	3
Total		**37**

Number of Labs Reporting Data: 8
Fail Rate of Operationally Valid Tests: 9%

D5133: Gelation Index

Statistically Unacceptable Tests (OC)	No. Of Tests
Gelation Index Mild	3
Gelation Index Severe	0

- No operationally invalid tests reported this period

- New instrument G3 reported two shakedown runs (validity NN) followed by a failing calibration excluded from period statistics (MC) because instrument failed to demonstrate a passing run. Instrument subsequently passed calibration.

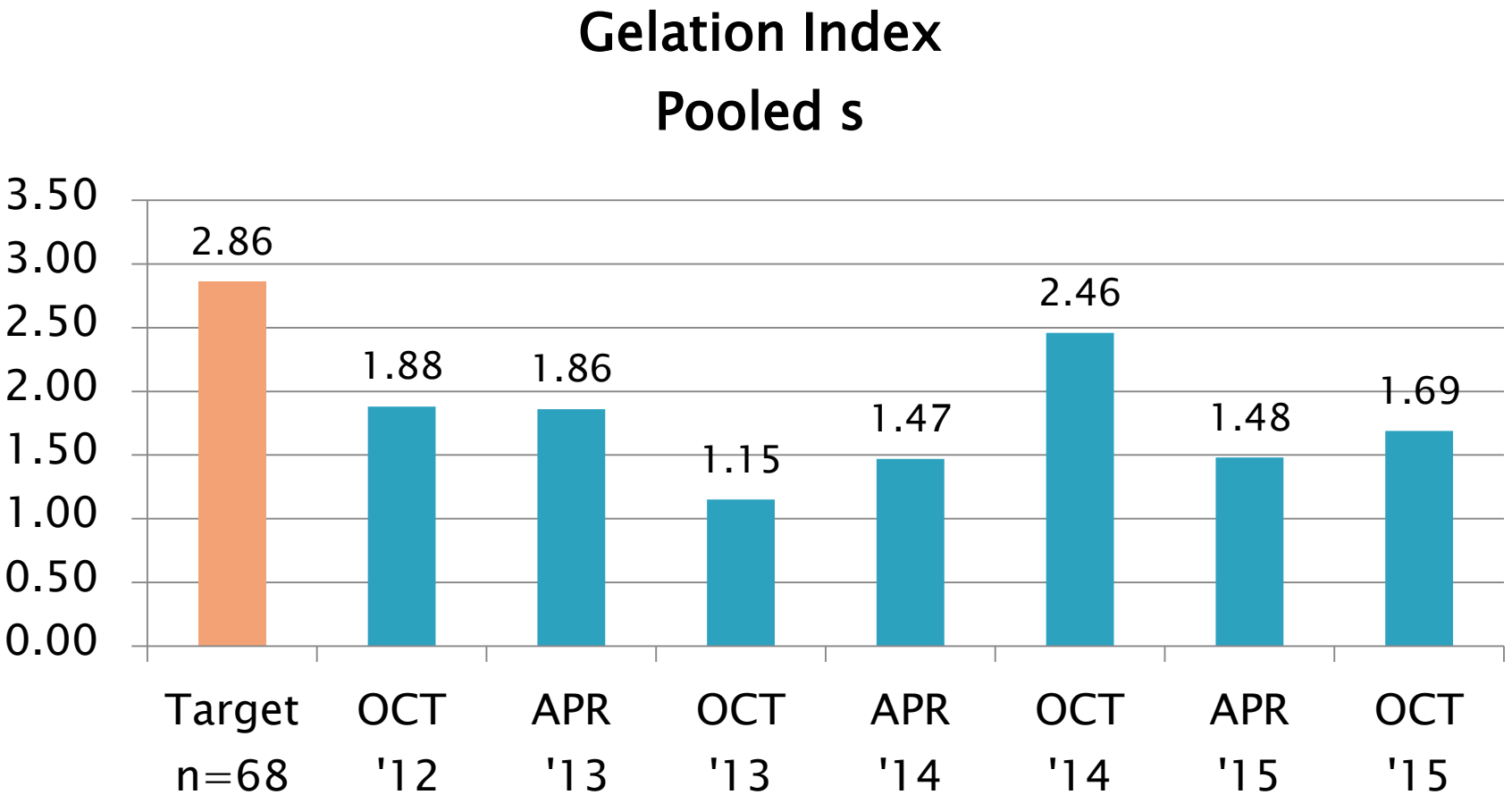
- No TMC technical updates issued this period

D5133: Gelation Index

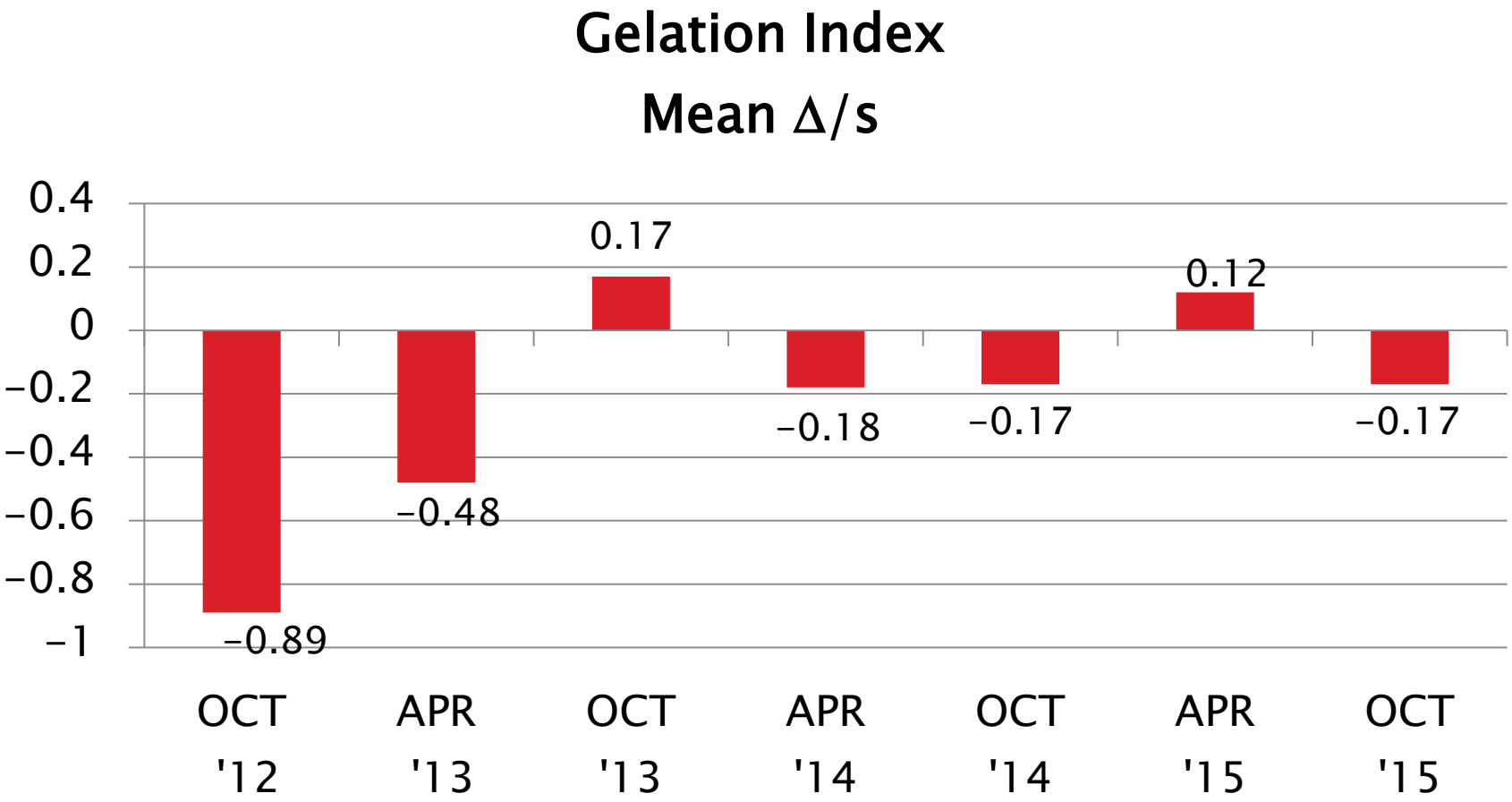
Period Precision and Severity Estimates

Gelation Index	n	df	Pooled s	Mean Δ/s
Current Targets 7/15/2003	68	65	2.86	-----
4/1/12 through 9/30/12	24	21	1.88	-0.89
10/1/12 through 3/31/13	22	19	1.86	-0.48
4/1/13 through 9/30/13	19	16	1.15	0.17
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

D5133 Precision Estimates



D5133 Severity Estimates



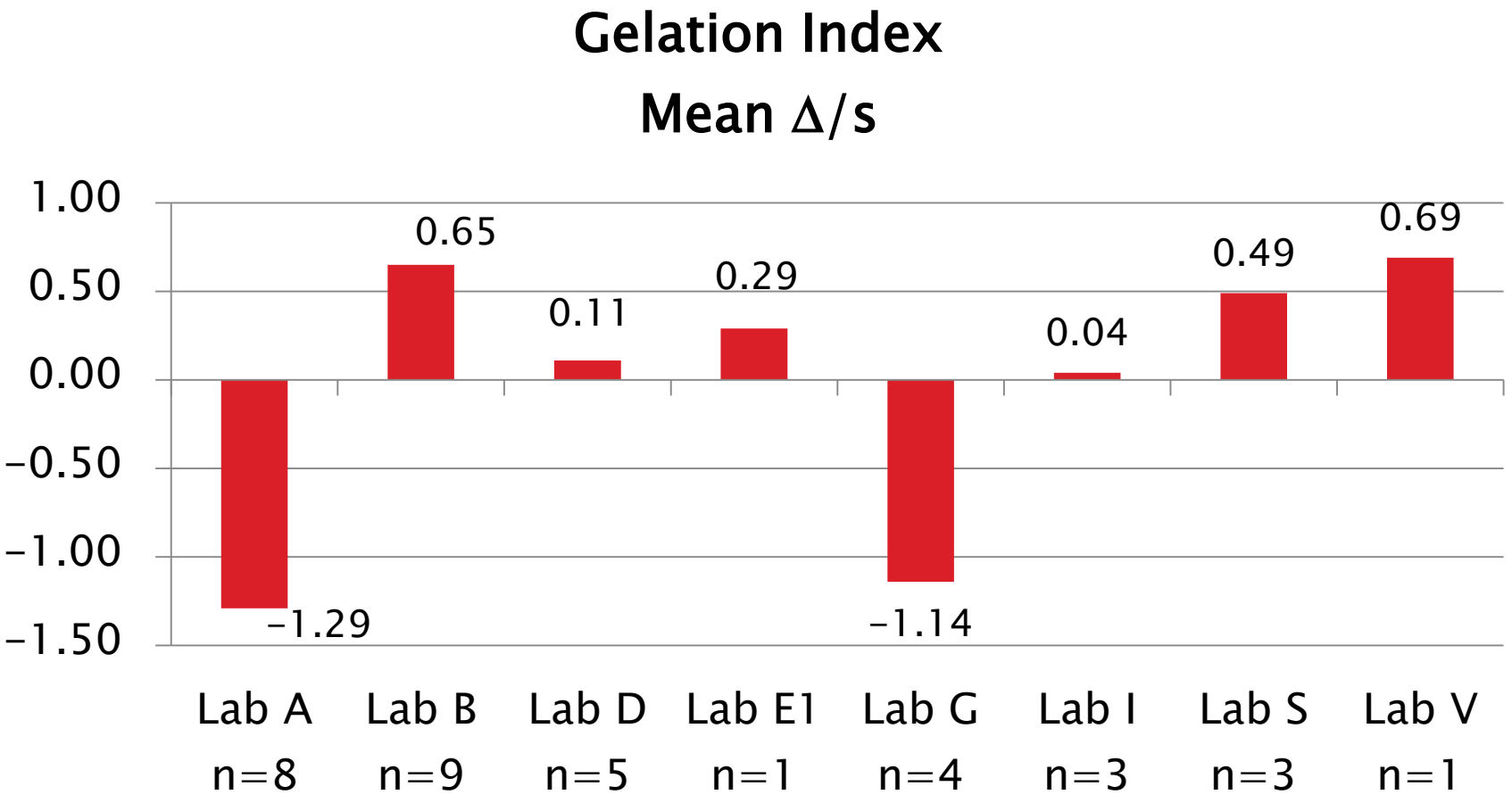
D5133: Gelation Index

Current Period Severity Estimates by Lab

Gelation Index

	n	Mean Δ/s
Lab A	8	-1.29
Lab B	9	0.65
Lab D	5	0.11
Lab E1	1	0.29
Lab G	4	-1.14
Lab I	3	0.04
Lab S	3	0.49
Lab V	1	0.69

D5133 Lab Severity Estimates



D5133: Gelation Index

- Precision (Pooled s) is less precise than prior period
  - More precise than target precision
- Performance (Mean Δ/s) is -0.17 s mild
- Reference oil 62 inventory is down to 1.2 gallons remaining (but only 0.2 gallons shipped prior 12 months).

D5133 GELATION INDEX INDUSTRY OPERATIONALLY VALID DATA

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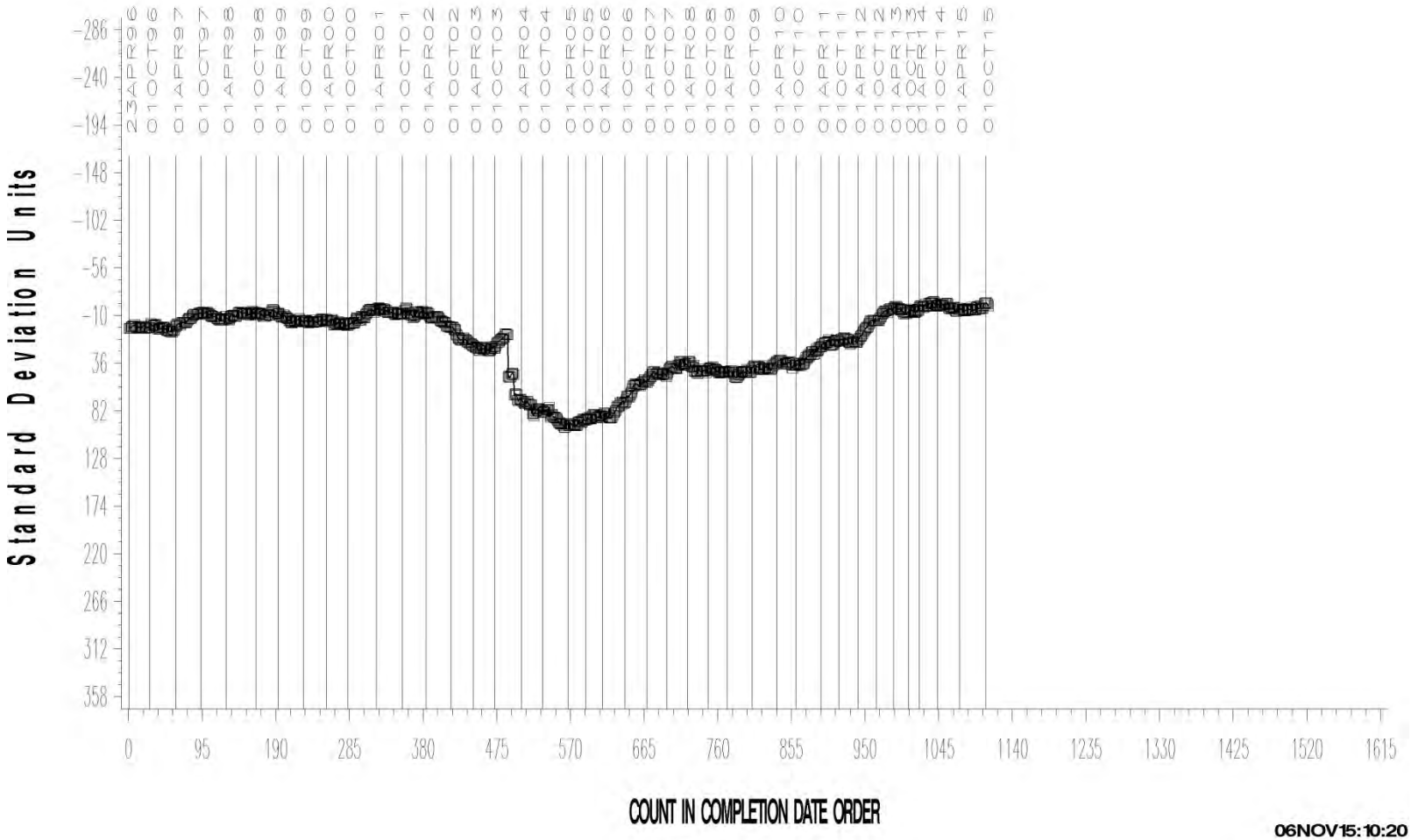
GELATION INDEX

CUSUM Severity Analysis



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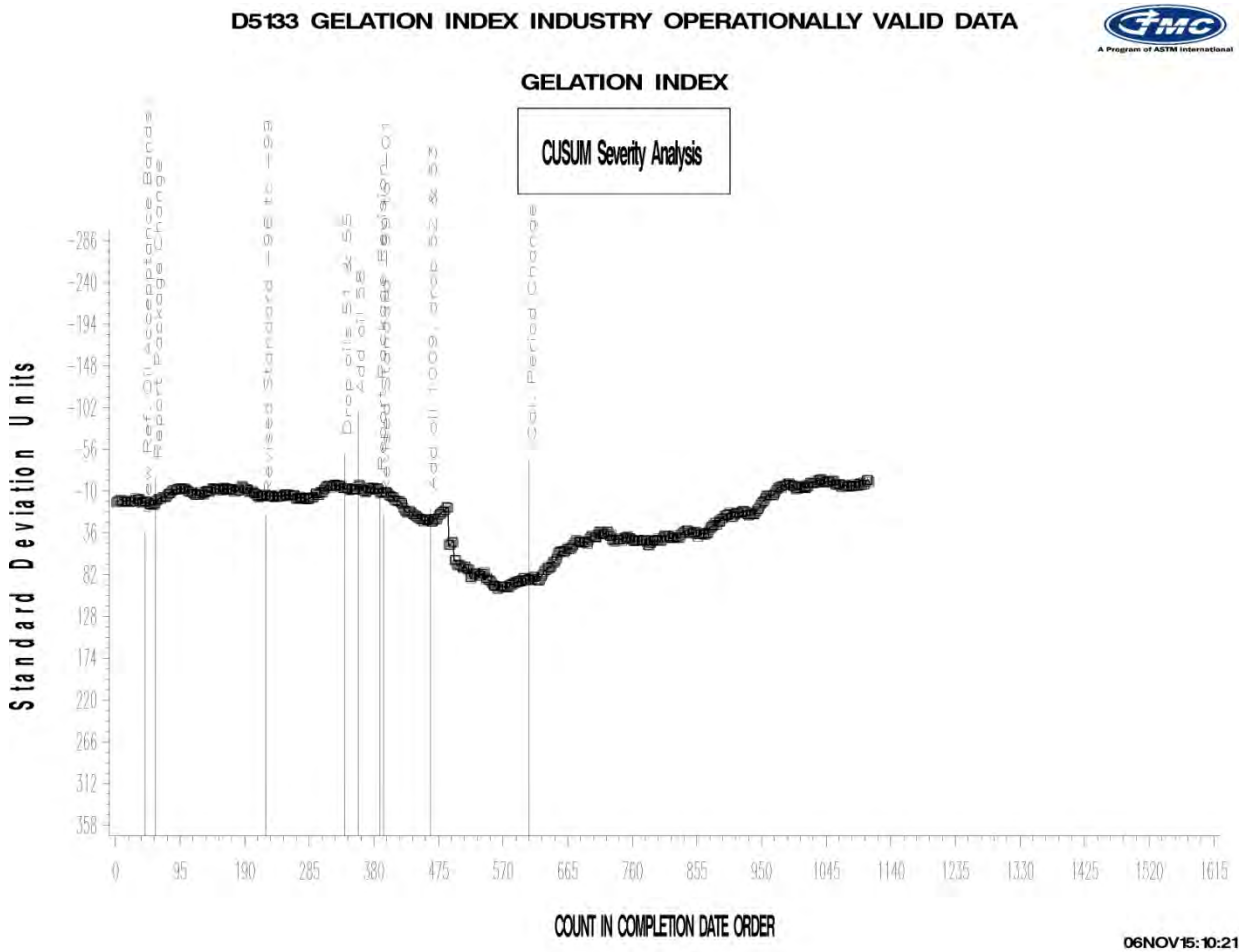
D5133: Gelation Index

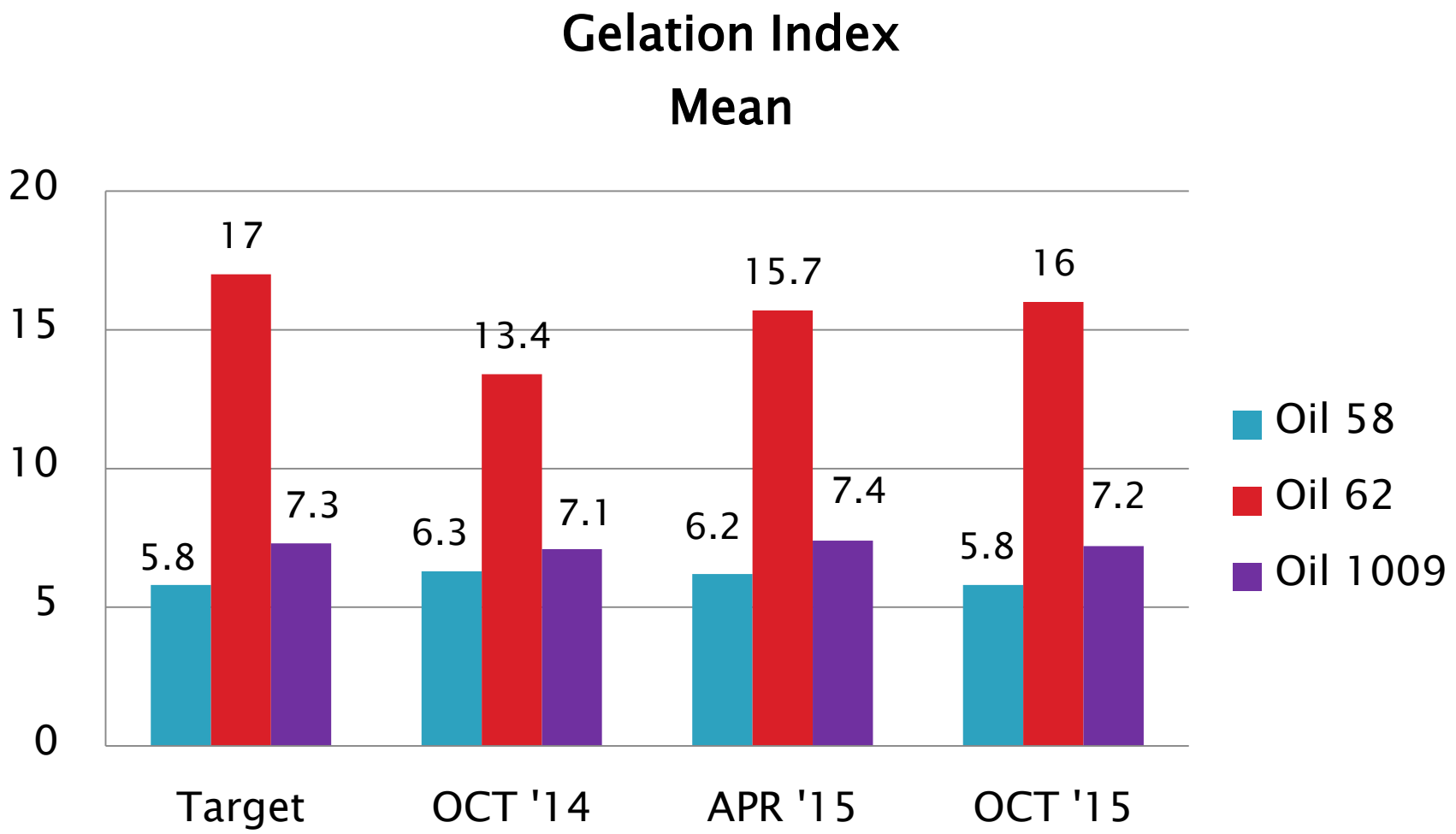


D5133 Performance by Oil

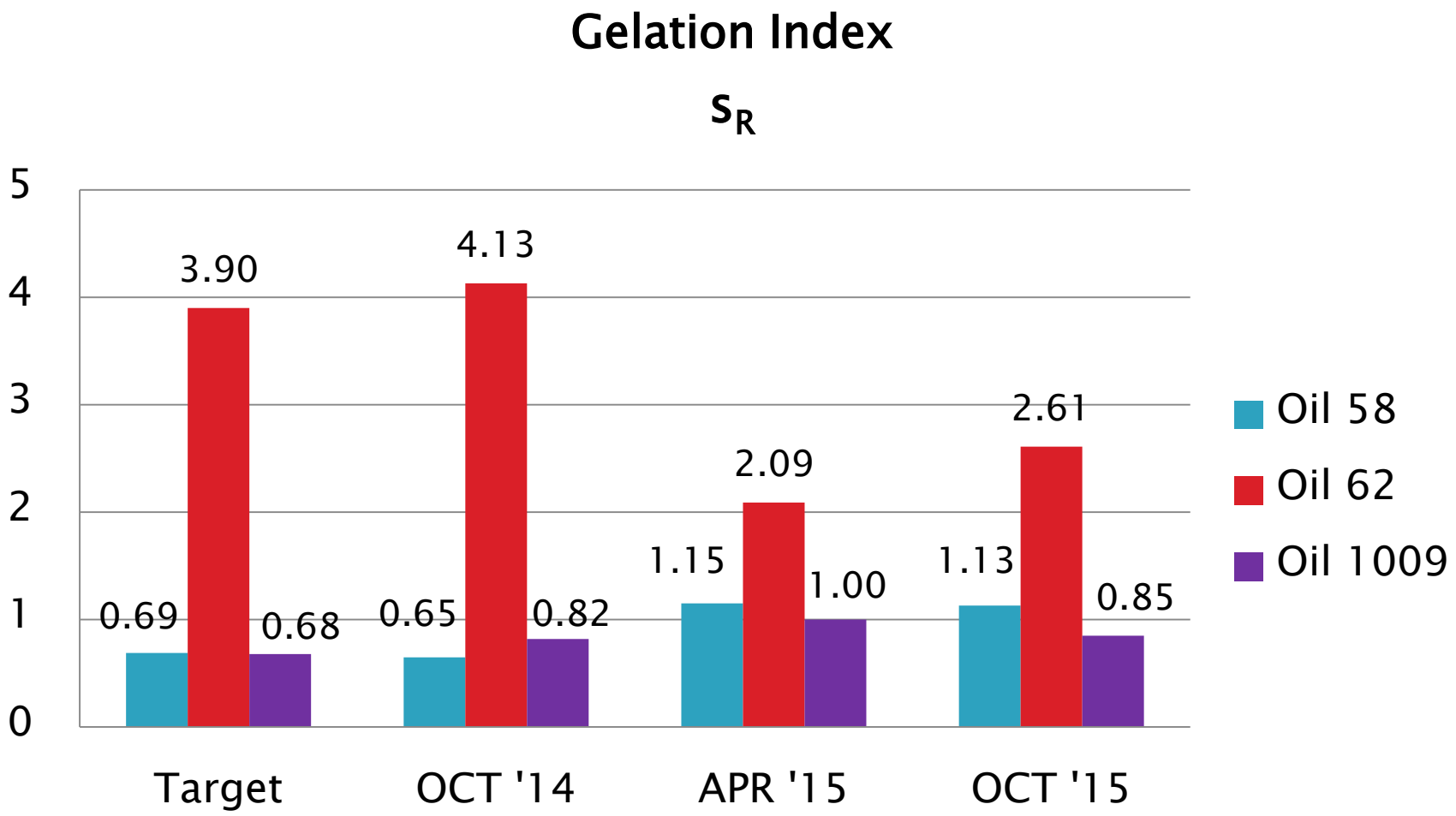
Gelation Index
Performance by Oil

	Targets			4/1/14 – 9/30/14				10/1/14 – 3/31/15				4/1/145– 9/30/15			
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	8	6.3	0.65	0.76	9	6.2	1.15	0.58	11	5.8	1.13	-0.03
62	35	17.0	3.90	8	13.4	4.13	-0.92	9	15.7	2.09	-0.34	11	16.0	2.61	-0.26
1009	16	7.30	0.68	8	7.1	0.82	-0.35	10	7.4	1.00	0.12	12	7.2	0.85	-0.22

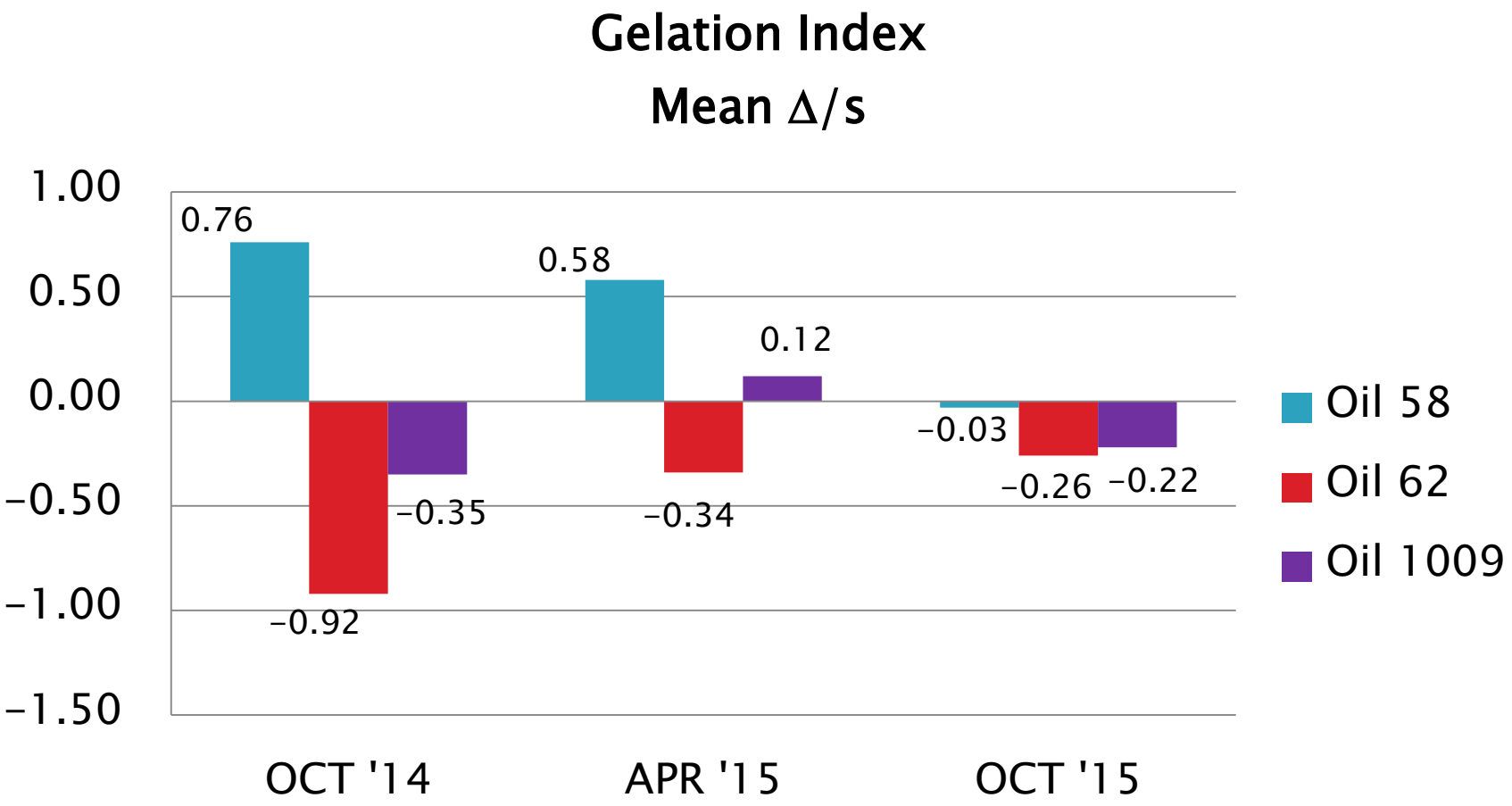
D5133 Performance by Oil



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	15
Failed Calibration Test	OC	1
Operationally Invalidated by Lab	LC, XC	1
Operationally Invalidated After Initially Reported as Valid	RC	0
Total		**17**

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

D6335: Deposits by TEOST-33C

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

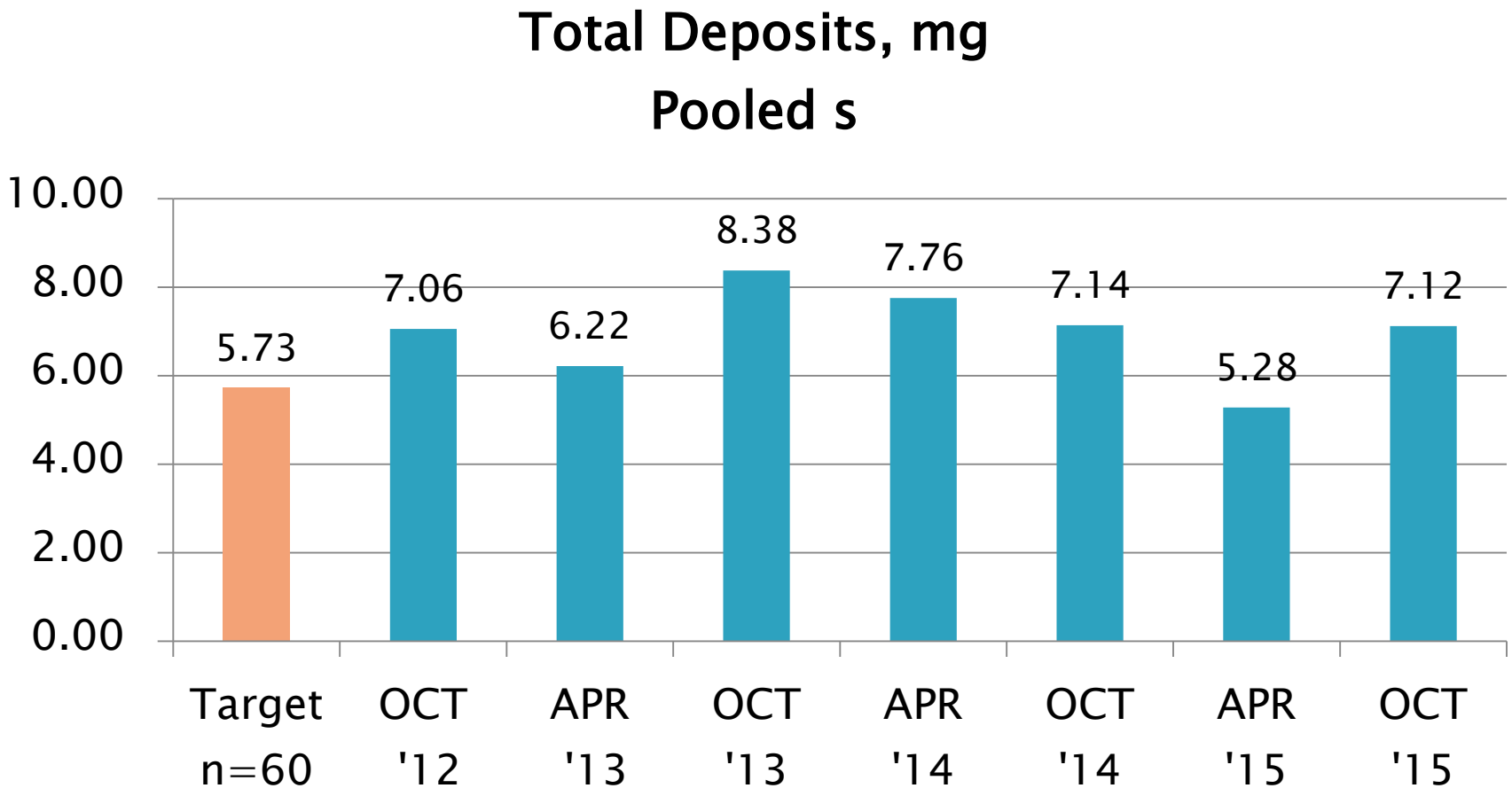
- One operationally invalid tests reported this period:
  - Reported as invalid due to air leak.
- No TMC technical updates issued this period

D6335: Deposits by TEOST-33C

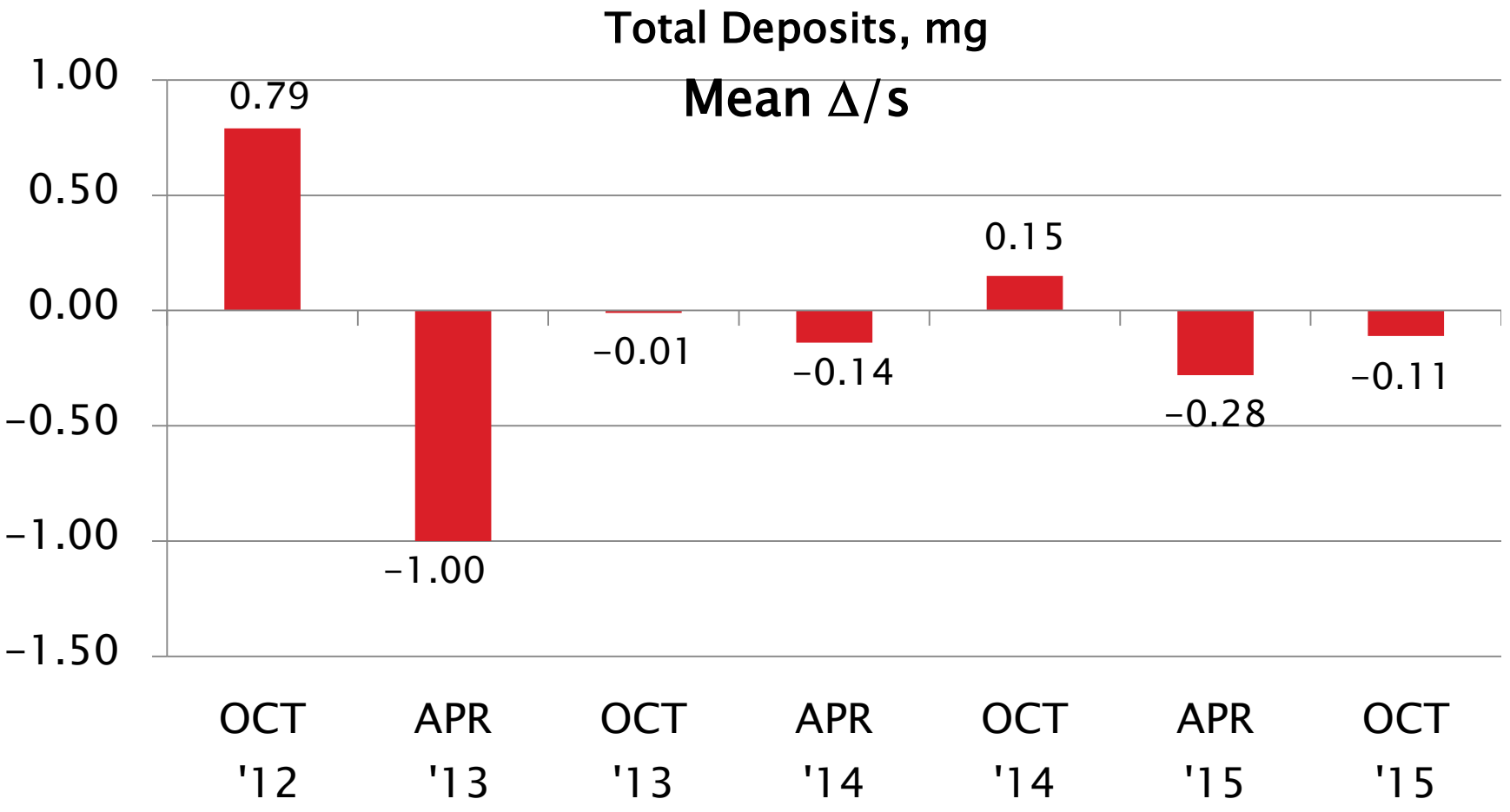
Period Precision and Severity Estimates

Total Deposits, mg	n	df	Pooled s	Mean Δ/s
Updated Targets 20130415	60	58	5.73	-----
4/1/12 through 9/30/12	18	15	7.06	0.79
10/1/12 through 3/31/13	22	20	6.22	-1.00
4/1/13 through 9/30/13	17	15	8.38	-0.01
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

D6335 Precision Estimates



D6335 Severity Estimates

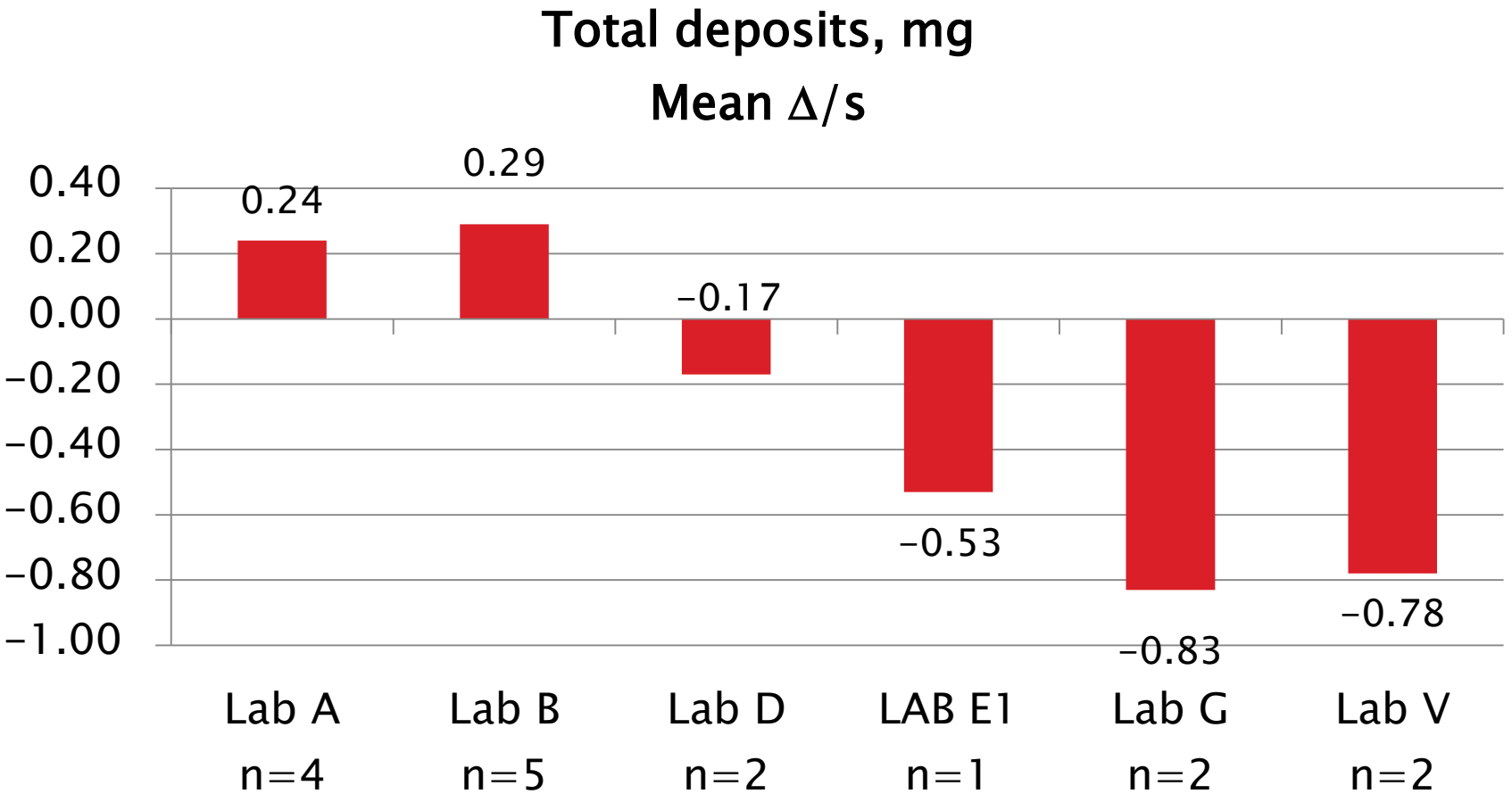


D6335: Deposits by TEOST-33C

Current Period Severity Estimates by Lab
Total Deposits, mg

	n	Mean Δ/s
Lab A	4	0.24
Lab B	5	0.29
Lab D	2	-0.17
Lab E1	1	-0.53
Lab G	2	-0.83
Lab V	2	-0.78

D6335 Lab Severity Estimates



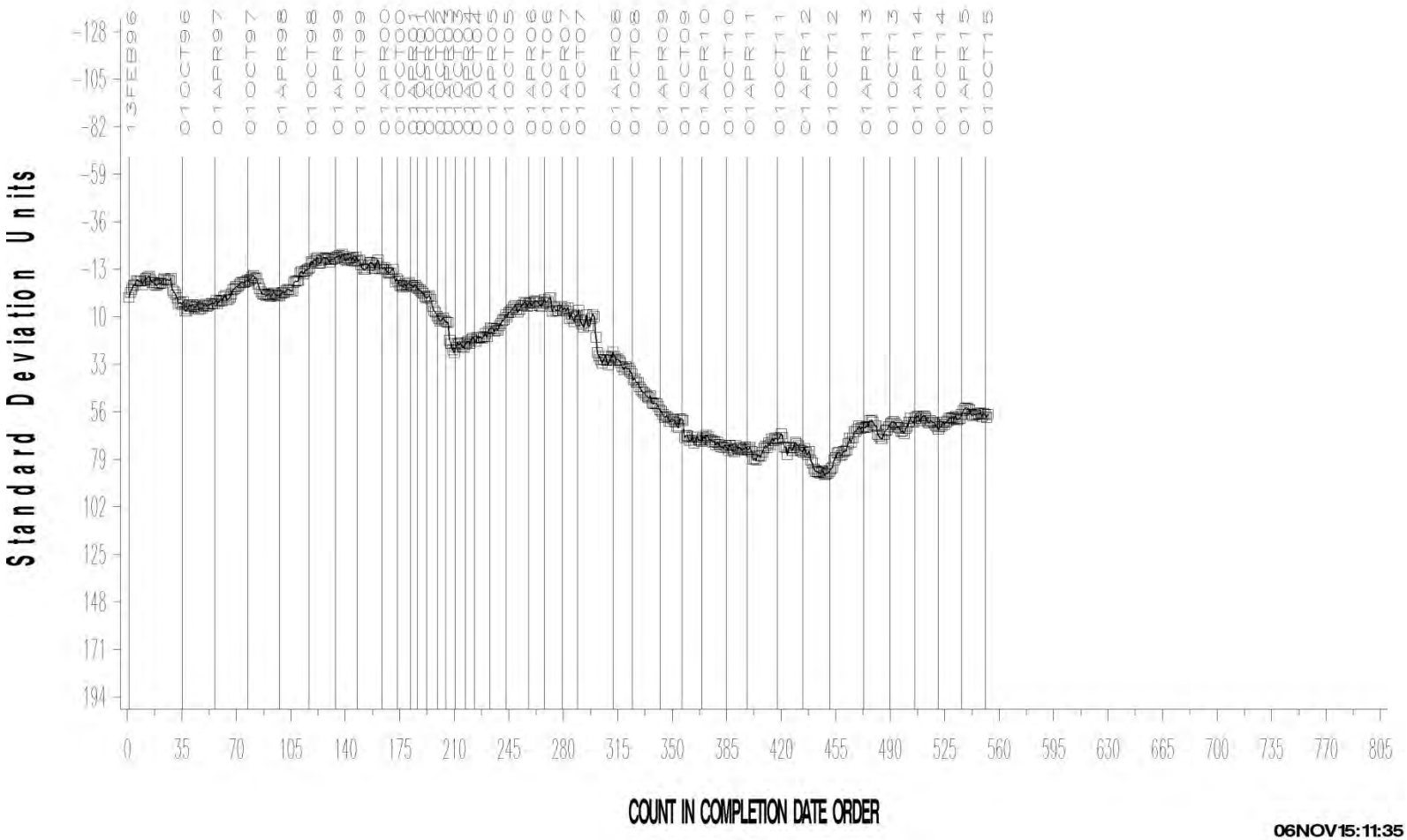
D6335: Deposits by TEOST-33C

- Precision (Pooled s) is less precise than prior period
  - Less precise than target precision.
- Performance (Mean Δ/s) is -0.11 s mild
- All tests this period report using Rod Batches L or M

TEOST—33C INDUSTRY OPERATIONALLY VALID DATA

TOTAL DEPOSITS MG

CUSUM Severity Analysis



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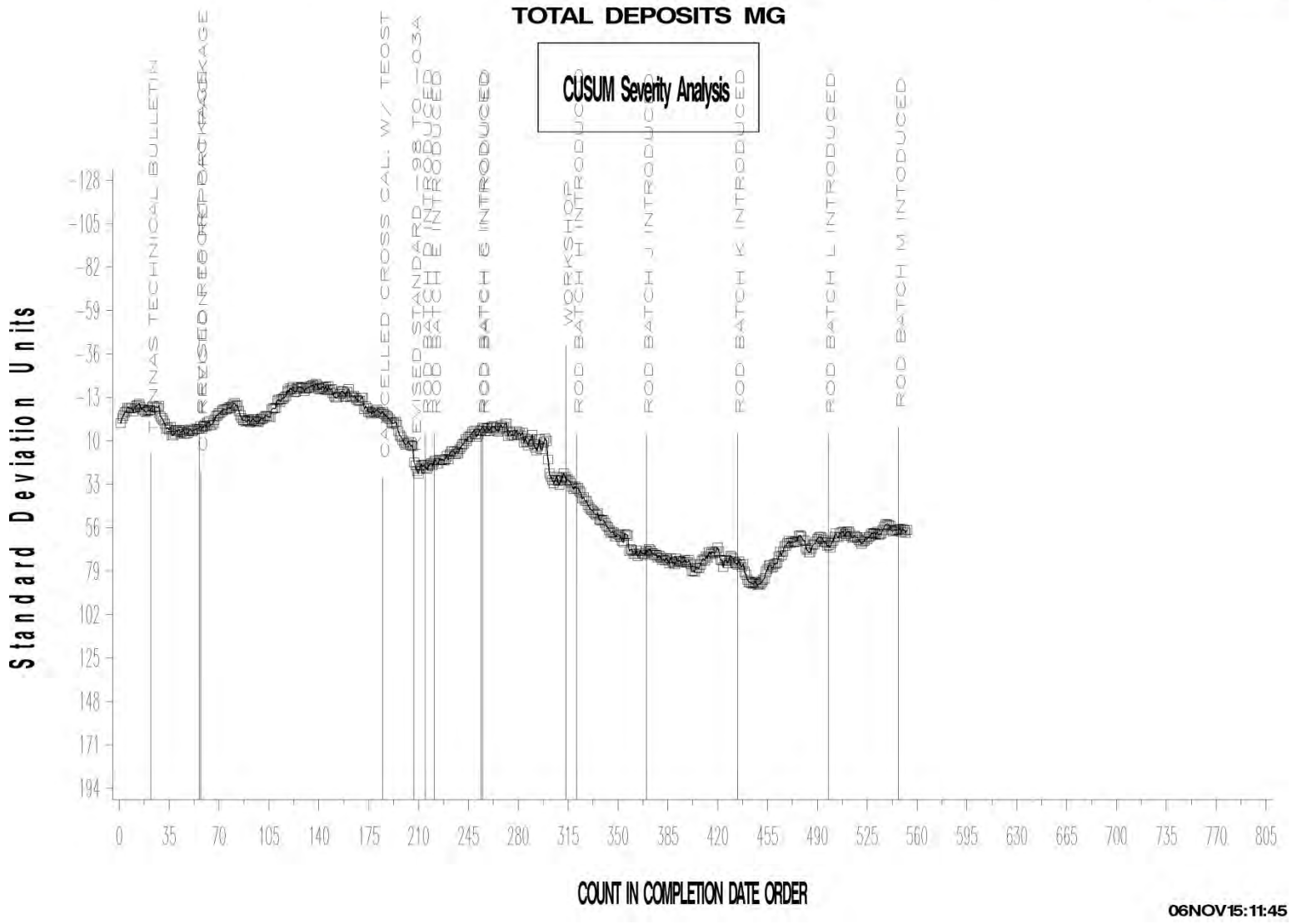
TEOST–33C INDUSTRY OPERATIONALLY VALID DATA



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Test Monitoring Center

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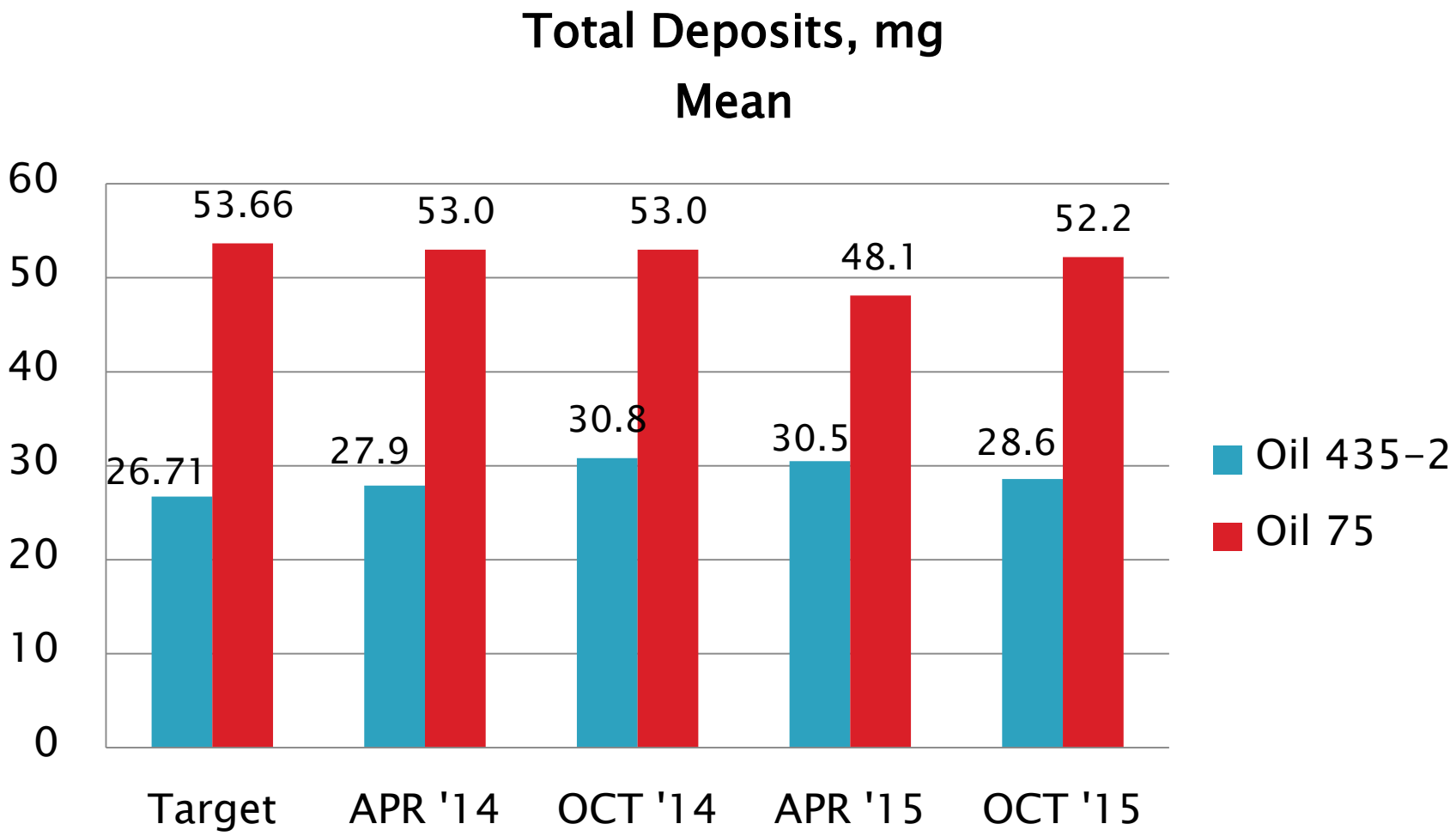
D6335 Performance by Oil

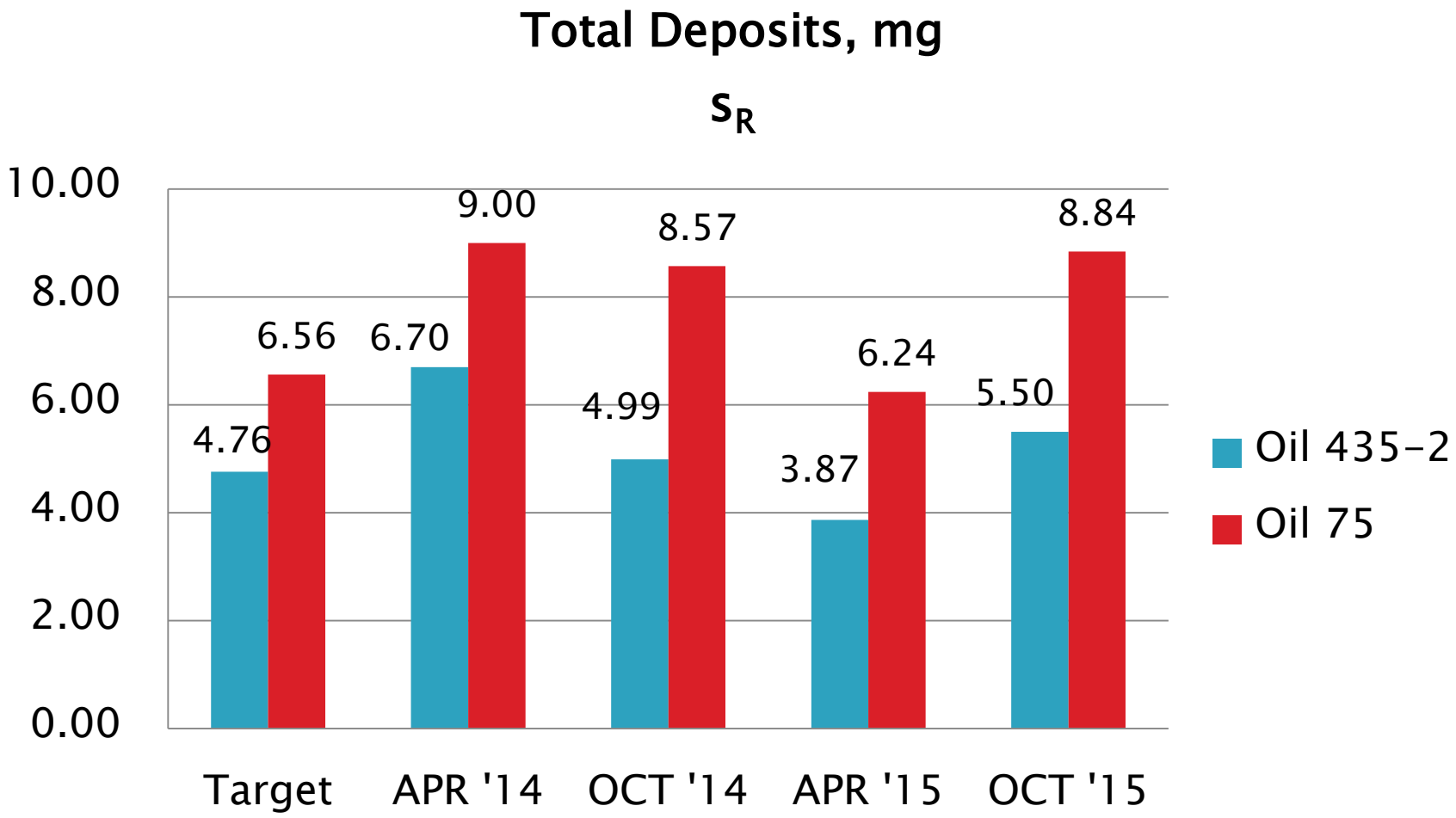
Total Deposits, mg
Performance by Oil

	Targets 20130415			4/1/14 – 9/30/14				10/1/14 – 3/31/15				4/1/15 – 9/30/15			
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	7	30.8	4.99	0.44	7	30.5	3.87	0.37	9	28.6	5.50	-0.01
75	30	53.66	6.56	8	53.0	8.57	-0.10	8	48.1	6.24	-0.85	7	52.2	8.84	-0.22

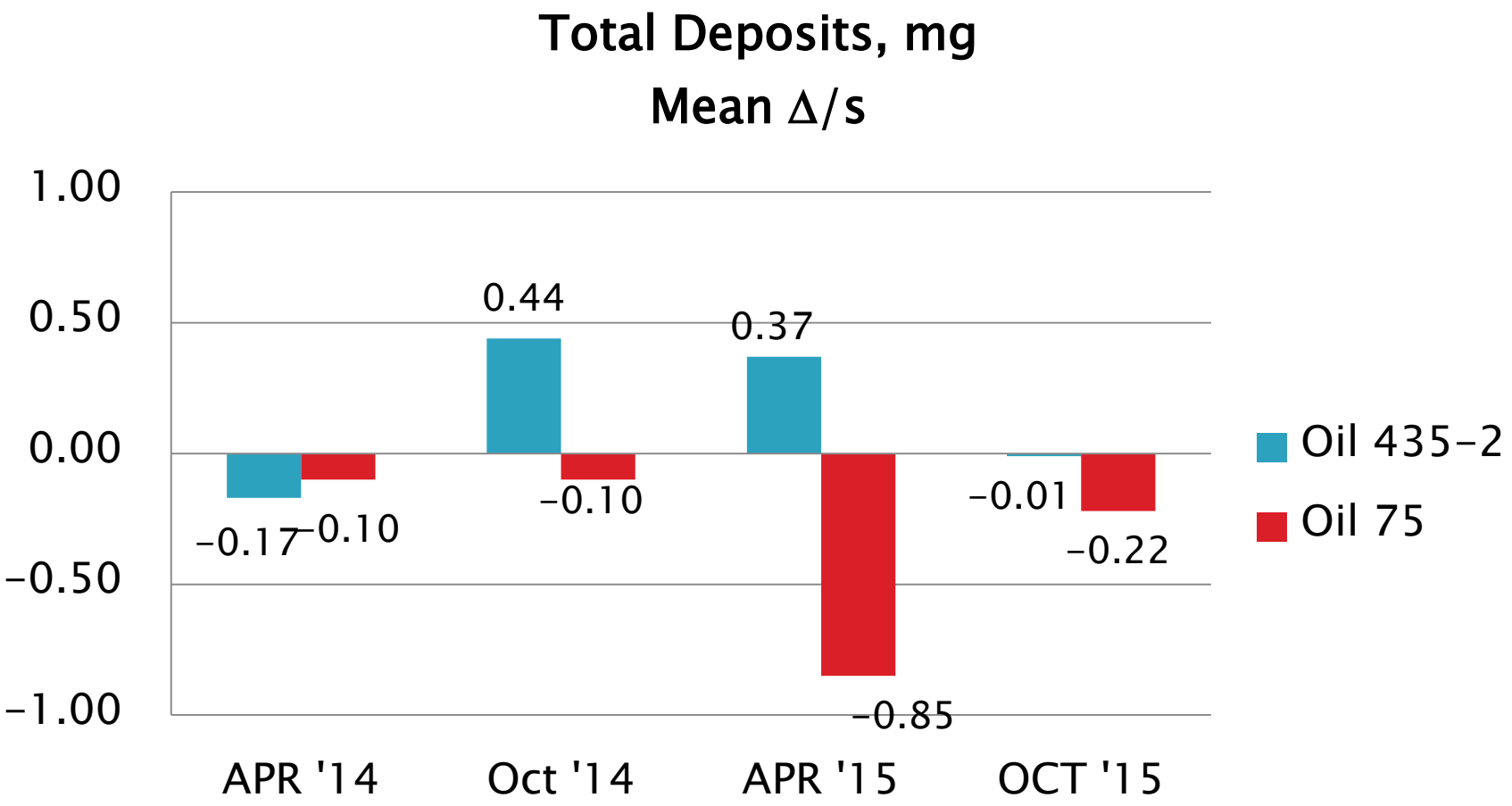
D6335 Performance by Oil



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	73
Failed Calibration Test	OC	11
Operationally Invalidated by Lab	XC	4
Operationally Invalidated After Initially Reported as Valid	RC	2
Donated Catalyst Screener Runs	AG, OG	11
Non-blind Shakedown Run	NN, ON	5
Excluded from Statistics (New Rig)	MC	4
Total		**110**

Number of Labs Reporting Data: 8

Fail Rate of Operationally Valid Tests: 13%

D7097: Deposits by MHT TEOST

Statistically Unacceptable Tests (OC)	No. Of Tests
Total Deposits Mild	1
Total Deposits Severe	10

- Six operationally invalid calibration tests this period:
  - Oil leak, one test (XC)
  - Negative filter deposits reported, one test (RC)
  - Spilled reference sample at start of test, one test (XC)
  - Power failure, one test (XC)
  - Test ran over specified time, one test (XC)
  - Neat sample weight off-spec, one test (RC)

- Two test excluded from statistics (MC), new rig, reported as operationally valid but failed to calibrate.

D7097: Deposits by MHT TEOST

- Five shakedown runs (NN, ON) to troubleshoot Instrument G1, which had seven consecutive prior calibration run fails (5 OC's severe, included in statistics, 4 from last period and 1 this period). Instrument subsequently calibrated successfully.
  - Last period overall statistics shown including and excluding instrument G1
  - Last period statistics by oil exclude all instrument G1 runs.

- 11 donated runs to screen catalyst batch 15AA (AG, OG)

- No TMC technical updates issued this period

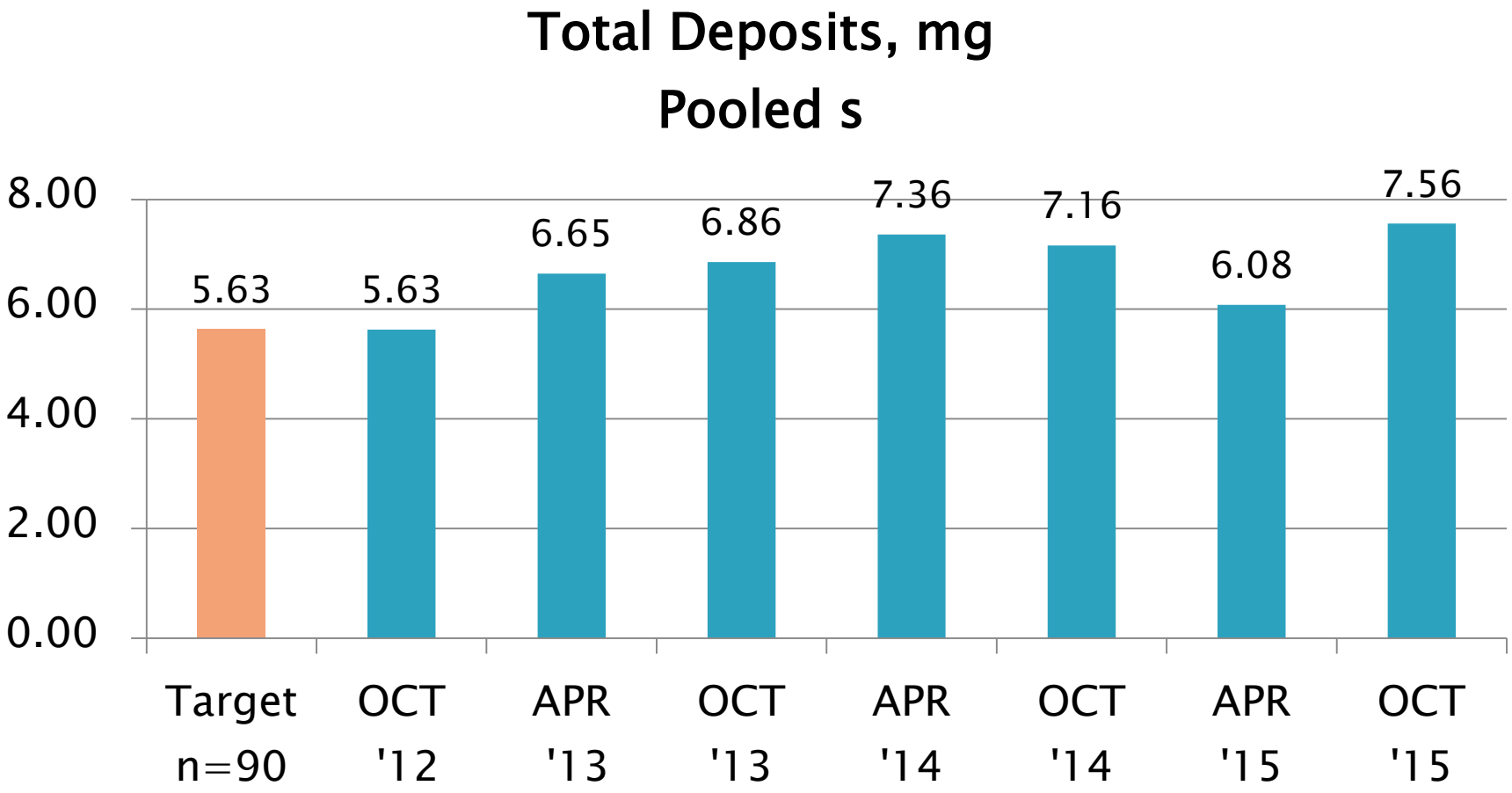
D7097: Deposits by MHT TEOST

Period Precision and Severity Estimates

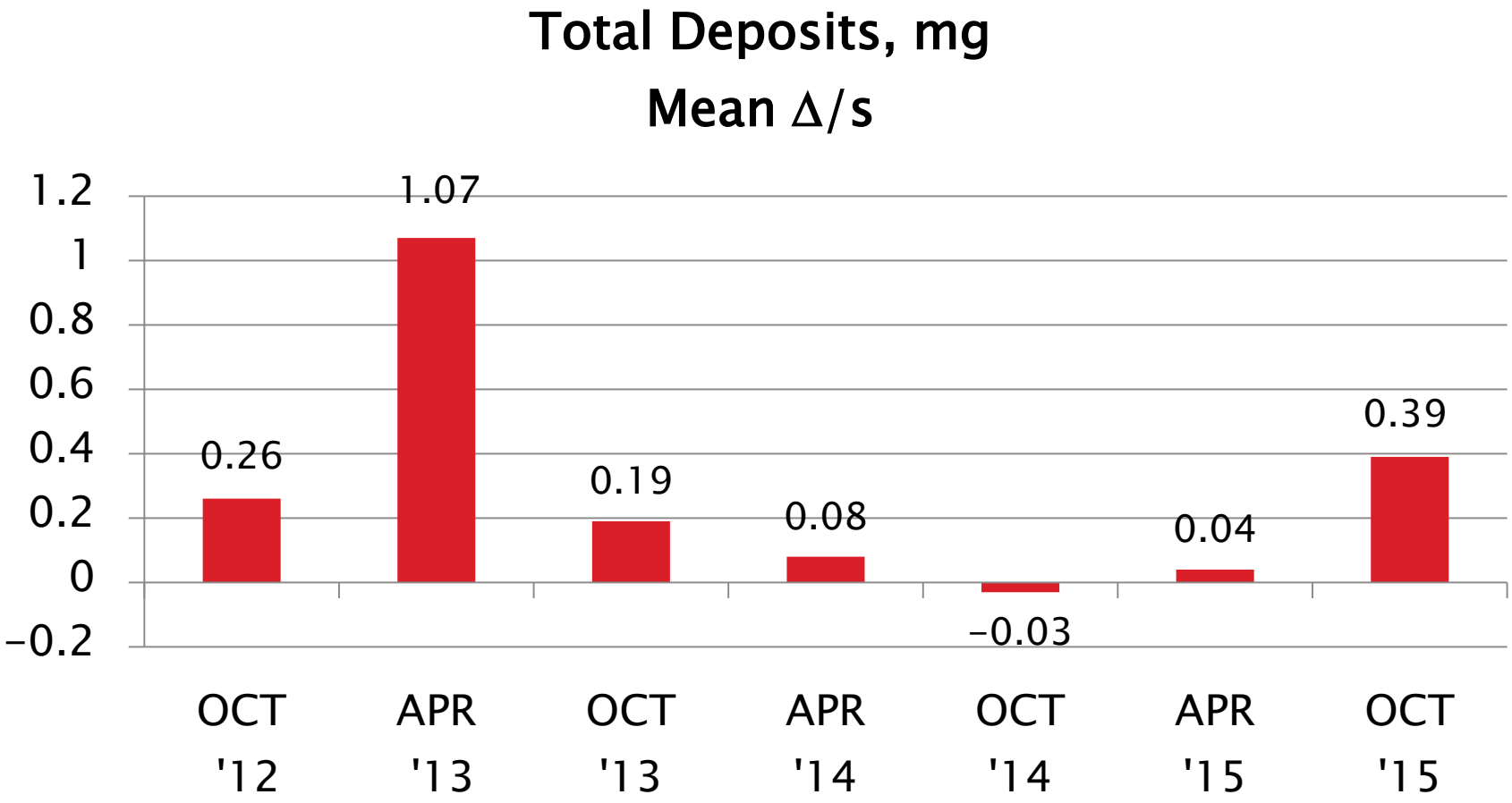
Total Deposits, mg	n	df	Pooled s	Mean Δ/s
Current Targets 7/31/2006	90	87	5.63	-----
4/1/12 through 9/30/12	65	62	5.63	0.26
10/1/12 through 3/31/13	68	66	6.65	1.07
4/1/13 through 9/30/13	85	83	6.86	0.19
10/1/13 through 3/31/14	71	69	7.36	0.08
4/1/14 through 9/30/14	76	74	7.16	-0.03
10/1/14 through 3/31/15* 10/1/14 through 3/31/15*	94 90	92 88	6.60 6.08	0.19 0.04
4/1/15 through 9/30/15	84	82	7.56	0.39

*Four severe OC tests from instrument G1 included and excluded

D7097 Precision Estimates



D7097 Severity Estimates

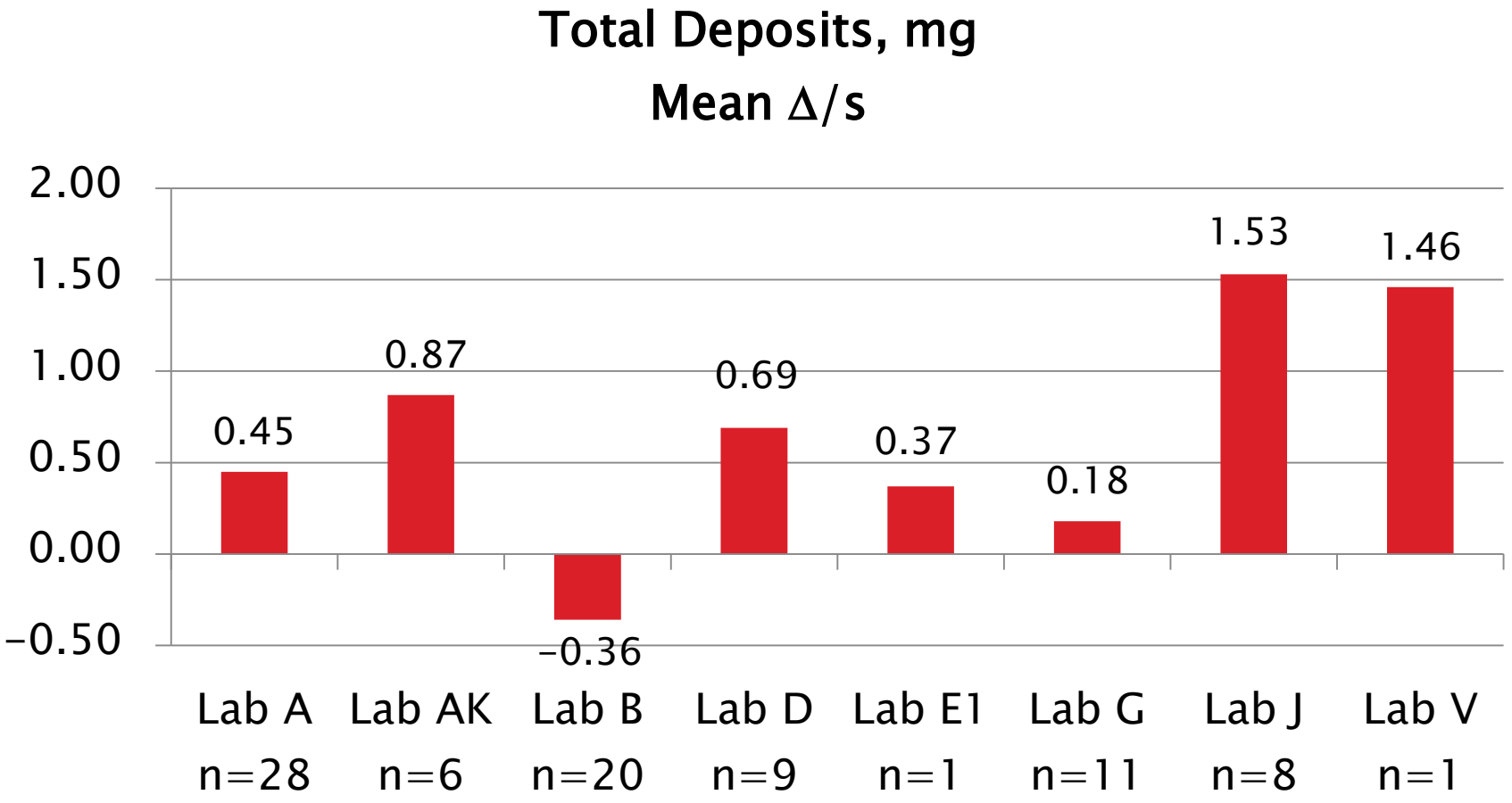


D7097: Deposits by MHT TEOST

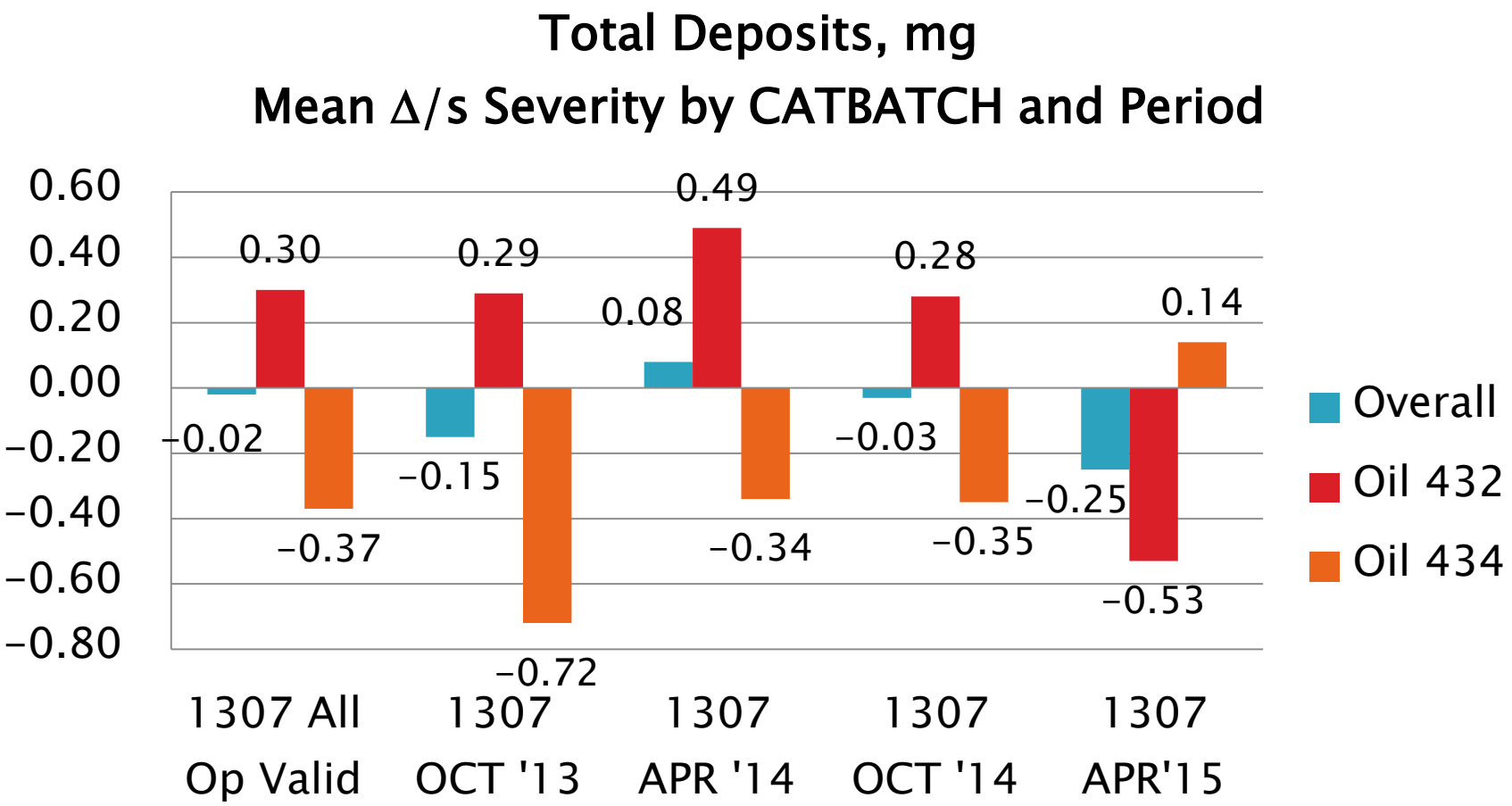
Current Period Severity Estimates by Lab
Total Deposits, mg

	n	Mean Δ/s
Lab A	28	0.45
Lab AK	6	0.87
Lab B	20	-0.36
Lab D	9	0.69
LAB E1	1	0.37
Lab G	11	0.18
Lab J	8	1.53
Lab V	1	1.46

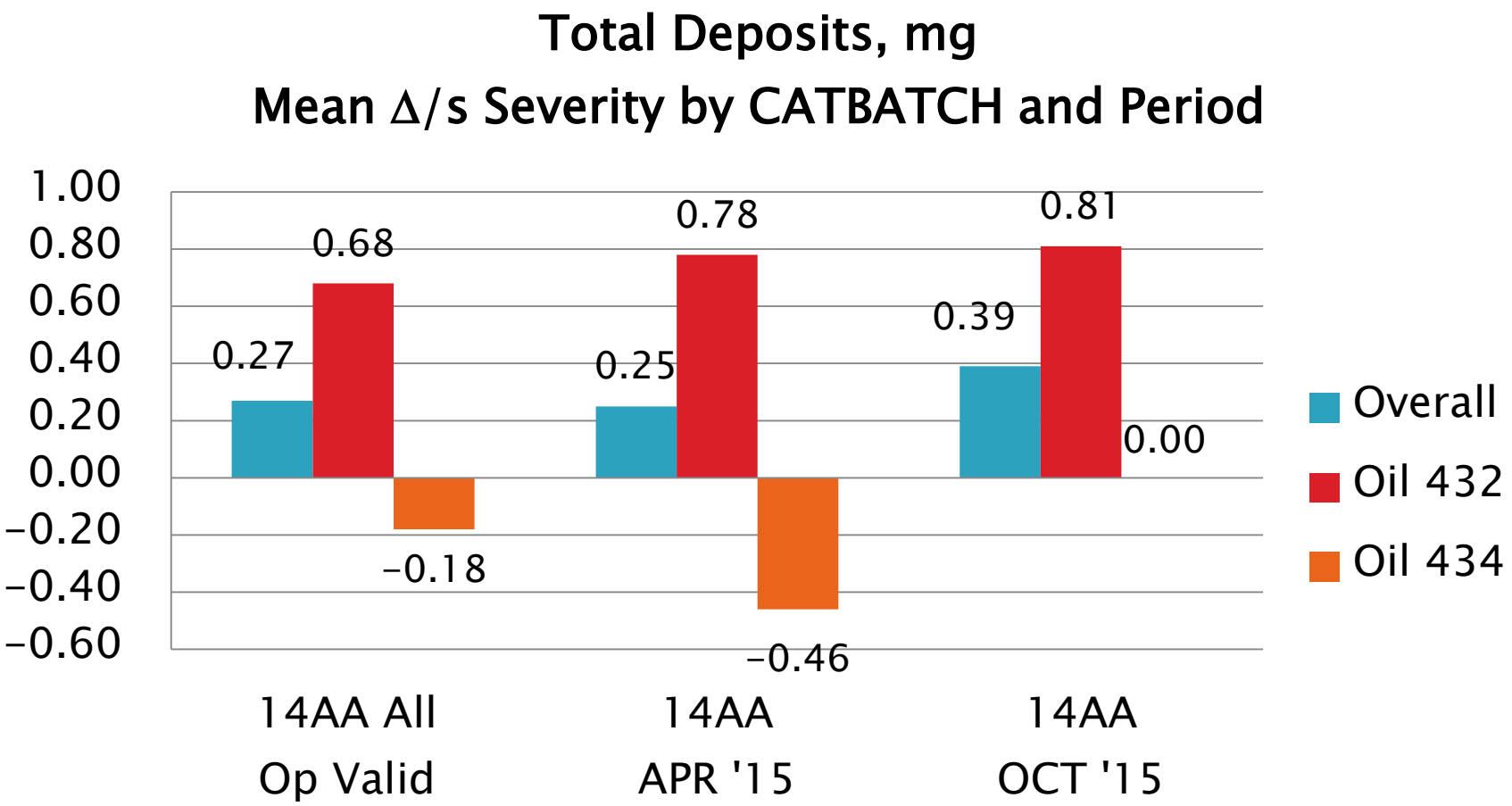
D7097 Lab Severity Estimates



D7097: Deposits by MHT TEOST



D7097: Deposits by MHT TEOST



D7097: Deposits by MHT TEOST

- Precision (Pooled s) is less precise than prior period
  - Less precise than target precision
- Performance (Mean Δ/s) is 0.39 s severe
- 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 , the first period with all results on batch 14AA

D7097: Deposits by MHT TEOST

- CUSUM severity plot shows slight severe trend this period with all labs reporting using catalyst batch 14AA
  - However, lab performance differences persist
  - Severe oil 432 continues to perform severe, but, unlike prior periods, mild performing oil 434 is running on-target rather than mild.
    - Catalyst batches have been observed to bias performance differently for different oils, and may partially explain observed severity differences between the two reference oils oil, but does not explain ongoing lab severity differences.

MHT—4 TEOST INDUSTRY OPERATIONALLY VALID DATA

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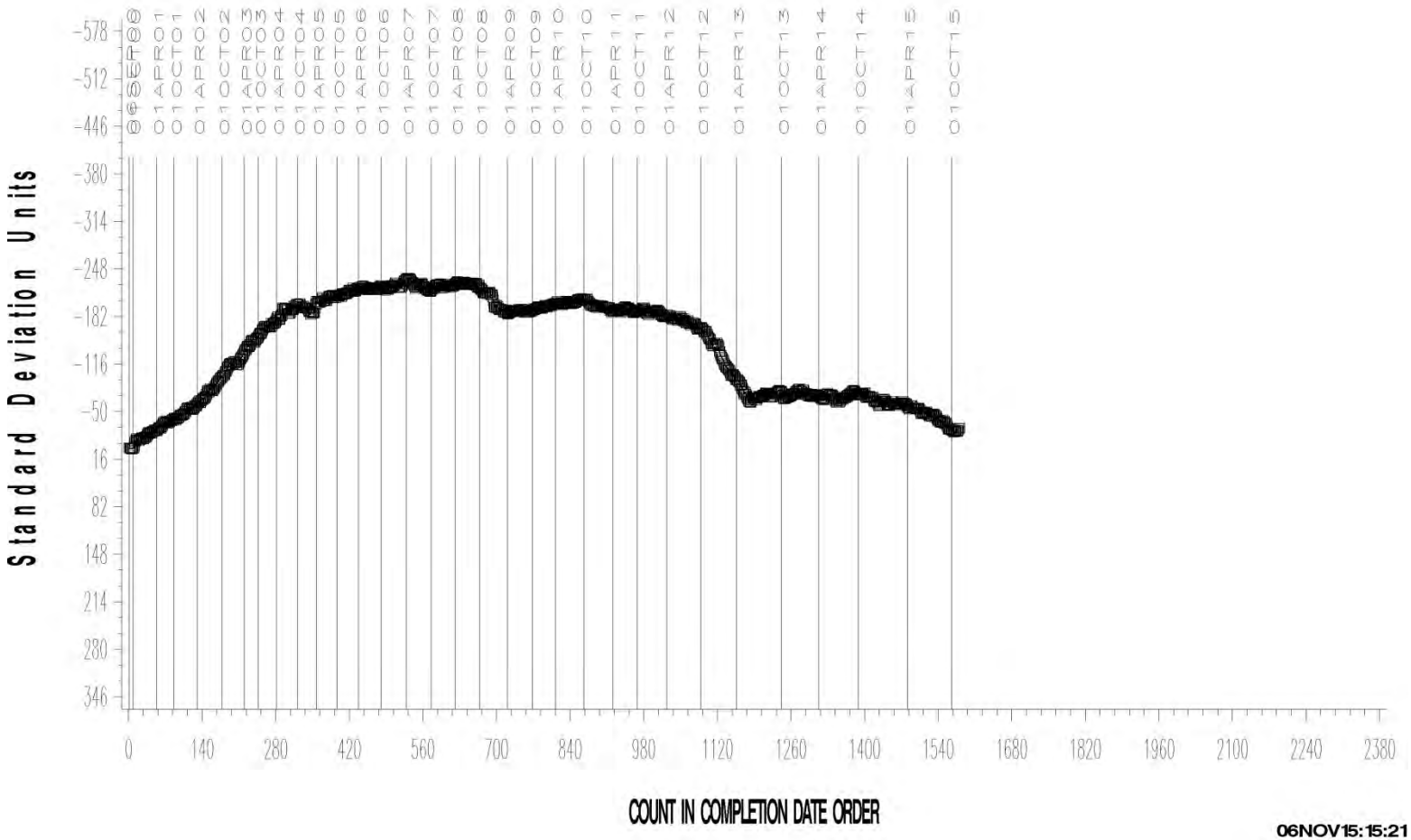
TOTAL DEPOSITS MG

CUSUM Severity Analysis



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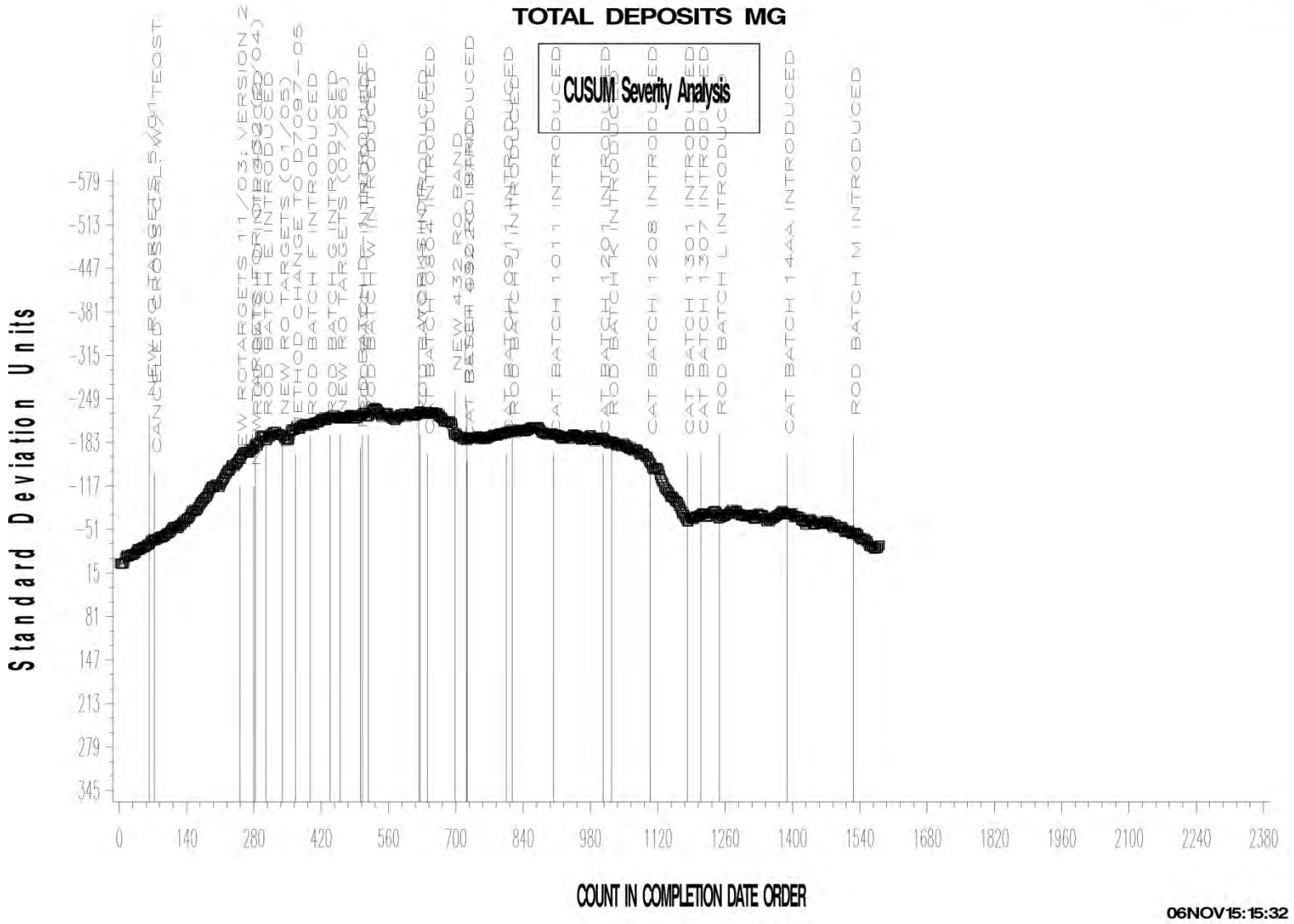
MHT—4 TEOST INDUSTRY OPERATIONALLY VALID DATA



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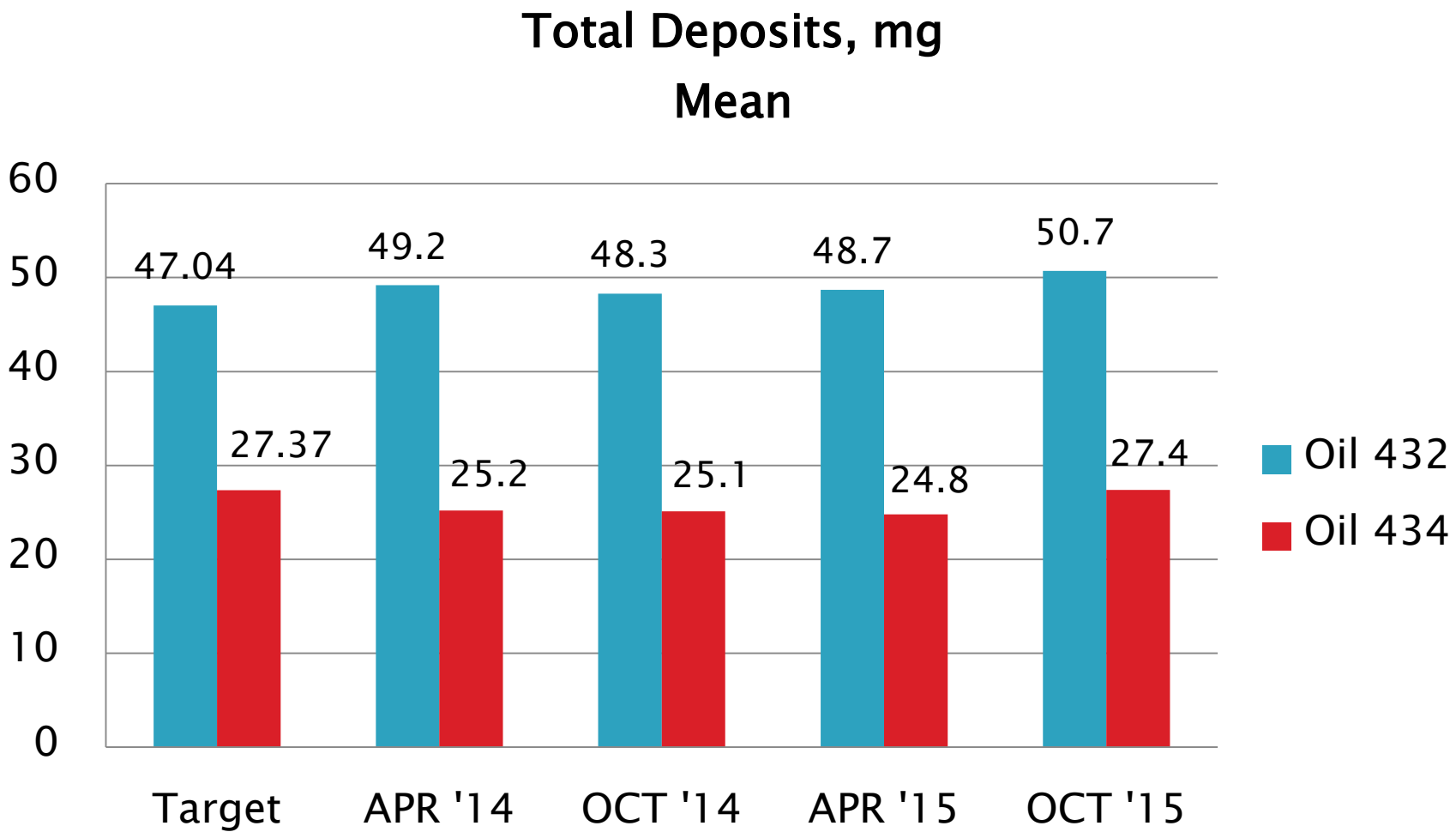
D7097 Performance by Oil

Total Deposits, mg
Performance by Oil

	Targets			4/1/14 – 9/30/14				10/1/14 – 3/31/15				4/1/15 – 9/30/15			
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	39	48.3	6.87	0.28	50	48.7	5.55	0.38	40	50.7	5.60	0.81
434	30	27.37	6.57	37	25.1	7.45	-0.35	40	24.8	6.68	-0.39	44	27.4	8.98	0.00

D7097 Performance by Oil



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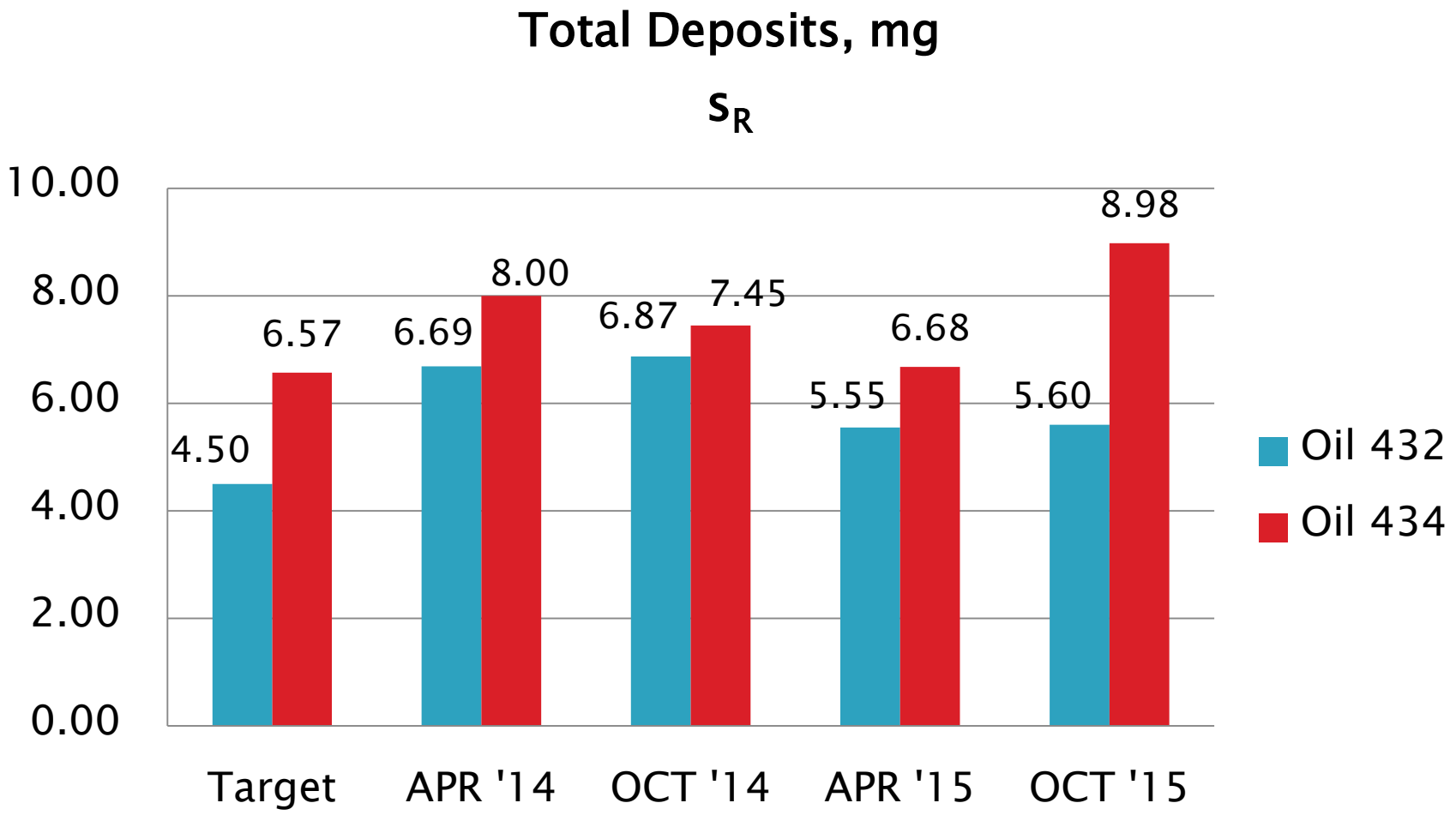
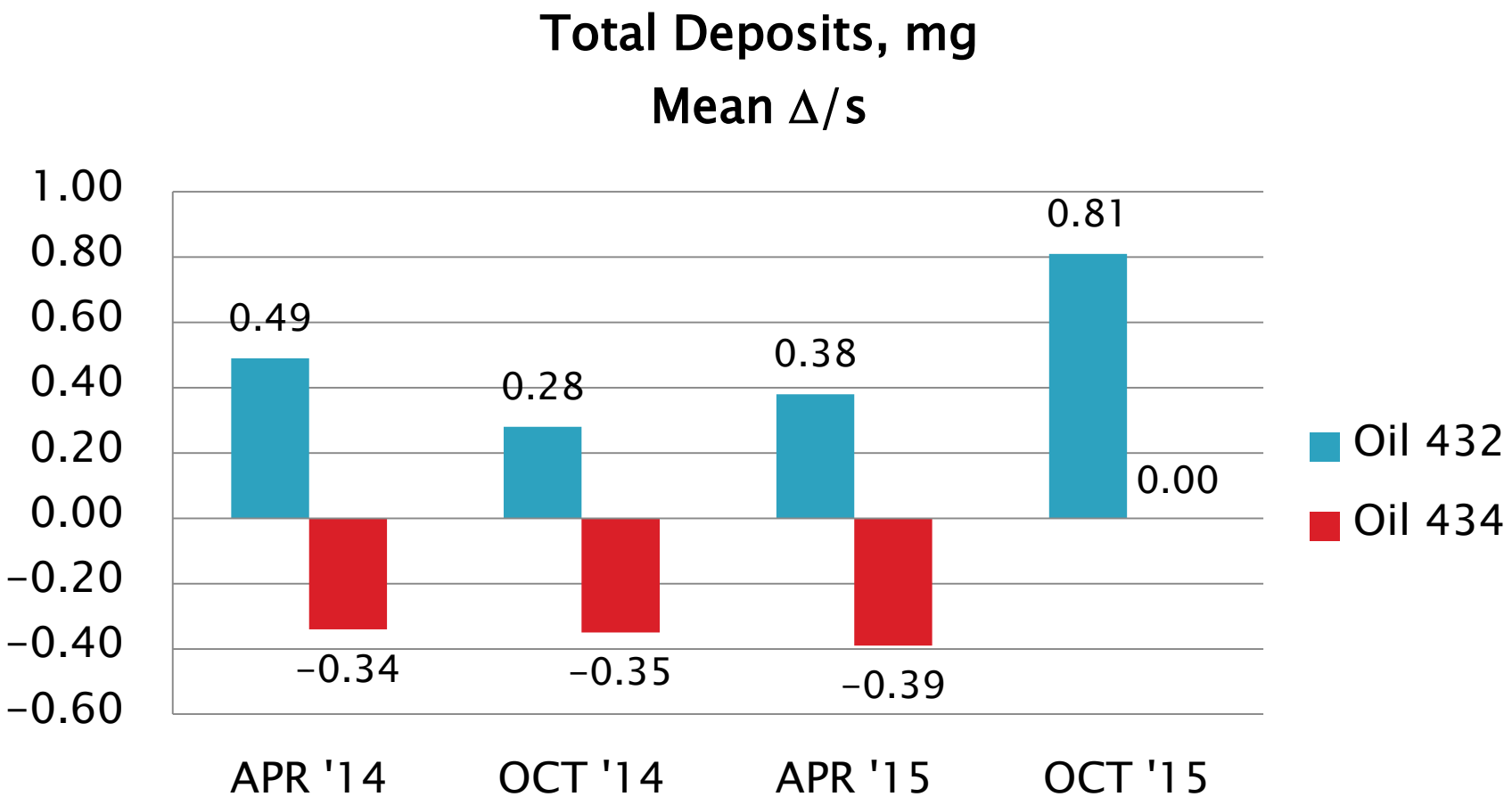
D7097: Deposits by MHT TEOST



D7097: Deposits by MHT TEOST



Return to Executive Summary

D6082: High Temperature Foam

Test Status	Validity Code	No. Tests
Acceptable Calibration Test	AC	11
Acceptable Discrimination Test	AS	5
Failed Calibration Test	OC	0
Operationally Invalidated by Lab	LC, XC	0
Operationally Invalidated After Initially Reported as Valid	RC	0
Total		**16**

Number of Labs Reporting Data: 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 operationally or statistically invalid tests reported this period

- All operationally valid discrimination runs reported this period could discriminate oil 66 as a GF-5/SN failing oil for Foam Tendency.

- No TMC technical updates issued this period

D6082: High Temperature Foam

Period Precision and Severity Estimates Oil 1007

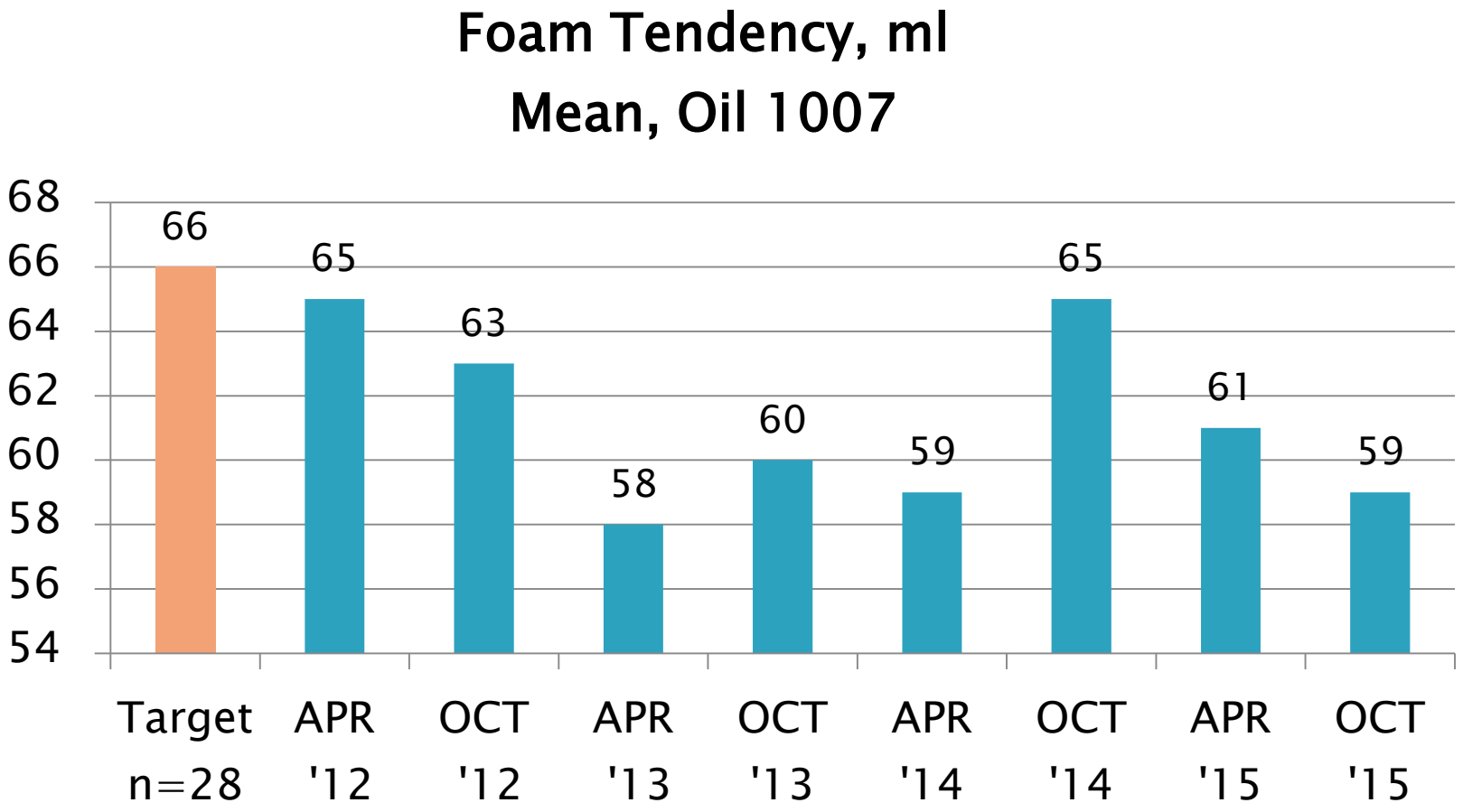
Foam Tendency, ml	n	Mean	Pooled s	Mean Δ/s
Current Targets	28	65.71	19.28	-----
10/1/11 through 3/31/12	8	65	13	-0.05
4/1/12 through 9/30/12	9	63	13	-0.14
10/1/12 through 3/31/13	8	58	10	-0.45
4/1/13 through 9/30/13	9	60	7	-0.32
10/1/13 through 3/31/14	11	59	8	-0.39
4/1/14 through 9/30/14	11	65	22	-0.05
10/1/14 through 3/31/15	10	61	12	-0.26
4/1/15 through 9/30/15	11	59	16	-0.36

D6082: High Temperature Foam

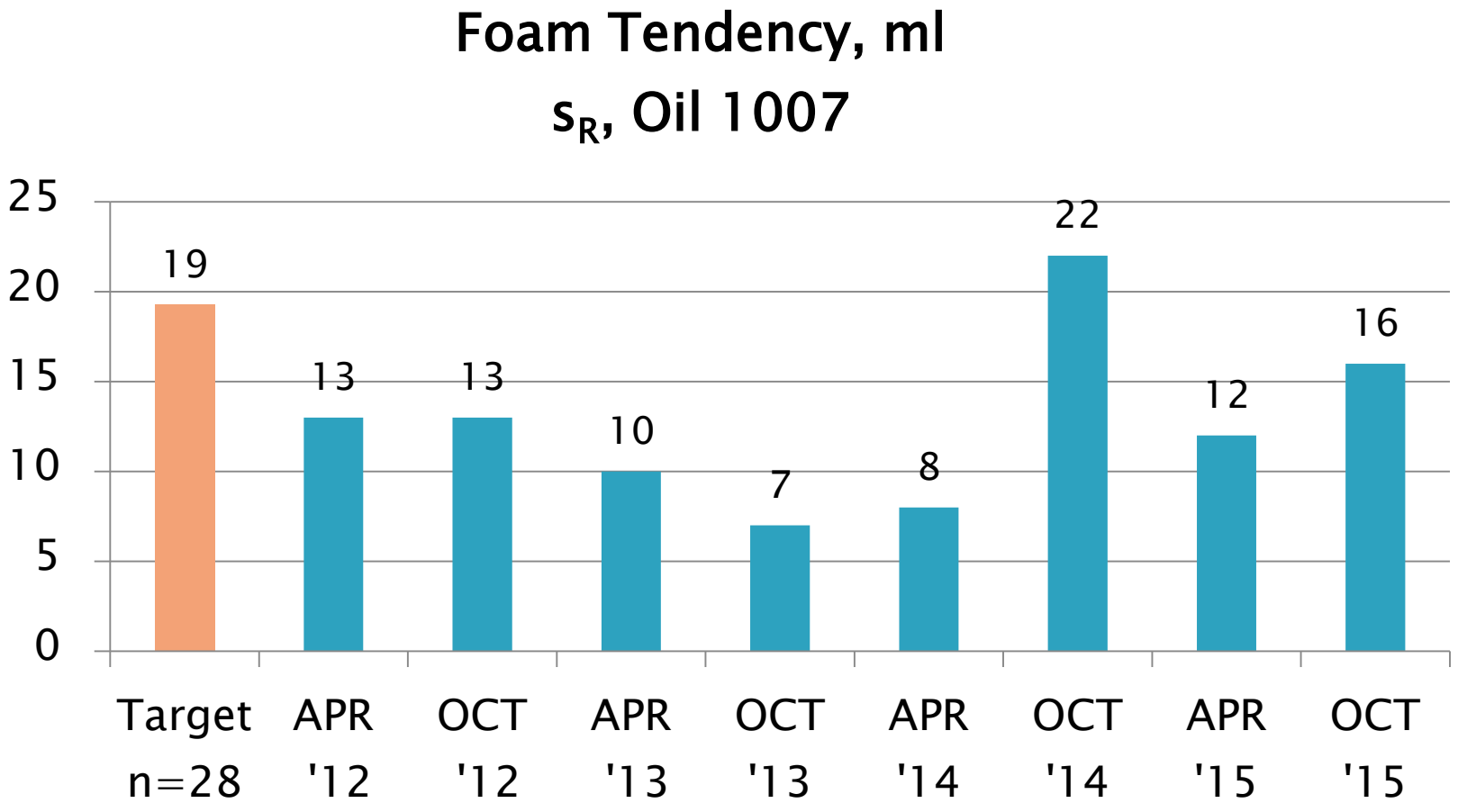
Period Precision and Severity Estimates Oil 1007

Foam Stability @ 1 min, ml	n	Mean	s
Current Targets	28	0.00	0.00
10/1/11 through 3/31/12	8	No non-zero occurrences	
4/1/12 through 9/30/12	9	No non-zero occurrences	
10/1/12 through 3/31/13	8	No non-zero occurrences	
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	

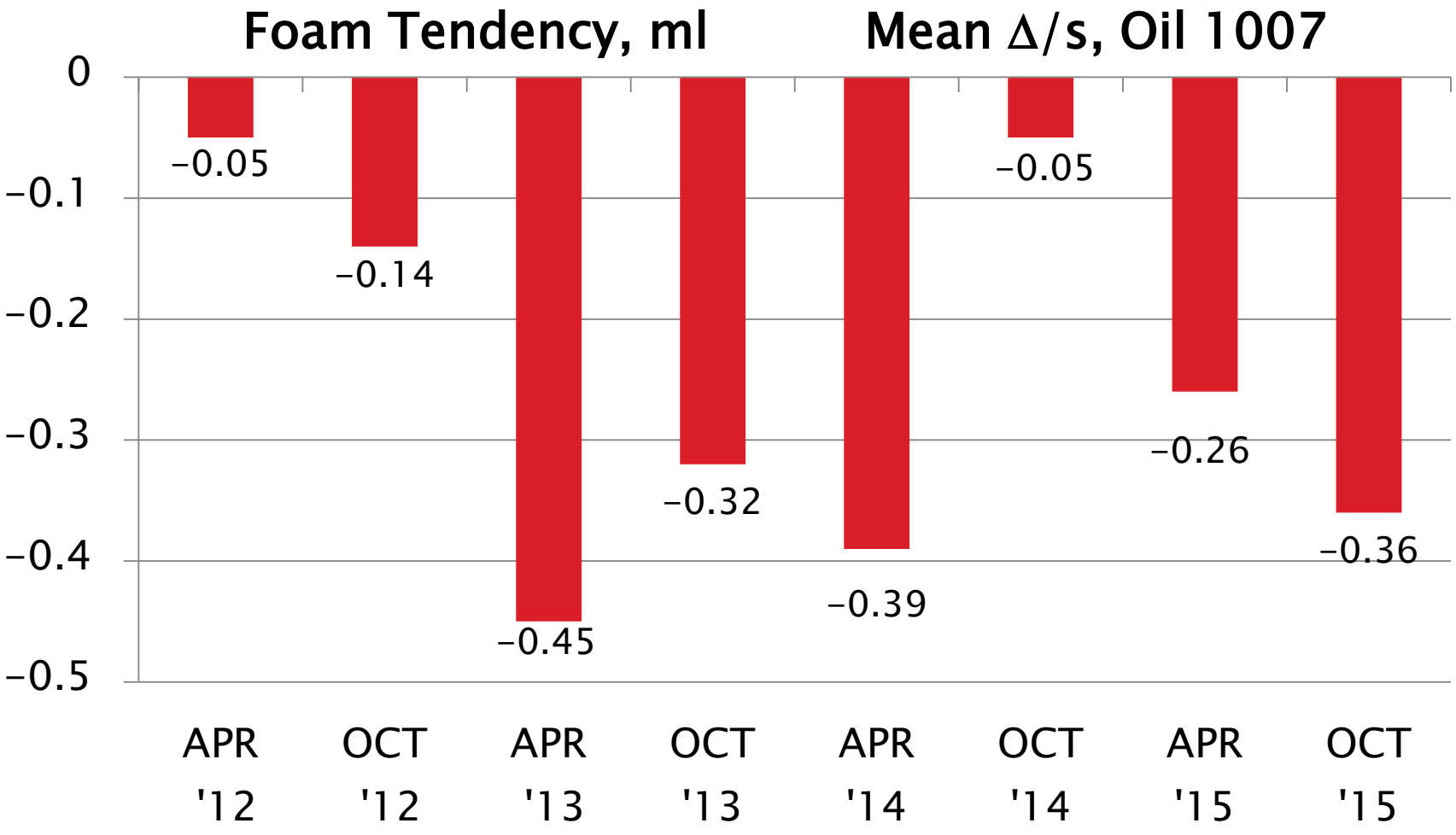
D6082: High Temperature Foam



D6082: High Temperature Foam



D6082: High Temperature Foam

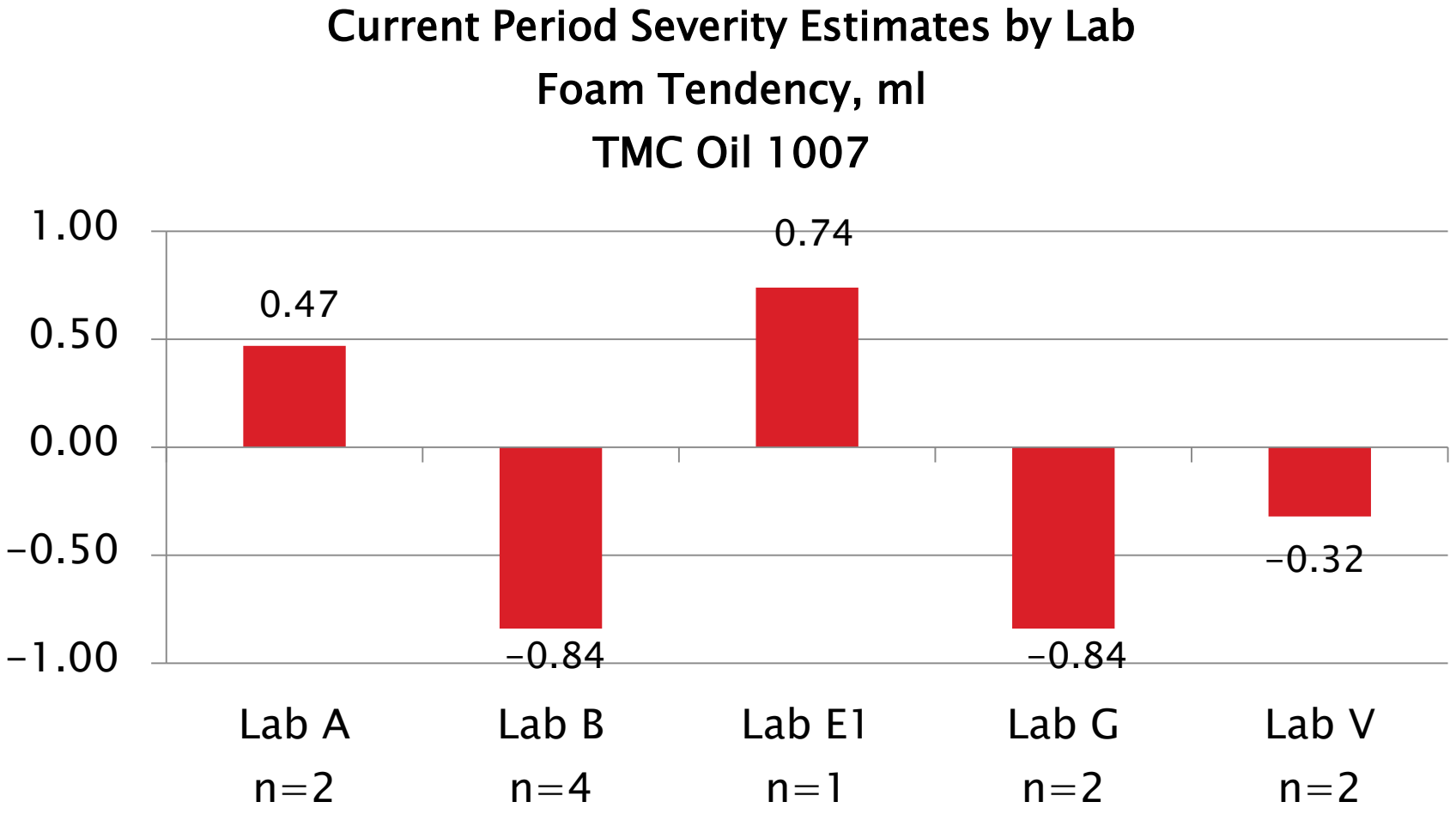


D6082: High Temperature Foam

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

	n	Mean Δ/s
Lab A	2	0.47
Lab B	4	-0.84
Lab E1	1	0.74
Lab G	2	-0.84
Lab V	2	-0.32

D6082: High Temperature Foam



D6082: High Temperature Foam

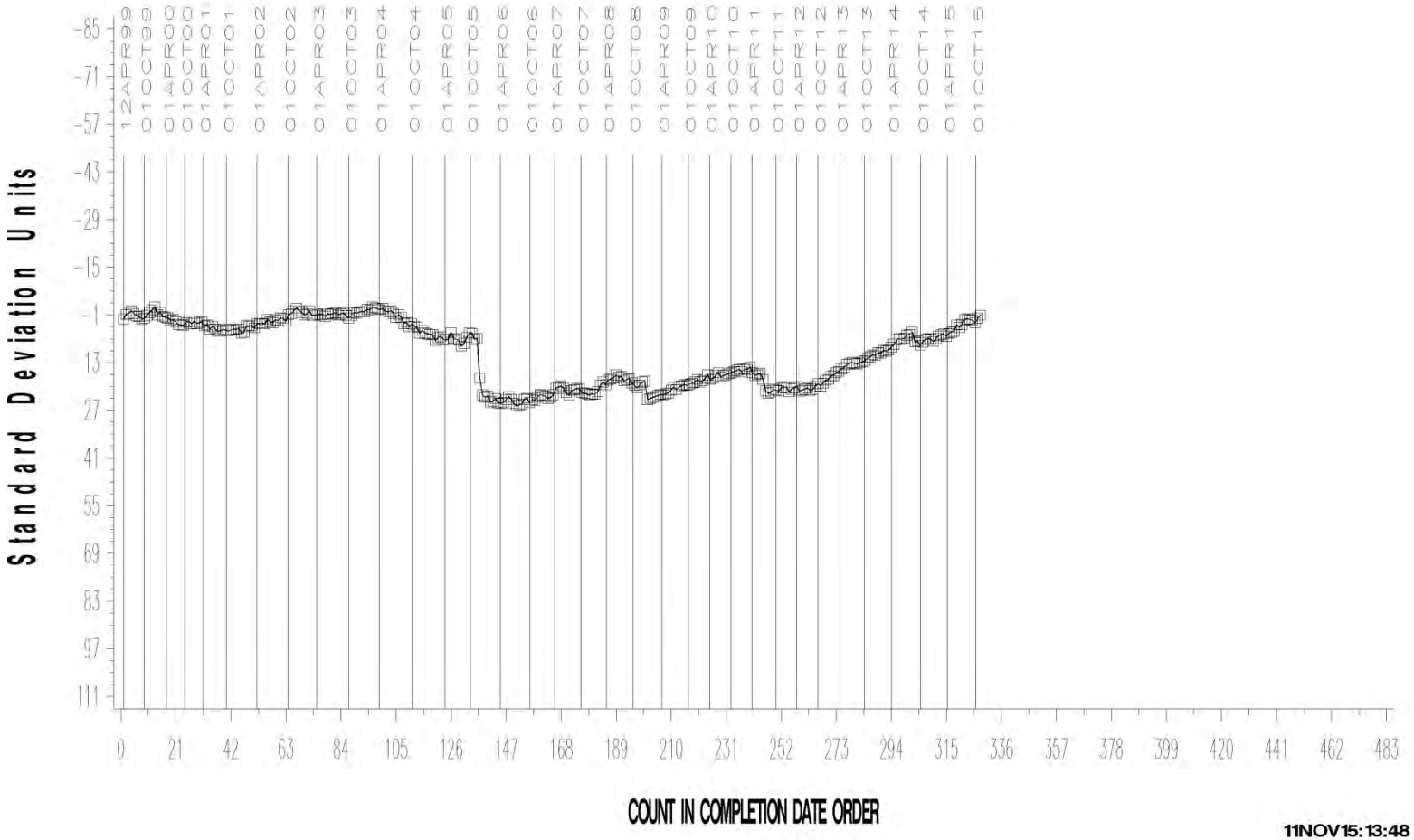
- Foam Tendency Precision (Pooled s) is less precise than prior period
  - More precise than target precision
- Performance (Mean Δ/s) is -0.36 s mild
- No non-zero occurrences of Foam Stability
- All operationally valid discrimination runs demonstrated acceptable discrimination

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	6
Failed Calibration Test	OC	2
Operationally Invalidated by Lab	LC, XC	0
Operationally Invalidated After Initially Reported as Valid	RC	0
Total		**8**

Number of Labs Reporting Data: 3
Fail Rate of Operationally Valid Tests: 25%

D874: Sulfated Ash

Statistically Unacceptable Tests (OC)	No. Of Tests
Sulfated Ash Mild	2
Sulfated Ash Severe	0

- Lab A reported two consecutive very mild results before passing calibration on a third run.
- No operationally invalid tests reported this period
- No TMC technical updates issued this period

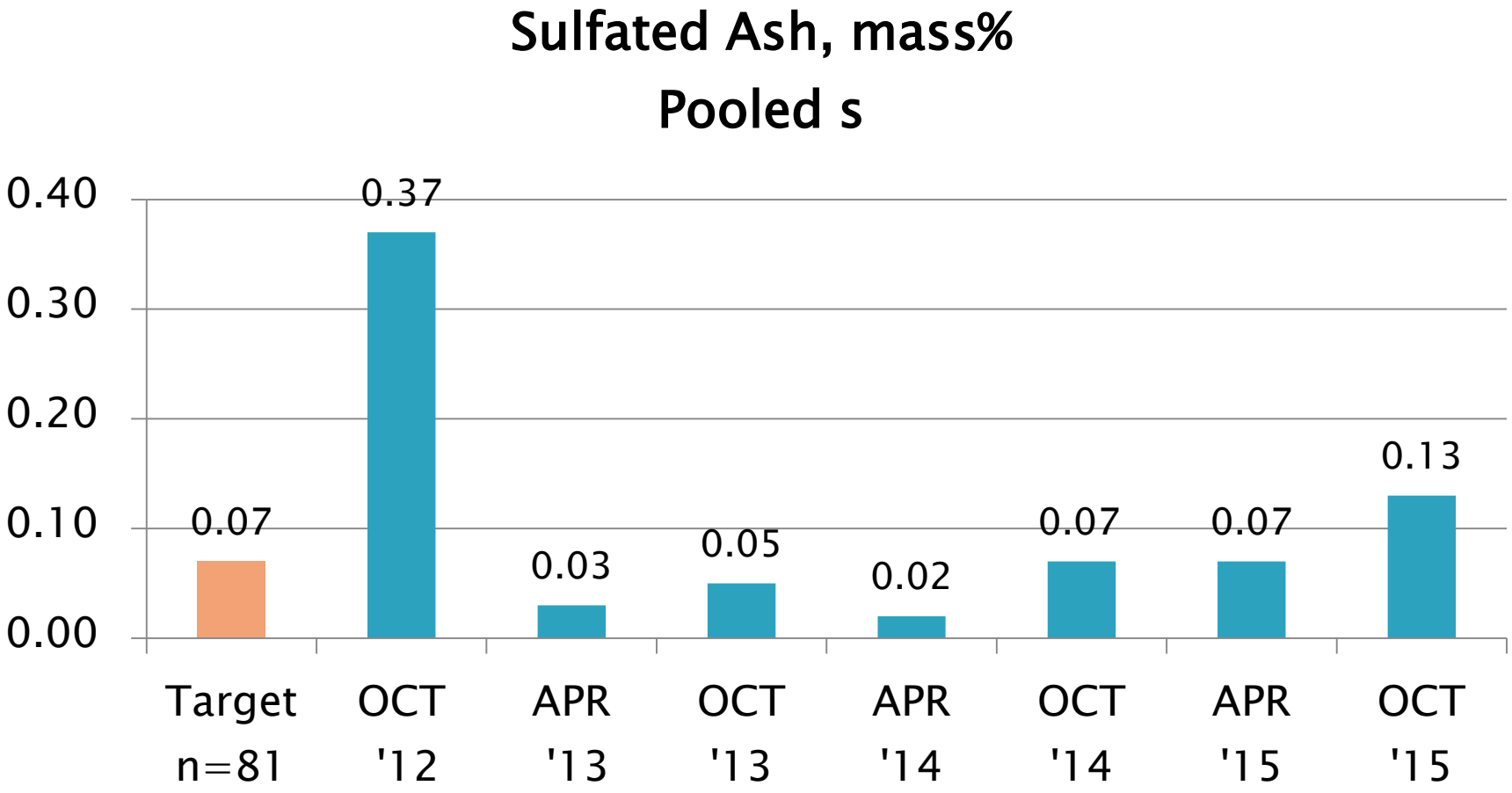
D874: Sulfated Ash

Period Precision and Severity Estimates

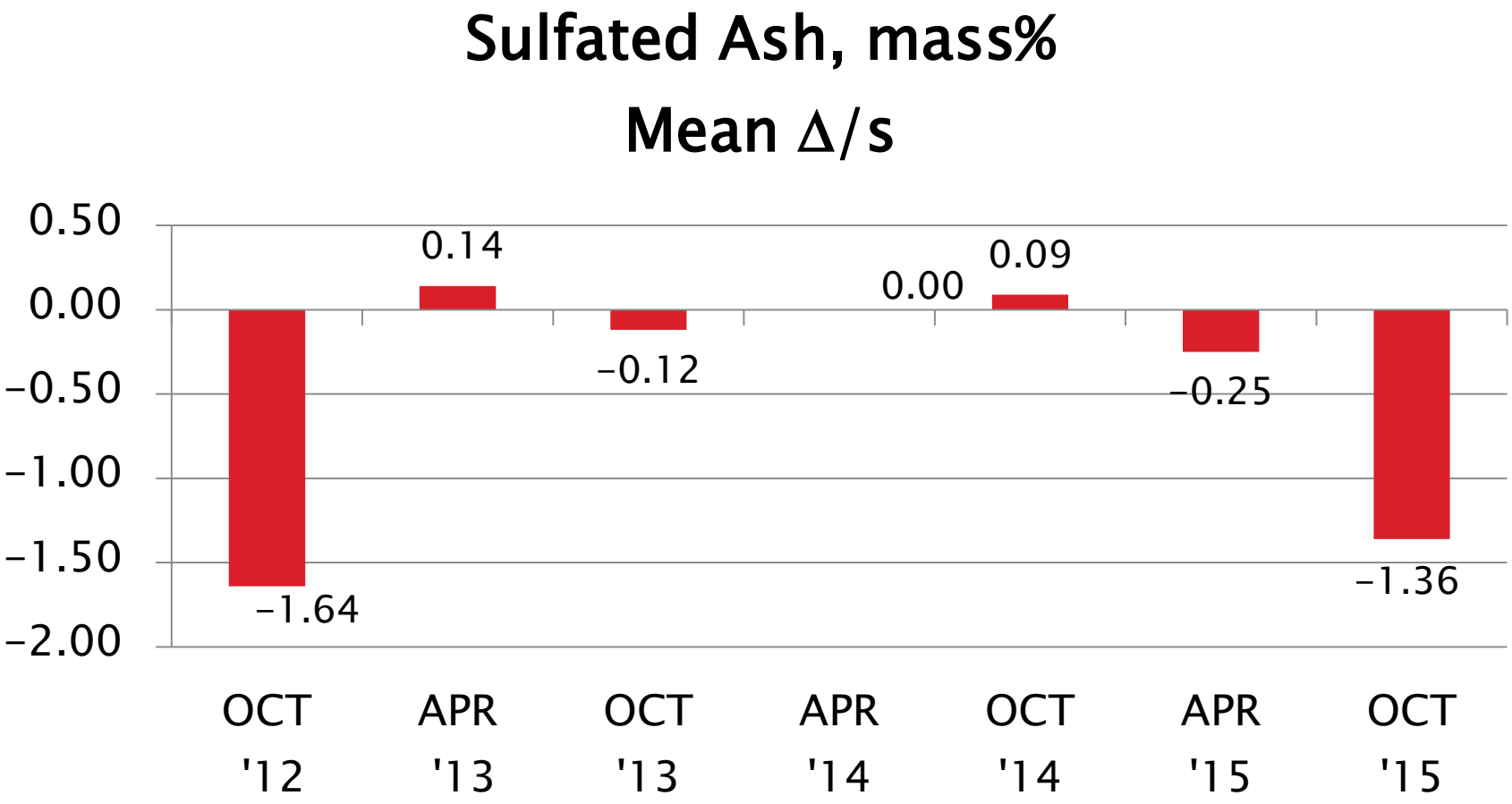
Total Deposits, mg	n	df	Pooled s	Mean Δ/s
Current Targets	81	78	0.07	-----
4/1/12 through 9/30/12*	7	4	0.37	-1.64
4/1/12 through 9/30/12*	6	3	0.04	0.01
10/1/12 through 3/31/13	7	4	0.03	0.14
4/1/13 through 9/30/13	6	3	0.05	-0.12
10/1/13 through 3/31/14	5	2	0.02	0.00
4/1/14 through 9/30/14	6	3	0.07	0.09
10/1/14 through 3/31/15	6	4	0.07	-0.25
4/1/15 through 9/30/15*	8	5	0.13	-1.36
4/1/15 through 9/30/15*	7	4	0.05	-0.36

*Period statistics with and without extreme result included

D874: Sulfated Ash



D874: Sulfated Ash

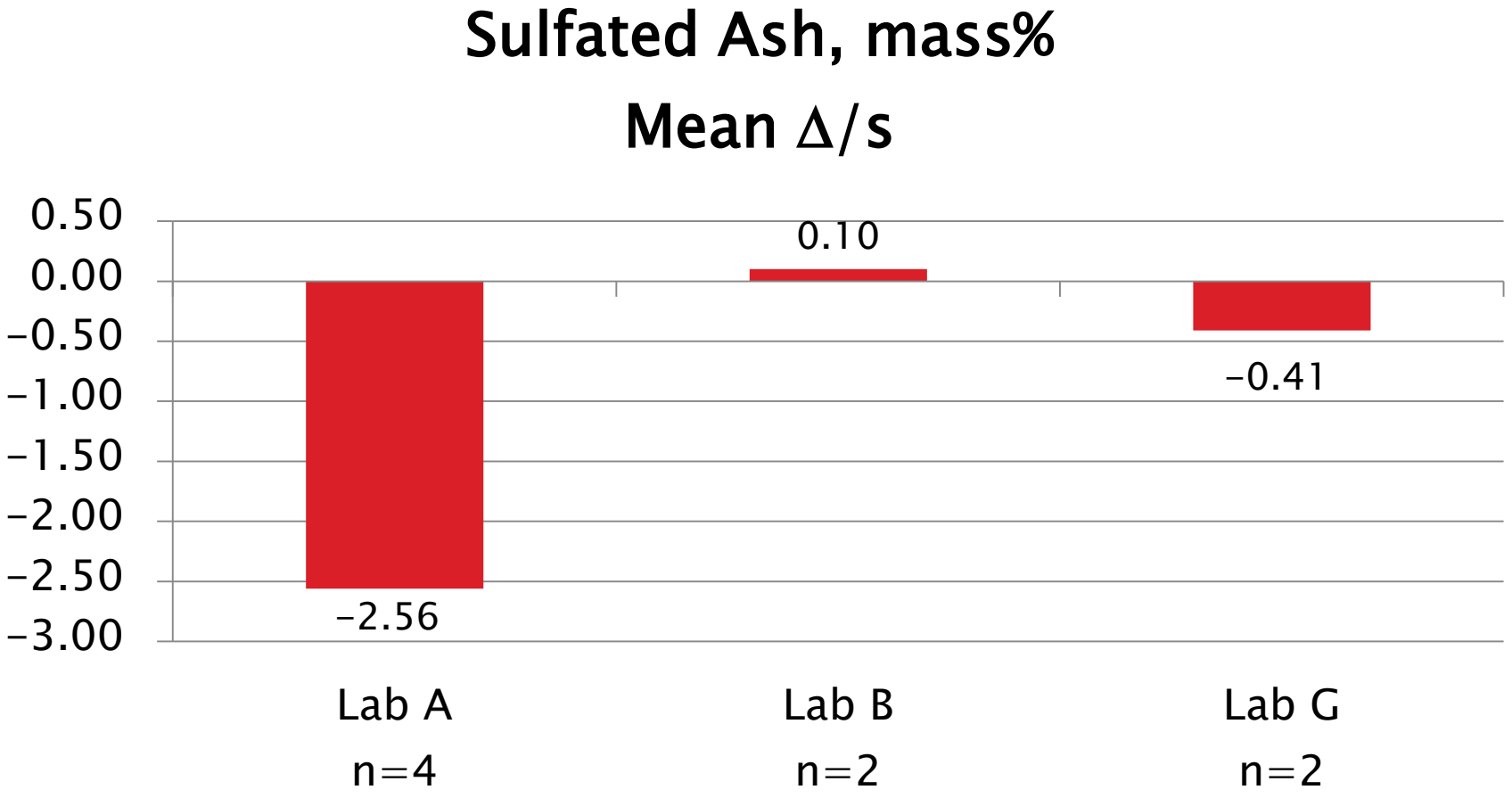


D874: Sulfated Ash

Current Period Severity Estimates by Lab
Sulfated Ash, mass%

	n	Mean Δ/s
Lab A	4	-2.56
Lab B	2	0.10
Lab G	2	-0.41

D874: Sulfated Ash

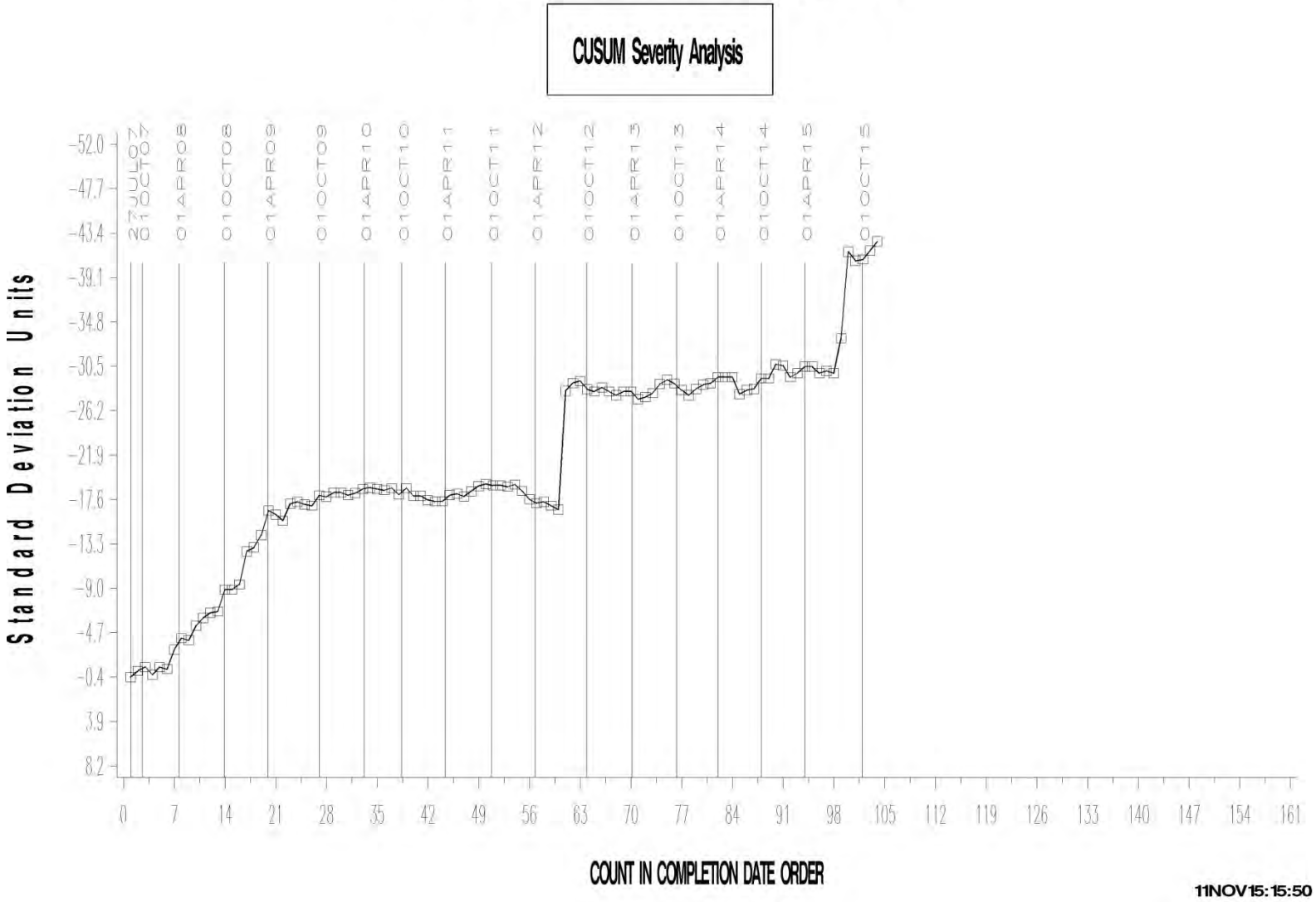


D874: Sulfated Ash

- Lab A reported two consecutive mild results (-3.4 s and -8.4 s mild), both reported as operationally valid.
  - Lab A subsequently calibrated successfully on third attempt
- Precision (Pooled s) is less precise than the prior period
  - Less precise than target precision
  - More precise than both with -8.4 s mild result excluded
- Performance (Mean Δ/s) is -1.36 s mild
  - -0.36 s mild with extreme mild result excluded

D874 INDUSTRY OPERATIONALLY VALID DATA

TEST SAMPLE PERCENT SULFATED ASH



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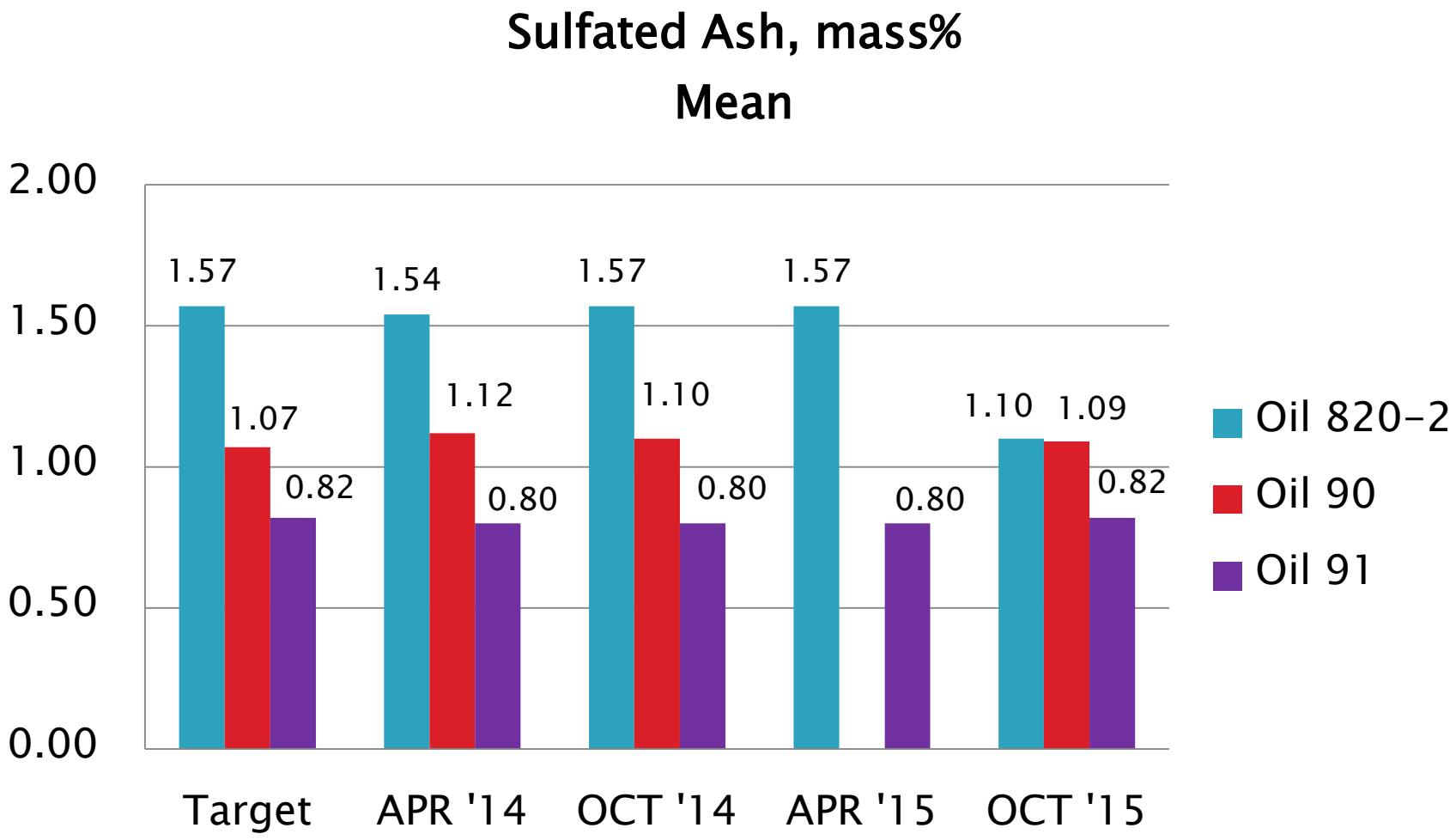
D874: Sulfated Ash

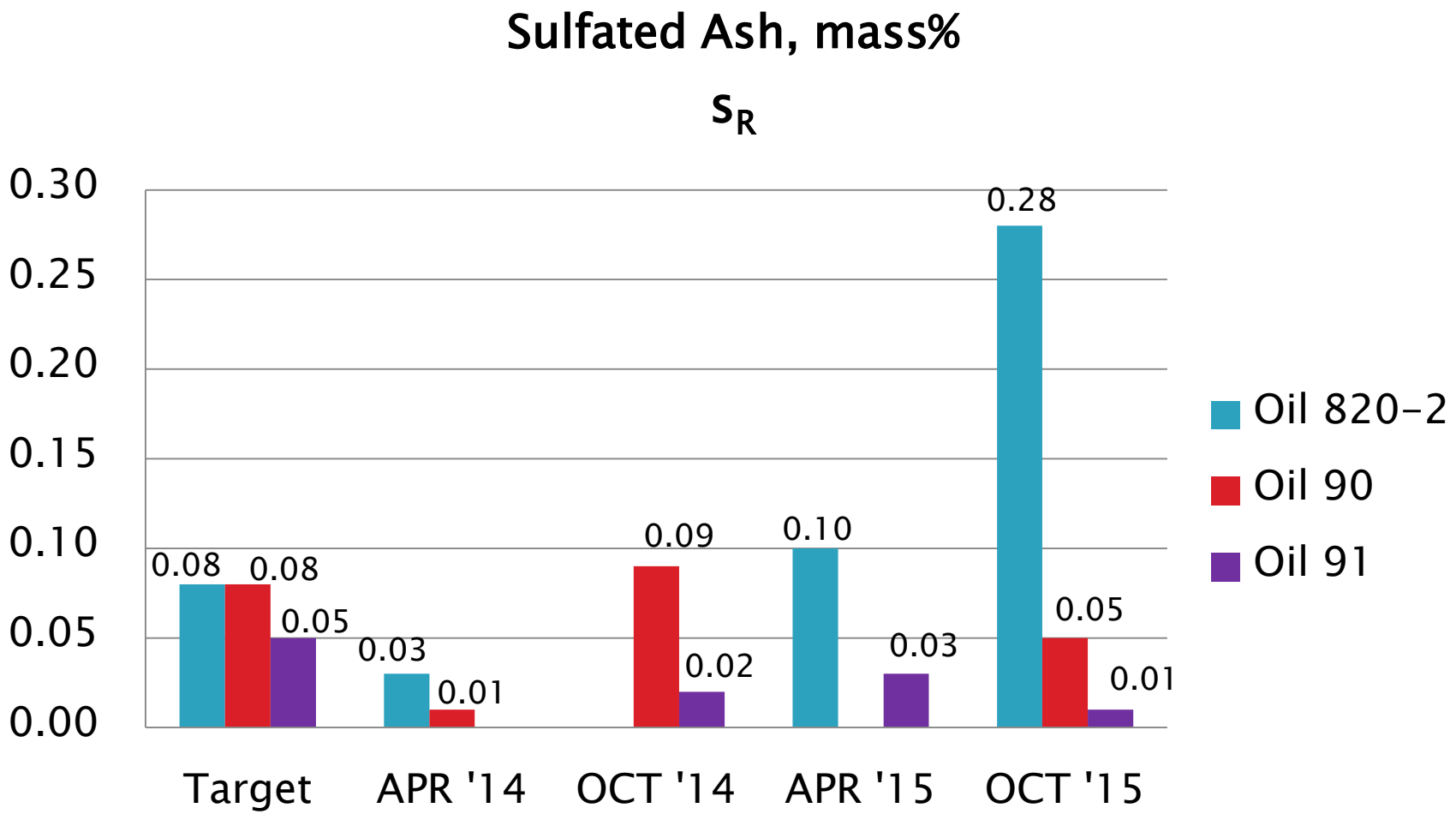
Performance by Oil
Sulfated Ash, mass%

	Targets			4/1/14 – 9/30/14				10/1/14 – 3/31/15				4/1/15 – 9/30/15			
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	1	1.57	---	0.00	3	1.57	0.10	-0.04	2	1.10	0.28	-5.88
90	27	1.07	0.08	3	1.10	0.09	0.38	0	---	---	---	4	1.09	0.05	0.22
91	27	0.82	0.05	2	0.80	0.02	-0.30	3	0.80	0.03	-0.47	2	0.82	0.01	0.00

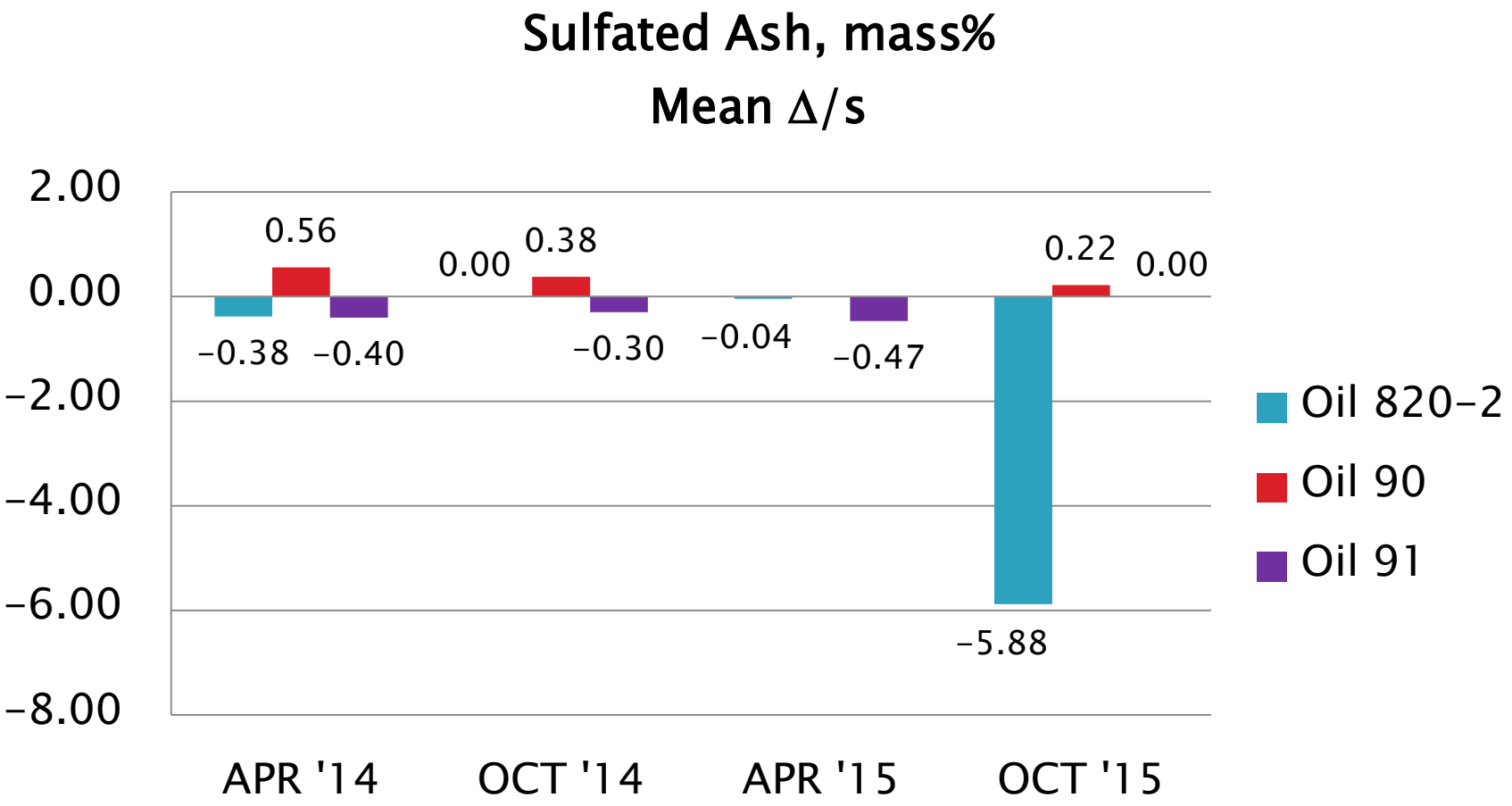
D874: Sulfated Ash



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	20
Operationally Invalidated by Lab	LC, XC	10
Operationally Invalidated After Initially Reported as Valid	RC	0
Non-reference shakedown, excluded from statistics	NN, MN	4
Misidentified samples, excluded from statistics	MC	8
Total		**107**

Number of Labs Reporting Data: 7

Fail Rate of Operationally Valid Tests: 24%

D7528: Oxidation by ROBO

Operationally Invalid Tests

- 2 tests vacuum system failure (LC)
- 2 tests heater or heater control failure (XC)
- 3 test power failure (XC)
- 2 tests NO_2 flow problems (LC)
- 1 test stirrer failure (XC)

- Also had 4 shakedown runs (NN, MN) to pre-qualify new rig B4A before proceeding to calibration (successfully)

- 8 runs (MC) were on samples misidentified by TMC at one lab, from one oil shipment, and results excluded from the statistics. Sample labeling procedures were modified and personnel re-trained at TMC to correct source of error going forward.

D7528: Oxidation by ROBO

Statistically Unacceptable Tests (OC)	No. Of Tests
Natural Log (MRV Viscosity) Mild	18
Natural Log (MRV Viscosity) Severe	2

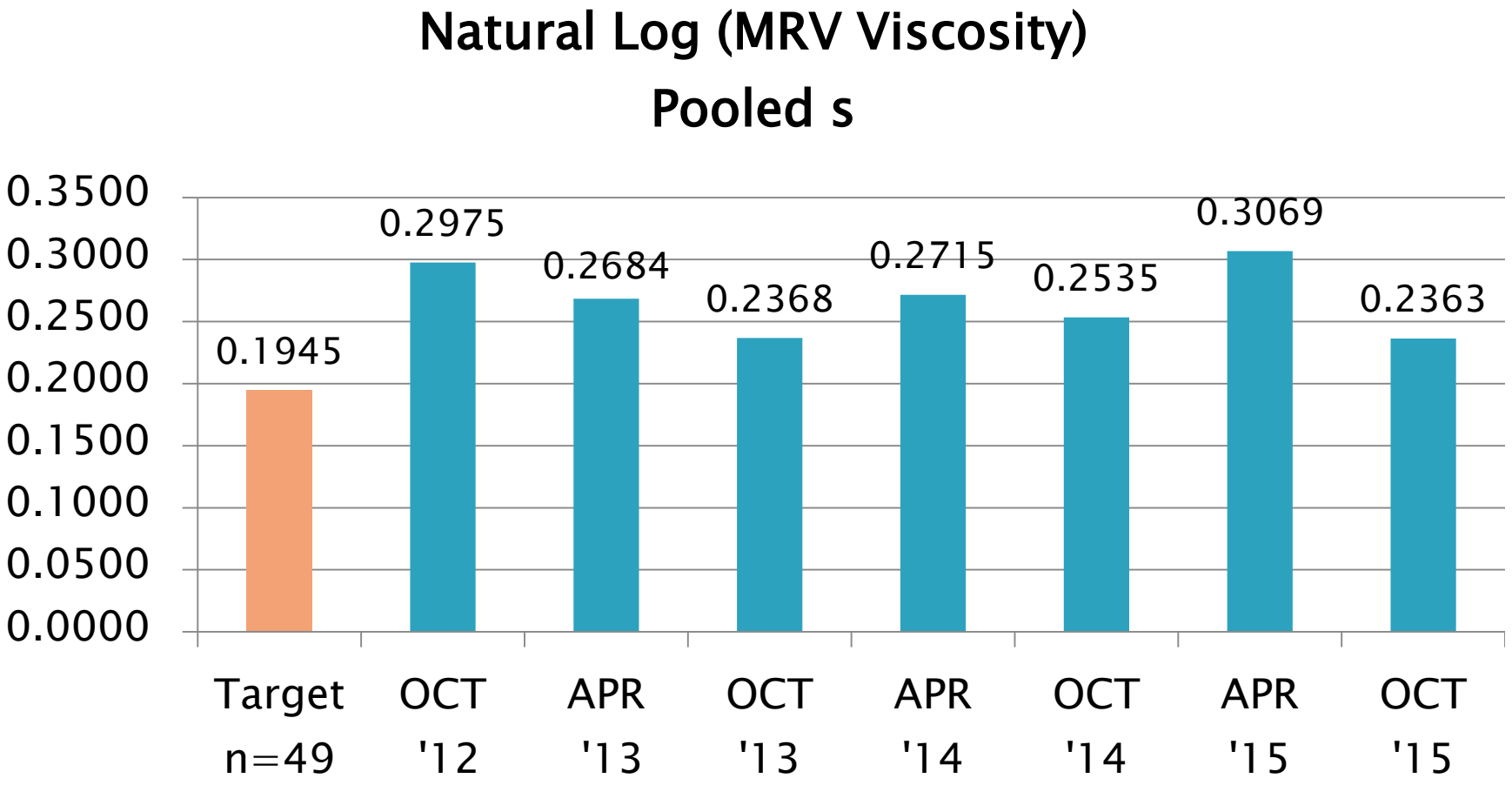
- No TMC technical updates issued this period.

D7528: Oxidation by ROBO

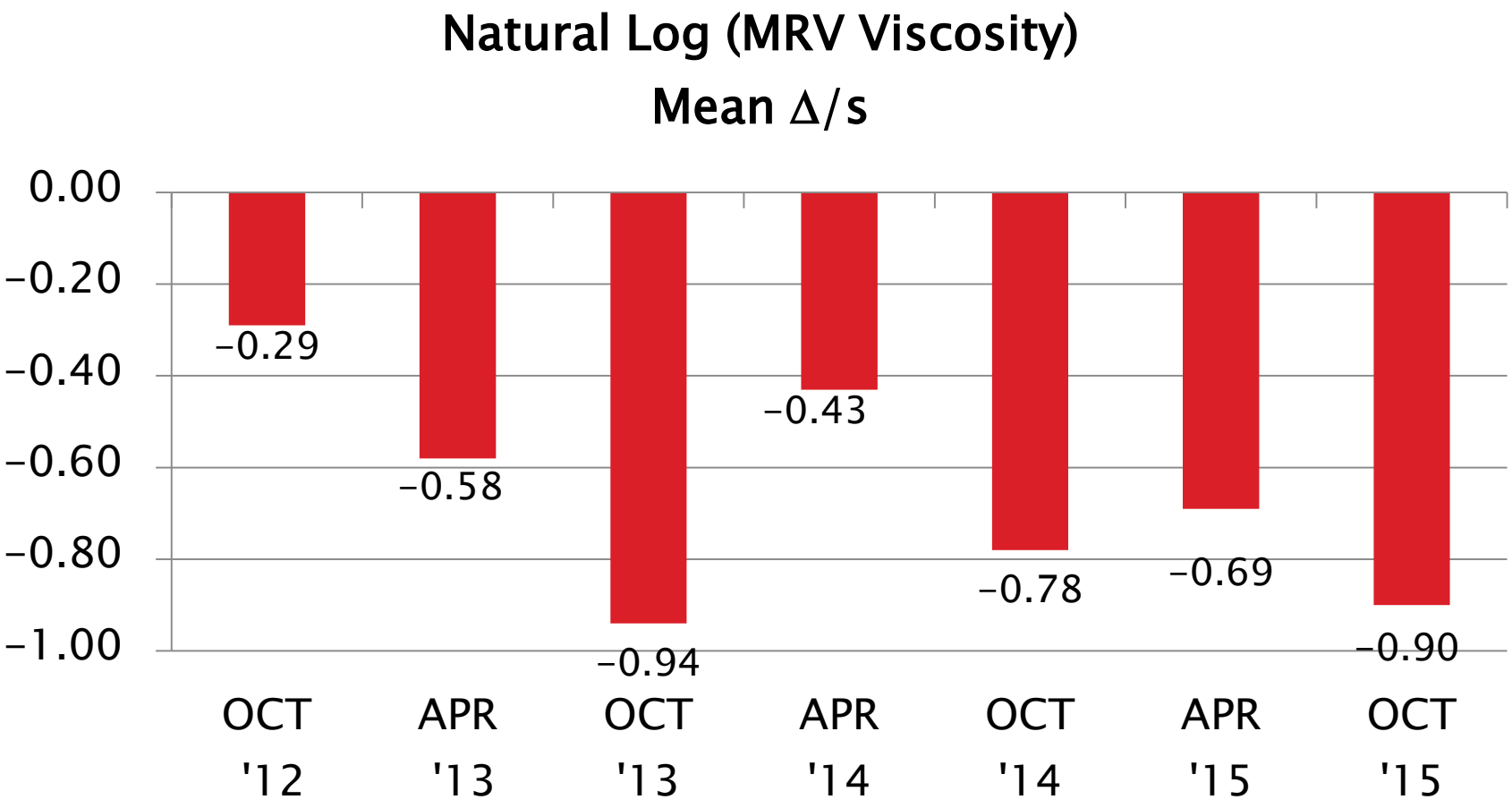
Period Precision and Severity Estimates

Natural Log (MRV Viscosity)	n	df	Pooled s	Mean Δ/s
Current Targets	49	46	0.1945	-----
10/1/11 through 3/31/12	93	90	0.2068	-0.39
4/1/12 through 9/30/12	86	83	0.2975	-0.29
10/1/12 through 3/31/13	109	106	0.2684	-0.58
4/1/13 through 9/30/13	90	87	0.2368	-0.94
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

D7528: Oxidation by ROBO



D7528: Oxidation by ROBO



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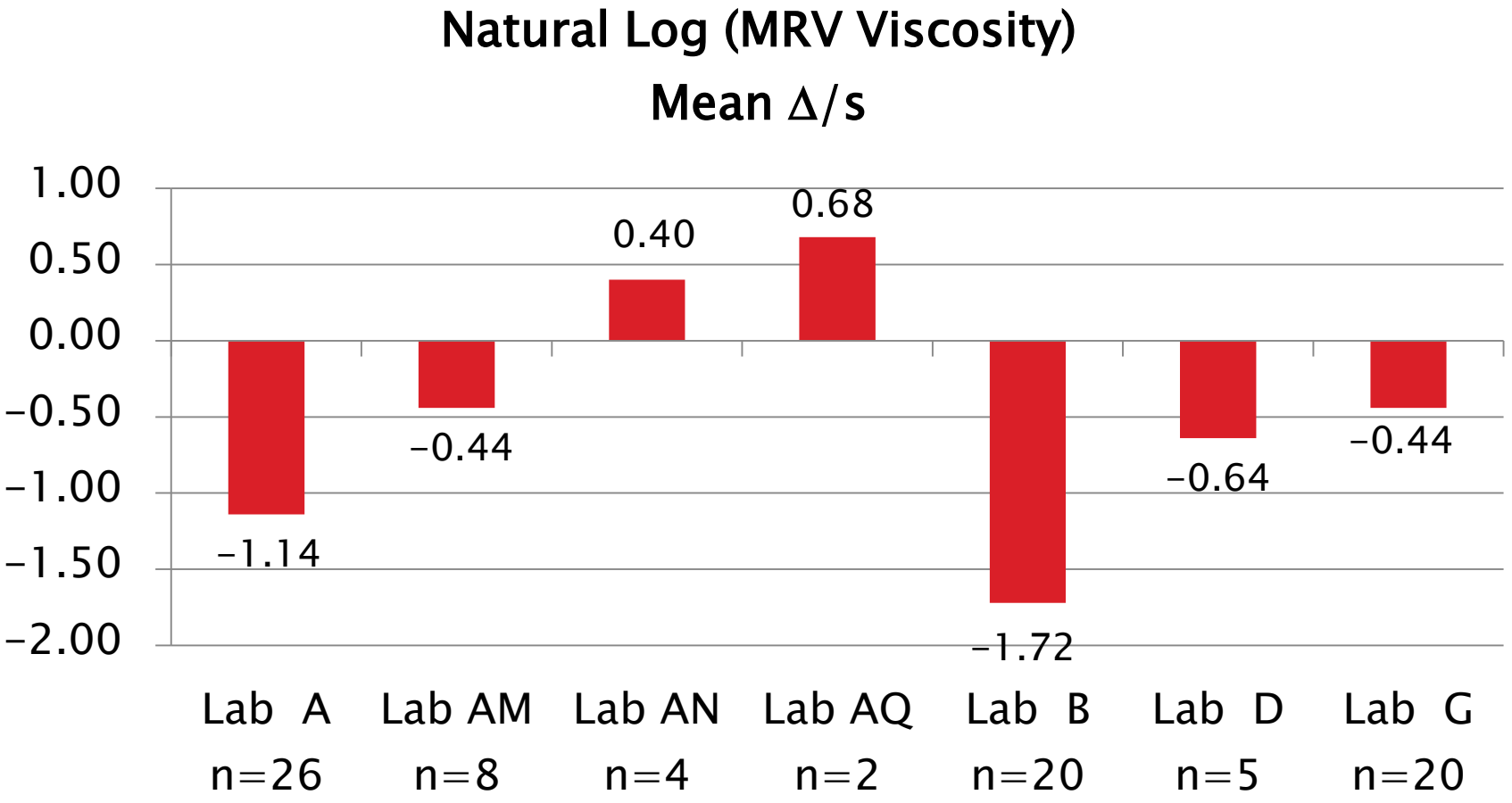
D7528: Oxidation by ROBO

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

	n	Mean Δ/s
Lab A	26	-1.14
Lab AM	8	-0.44
Lab AN	4	0.40
Lab AQ	2	0.68
Lab B	20	-1.72
Lab D	5	-0.64
Lab G	20	-0.44

D7528: Oxidation by ROBO



D7528: Oxidation by ROBO

- Precision (Pooled s) is more precise than prior period
  - Continues to be less precise than target precision

- Performance (Mean Δ/s) is -0.90 s mild
  - Two labs, A and B, more than -1 s mild, overall; with each lab contributing 20 or more tests for the period
  - Two tests reported as operationally valid were more than 3 s from target, (both failed to calibrate but are included in statistics):
    - Rig G4 -3.9 s mild, Oil 434-1
    - Rig G5 3.2 s severe, Oil 438
  - Compared to last period where one test exceeded 3 s

D7528: Oxidation by ROBO

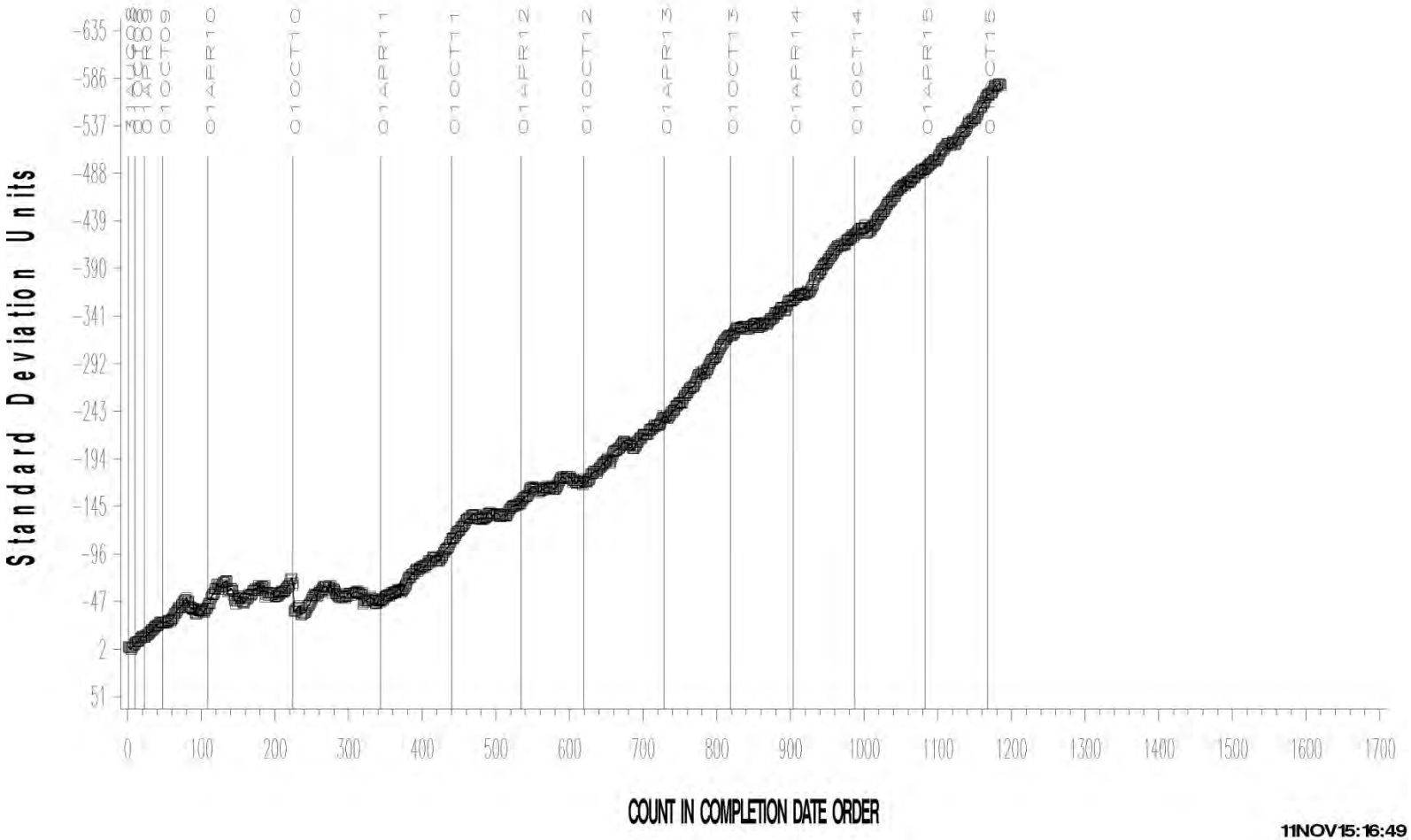
- Oil 434 performing -1.32 s mild for period
- Oil 438 is especially imprecise
  - Similar to prior period

- CUSUM Severity Plot shows an ongoing overall mild trend since the 01APR11 timeline (following the ROBO workshop) with only brief periods of leveling (on-target) performance.

ROBO TEST INDUSTRY OPERATIONALLY VALID DATA

AGED OIL MRV APPARENT VISCOSITY

CUSUM Severity Analysis



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ROBO TEST INDUSTRY OPERATIONALLY VALID DATA

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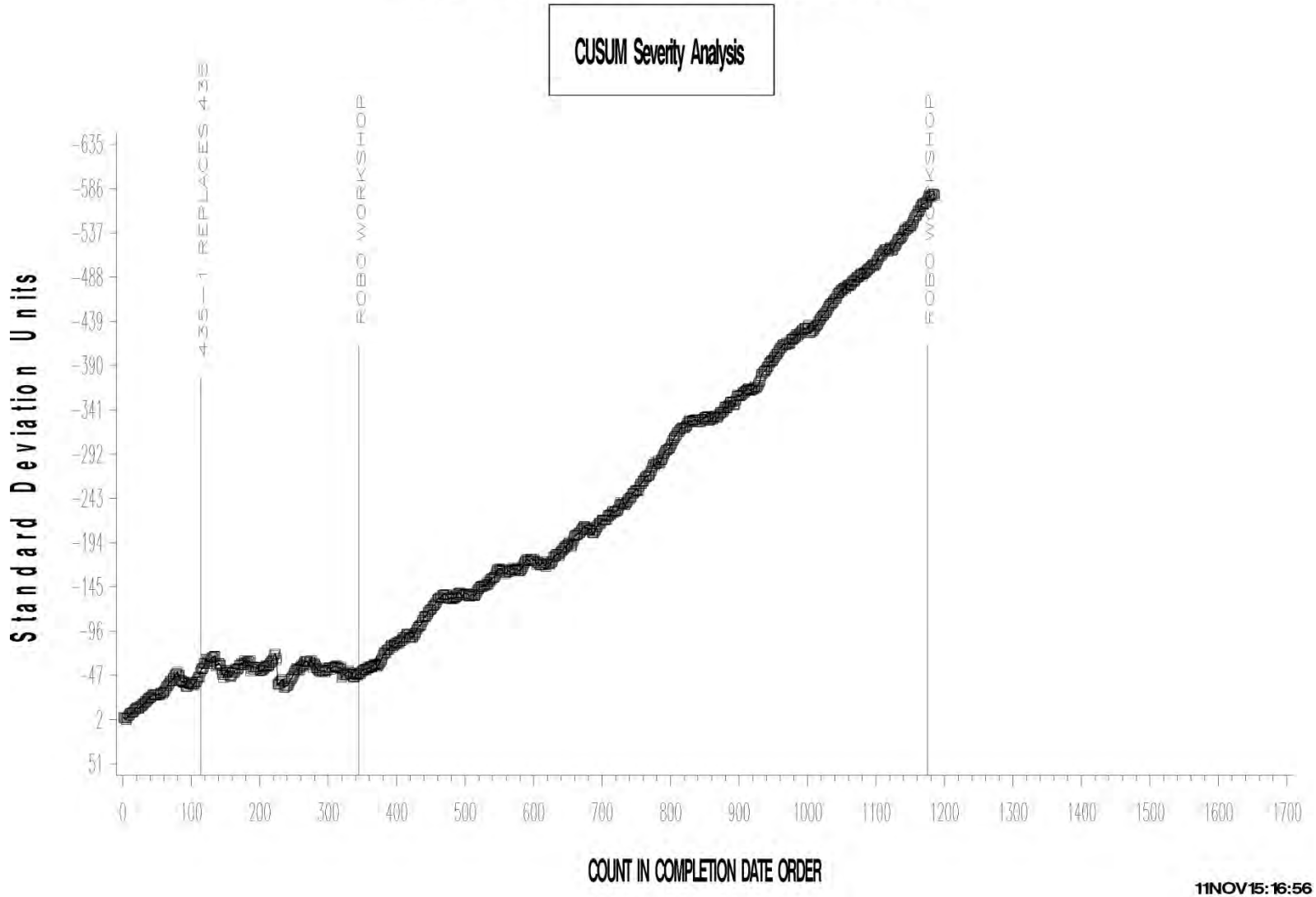
AGED OIL MRV APPARENT VISCOSITY



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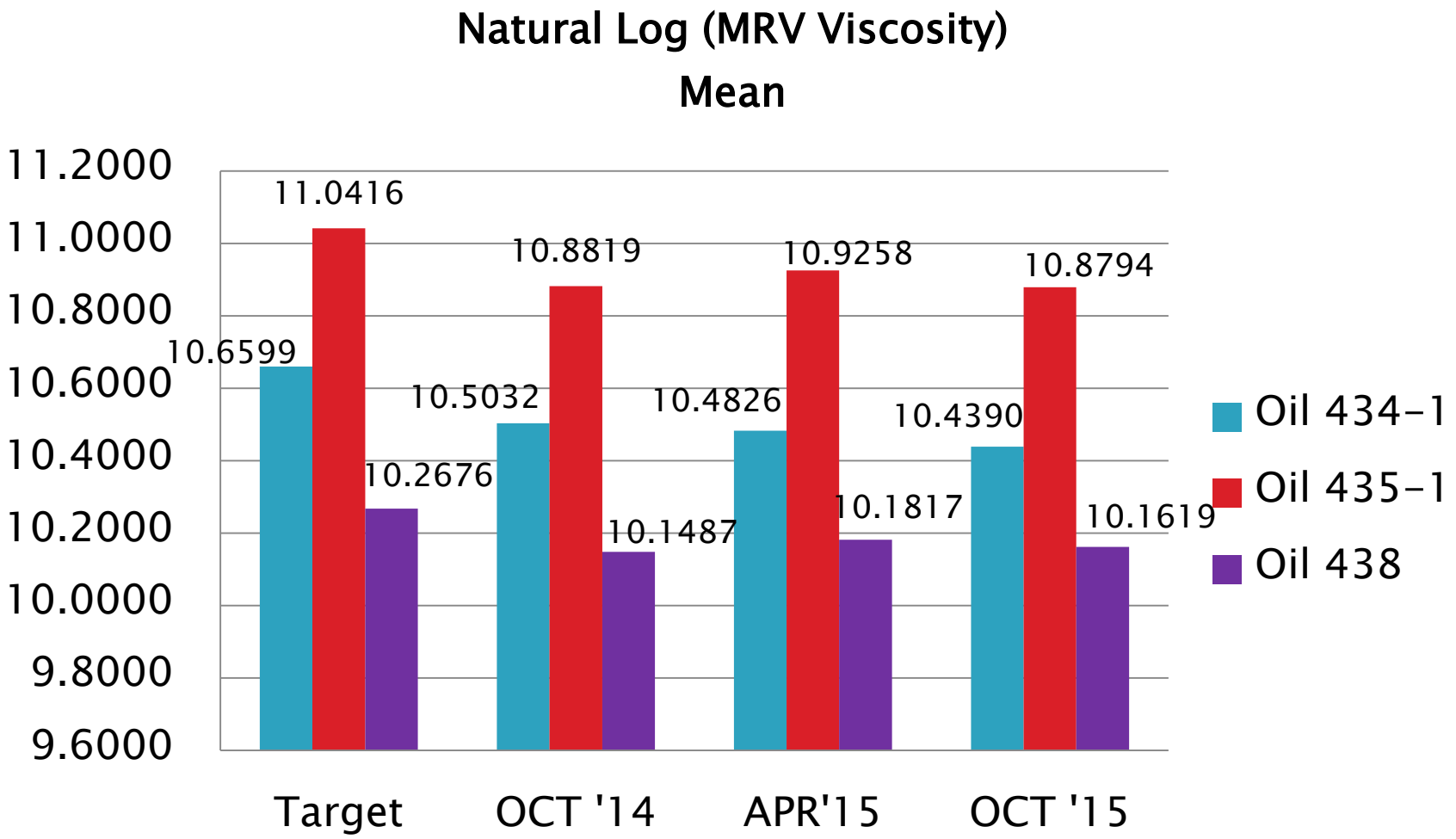
D7528: Oxidation by ROBO

Performance by Oil
Natural Log (MRV Viscosity)

	Targets			4/1/14 - 9/30/14				10/1/14 - 3/31/15				4/1/15 - 9/30/15			
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	22	10.5032	0.2142	-0.94	30	10.4826	0.2055	-1.06	26	10.4390	0.1991	-1.32
435-1	22	11.0416	0.2030	41	10.8819	0.2845	-0.79	44	10.9258	0.2345	-0.58	41	10.8794	0.2220	-0.80
438	14	10.2676	0.2037	20	10.1487	0.2223	-0.58	23	10.1817	0.4891	-0.42	18	10.1619	0.3085	-0.52

D7528: Oxidation by ROBO



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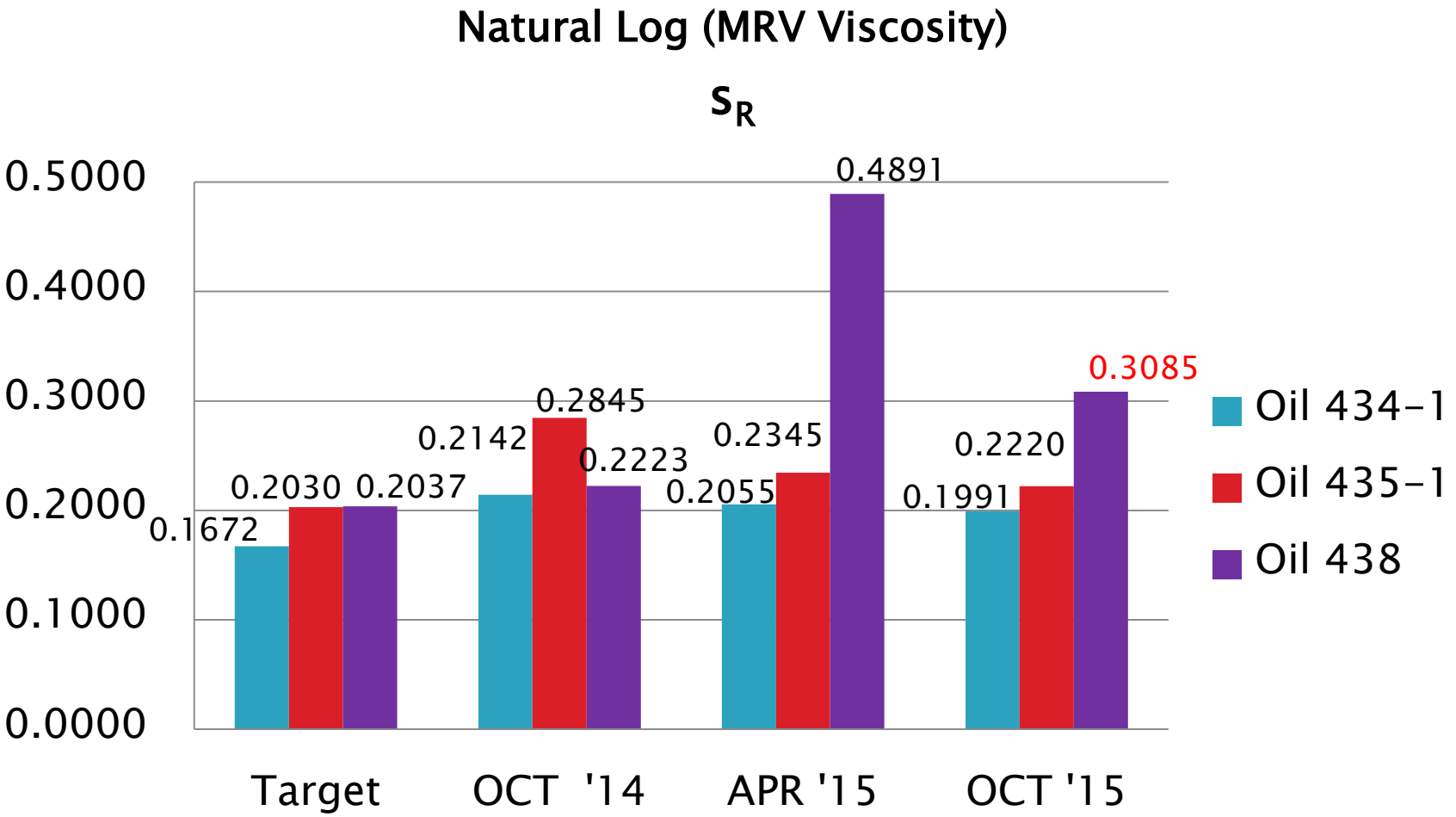
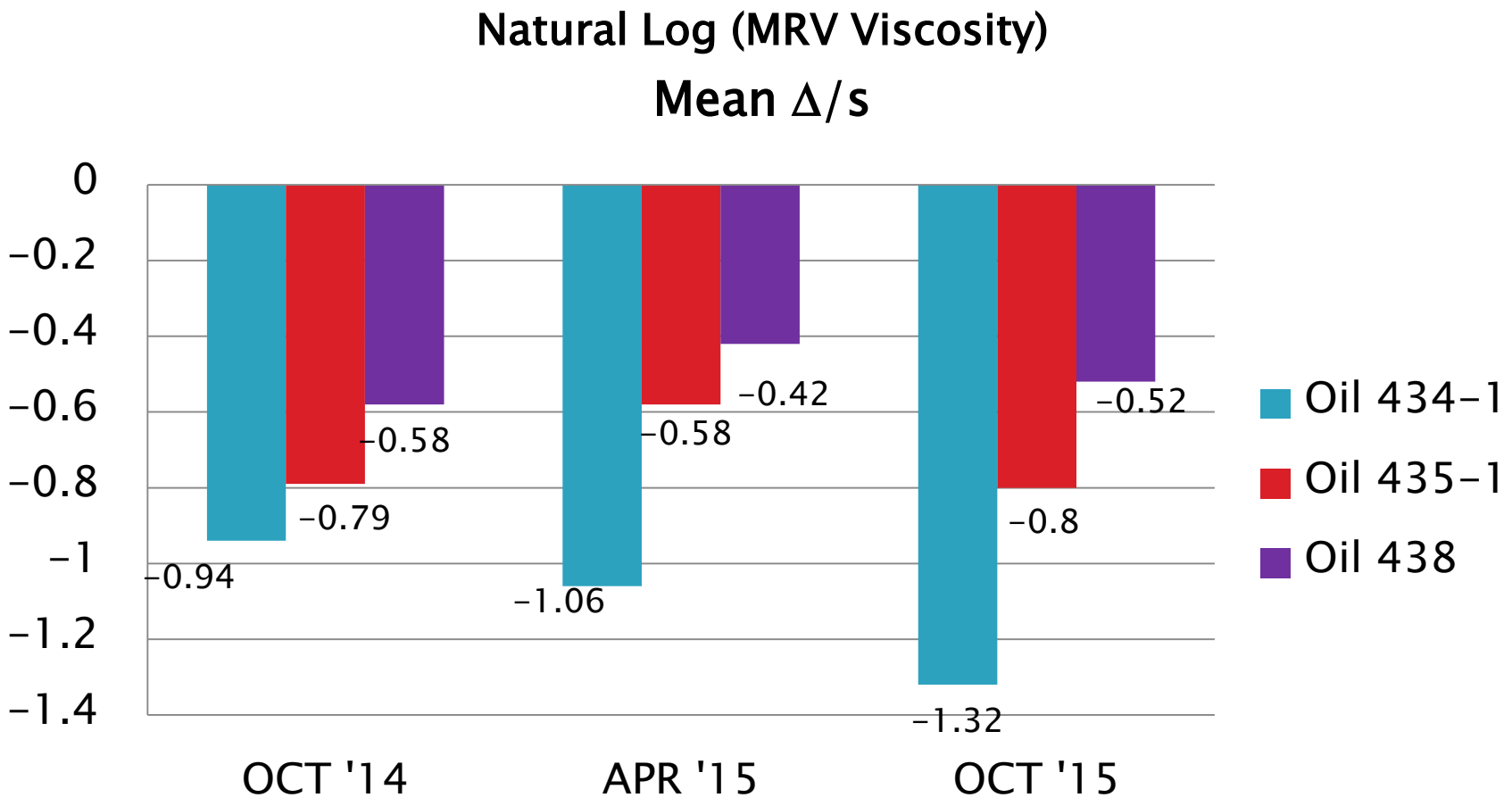
D7528: Oxidation by ROBO



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 12 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 9/30/2015

Reference Oil Inventory

D5800, D6417, GI

Oil	Year Rec'd By TMC	Tests	TMC Inventory, gallons	Gallons Shipped last 12 months
VOLC12	2013	D5800	47.9	3.6
VOLD12	2013	D5800	49.8	2.2
VOLE12	2013	D5800	48.7	3.1
VOLD14	2014	D5800QC	361.8	77.0
52	1995	D6417	59.1	0.0
55	1995	D6417	66.2	0.0
58	1998	D6417, GI	110.1	0.3
62	1996	GI	1.1	0.2
1009*	2002	GI	46.8	----

*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	109.0	1.4
434	2003	MTEOS	3.5	0.7
75	2010	TEOST	4.2	0.0
435-2*	2010	TEOST	45.4	----
434-1*	2008	ROBO	3.4	----
435-1	2008	ROBO	457.6	----
438*	2003	ROBO	16.7	----

*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	14.5	2.8
66	2002	D6082	88.4	1.2
820-2	2001	D874	10.2	0.1
90	2005	D874	26.5	4.3
91	2006	D874	4.0	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	135.7	7.9
HMB	2002	H&M	139.2	8.2
HMC	2003	H&M	126.0	7.7
HMD	2002	H&M	133.5	7.9
HME	2002	H&M	119.7	7.7
HMF	2002	H&M	142.2	7.7

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	7.9	0.0
EM2-1	2011	Emulsion	25.0	0.0
EM5	2011	Emulsion	7.9	0.0
EM5-1	2011	Emulsion	25.0	0.0

Reference Oil Shipping Aliquots

Test	Quantity
D6417	1 ml
D6417QC	118 ml
D5800	100 ml
GI	25 ml
MTEOS	17 ml
TEOST	125 ml
D6082	525 ml
D874	32 ml
D874QC	1000 ml
ROBO	300 ml
ROBOQC	1000 ml
H&M	1000 ml
D7563	1000 ml

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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