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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 2016

B0.07 Bench Testing Executive Summary

- D6417 (Volatility by GC)
- Precision (Pooled s) is less precise than last period
  - Comparable to target precision
- Performance (Mean Δ/s) is 0.24 s severe
- Three tests total were reported on new instrument D5 this period, one on each reference oil. Though all passing, each result was more than 1 s from target (mild or severe). This instrument is the primary source of the poorer overall precision and notable severity shifts by oil this period.

B0.07 Bench Testing
Executive Summary

- D5800 (Volatility by Noack)
- Precision (Pooled s), at 0.60 mass %, is less precise than prior period and less precise than the target precision.
- Performance (Mean Δ/s) is 0.99 s severe and comparable to the last two report periods.
- Fail rate of operationally valid tests (AC & OC) is 26% (fail rate of the four prior periods was 20%, 27% , 36% and 19%).
- Historical long-term severe trend continues with only a modest decrease in severity following the introduction of the new reference oils (3Q 2013), and an increase in severity to approximately 1 s for the past three report periods.

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 0.41 s severe
  - Considerably more severe than prior periods
  - Three labs performing more than 1 s severe
- Reference oil 62 inventory is down to 0.9 gallons remaining (but only 0.1 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

- Performance (Mean Δ/s) is -0.68 s mild
  - Most mild period since at least October 2013
  - Instrument G2 reported results contributing to the overall poor precision last period and continues to bias both precision and severity this period with three consecutive mild tests.

- All tests this period report using Rod Batch M

B0.07 Bench Testing Executive Summary

- D7097 (MHT-4 TEOST)
- Instrument P1 reported three consecutive severe fails (3s, 4s & 31s) as operationally valid, all are excluded from the period statistics. Lab successfully calibrated the instrument on 4th try but had no explanation for the failing runs.
- Precision (Pooled s) is comparable to prior period
  - Remains less precise than target precision
- Performance (Mean Δ/s) is 0.13 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 1307 (n=1), 14AA (n=10) or 15AA (n=94)

B0.07 Bench Testing Executive Summary

- D7097 (MHT-4 TEOST) continued

- CUSUM severity plot shows some leveling this period (except for a single very severe result)
  - However, lab performance differences persist

- Precision on oil 432 has improved compared to the last two periods, while precision on oil 434 has worsened.

- 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 less precise than prior period
  - More precise than target precision
- Performance (Mean Δ/s) is -0.38 s mild
- No non-zero occurrences of Foam Stability
- All operationally valid discrimination runs demonstrated acceptable discrimination

- 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 last period but less precise than all prior periods since at least October 2013
  - Continues to be less precise than target precision
  - Five tests on various rigs are between 3 and 6 s mild or severe this period
- Performance (Mean Δ/s) is -0.53 s mild

B0.07 Bench Testing Executive Summary

- D7528 (ROBO) continued
- Oils 434-1 and 435-1 continue to be especially imprecise

- CUSUM Severity Plot shows an overall mild trend since the 01APR11 timeline (following a 2011 ROBO workshop) with significant 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 replacement oil 434-2.

Calibrated Labs and Stands*

Test	Labs	Stands
D6417	4	5
D5800	9	22
D5133 (GI)	6	10
D6335 (TEOST)	6	8
D7097 (MTEOS)	11	41
D6082	5	6
D874	3	--
D7528 (ROBO)	5	15

*As of 9/30/2016

D02.B0.07
TMC Monitored Tests

- April 1, 2016 –
  September 30, 2016

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D6417: Estimation of Engine Oil Volatility by Capillary GC

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

Number of Labs Reporting Data: 4
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.

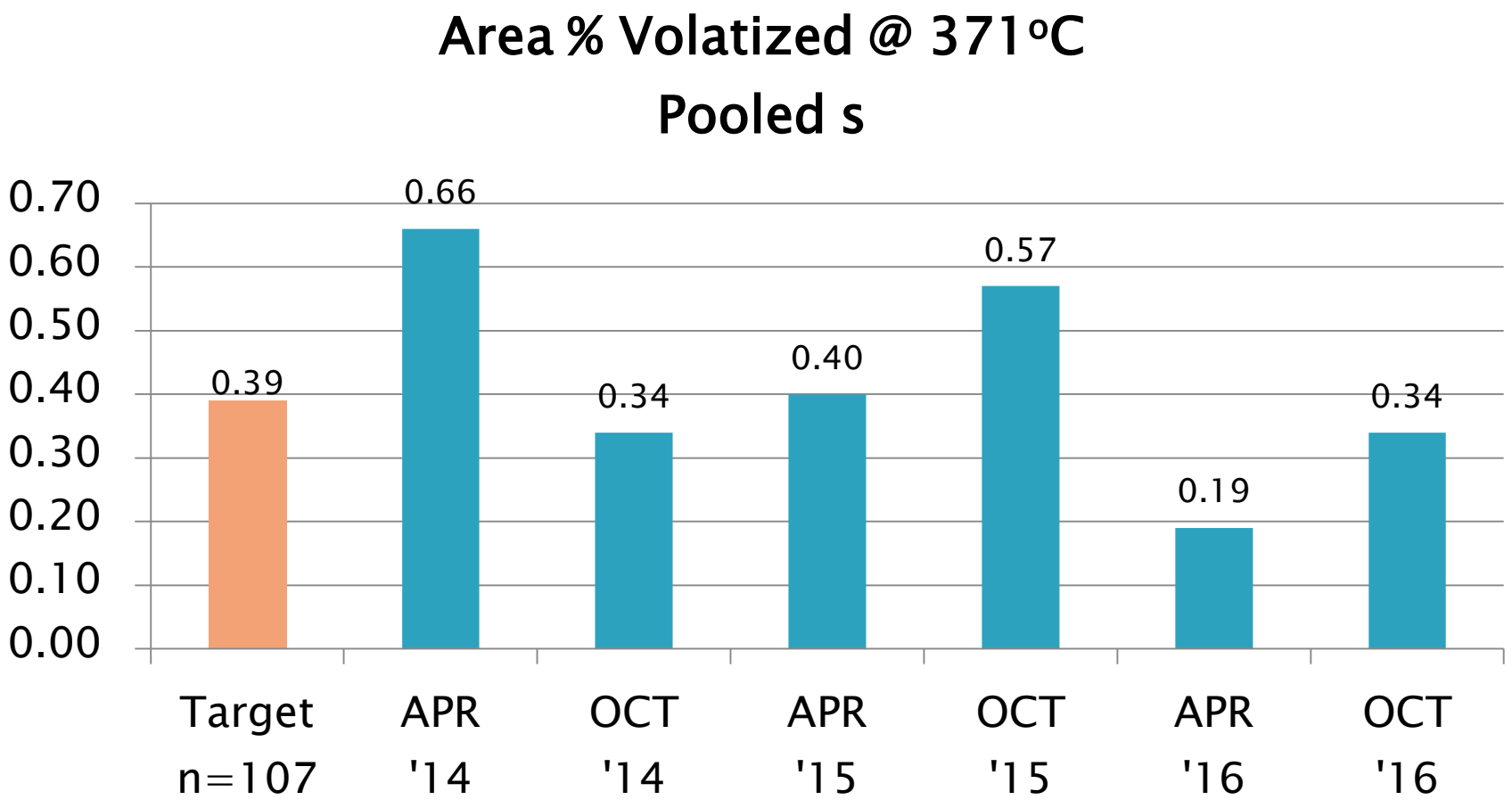
D6417: Estimation of Engine Oil Volatility by Capillary GC

Period Precision and Severity Estimates

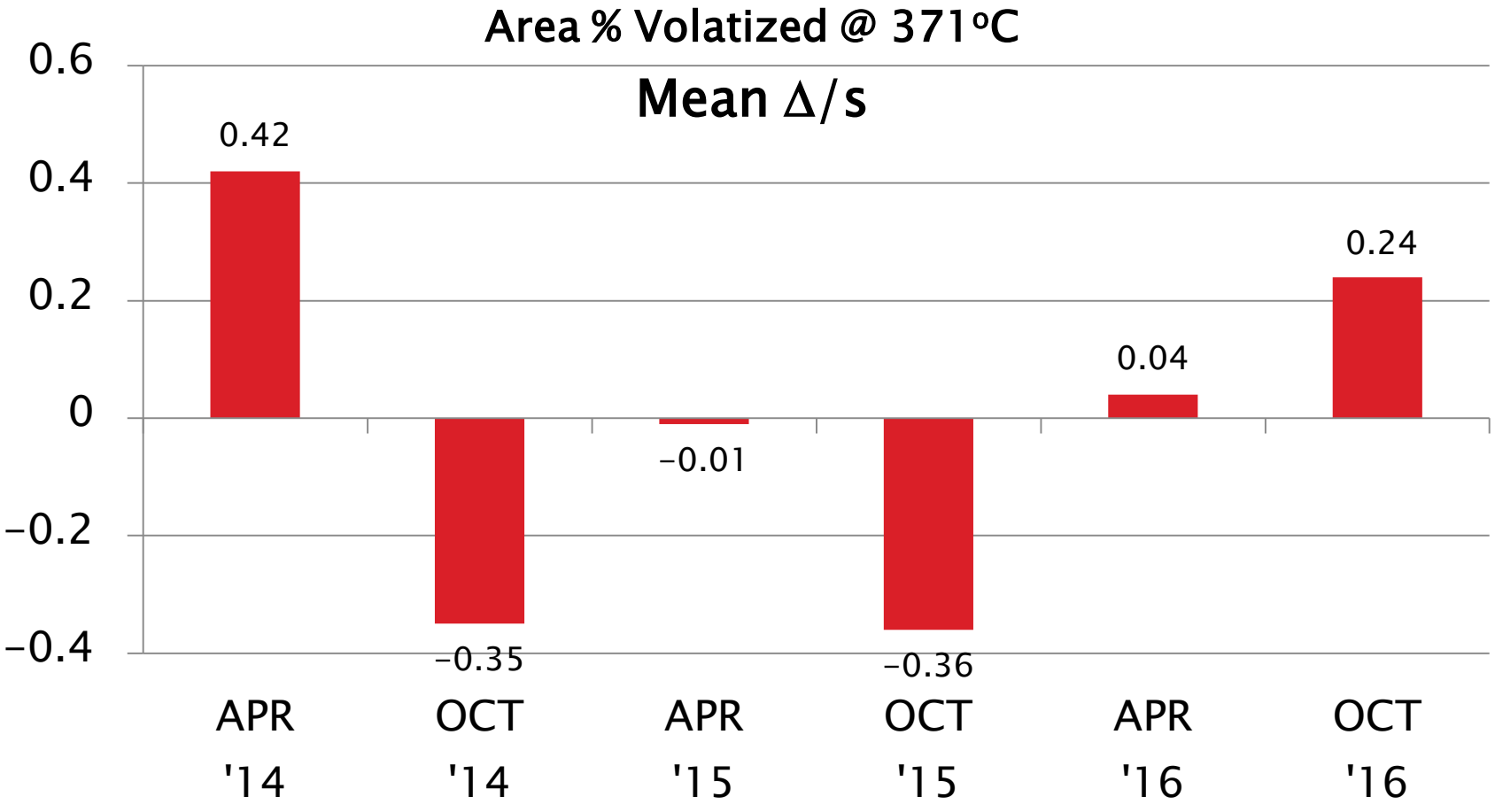
Area % Volatized @ 371°C	n	df	Pooled s	Mean Δ/s
Initial Selected Oils from RR	54	51	0.39	-----
10/1/13 through 3/31/14	15	12	0.66	0.42
4/1/14 through 9/30/14	15	12	0.34	-0.35
10/1/14 through 3/31/15	14	11	0.40	-0.01
4/1/15 through 9/30/15* 4/1/15 through 9/30/15*	16 15	13 12	0.57 0.42	-0.36 -0.04
10/1/15 through 3/31/16	13	10	0.19	0.04
4/1/16 through 9/30/16	11	8	0.34	0.24

*Extreme OC result included and excluded

D6417 Precision Estimates



D6417 Severity Estimates

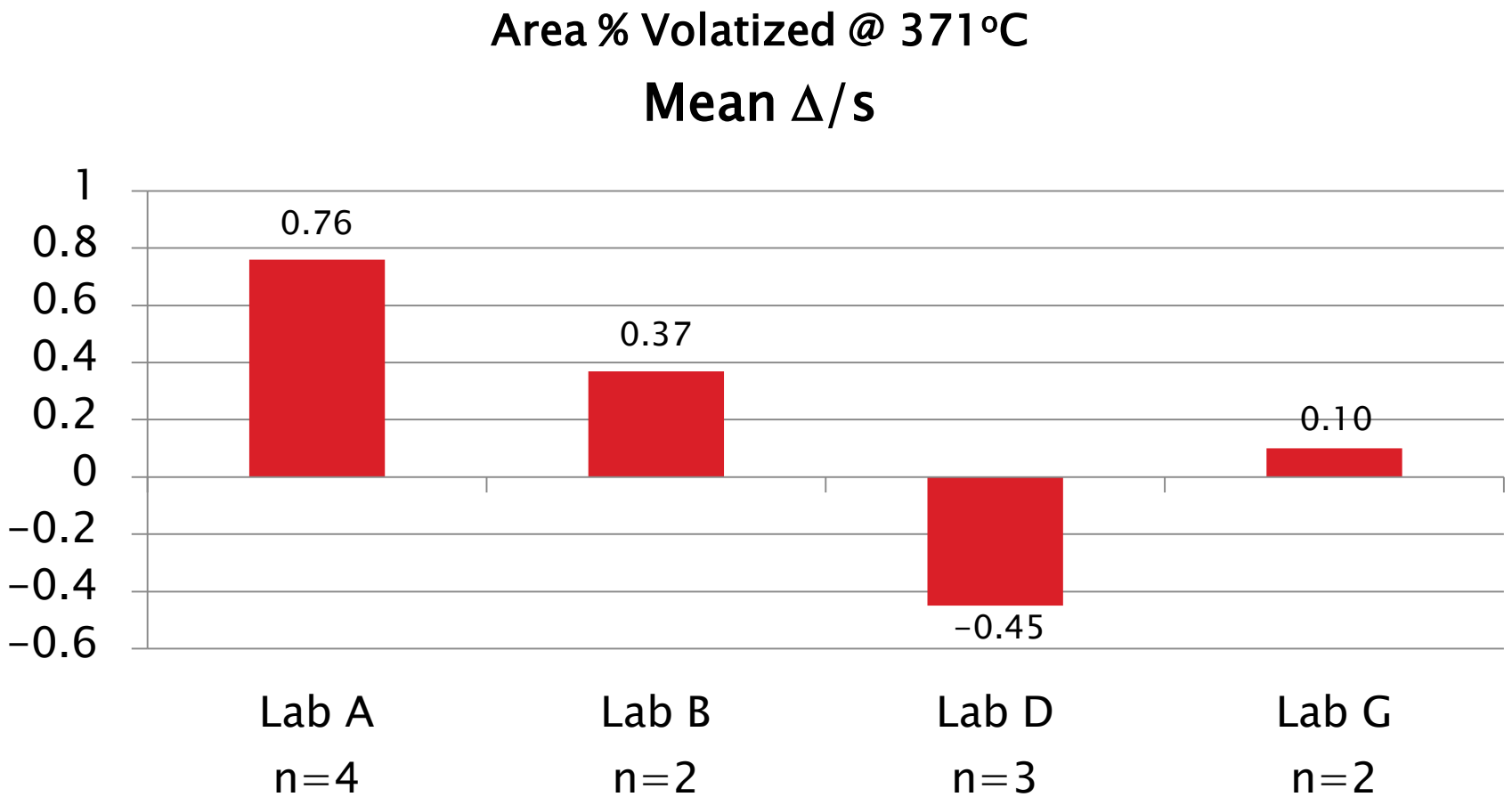


D6417: Estimation of Engine Oil Volatility by Capillary GC

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

	n	Mean Δ/s
Lab A	4	0.76
Lab B	2	0.37
Lab D	3	-0.45
Lab G	2	0.10

D6417 Lab Severity Estimates



D6417: Estimation of Engine Oil Volatility by Capillary GC

- Precision (Pooled s) is less precise than last period
  - Comparable to target precision
- Performance (Mean Δ/s) is 0.24 s severe
- Three tests total were reported on new instrument D5 this period, one on each reference oil. Though all passing, each result was more than 1 s from target (mild or severe). This instrument is the primary source of the poorer overall precision and notable severity shifts by oil this period.
- CUSUM plot shows overall slightly 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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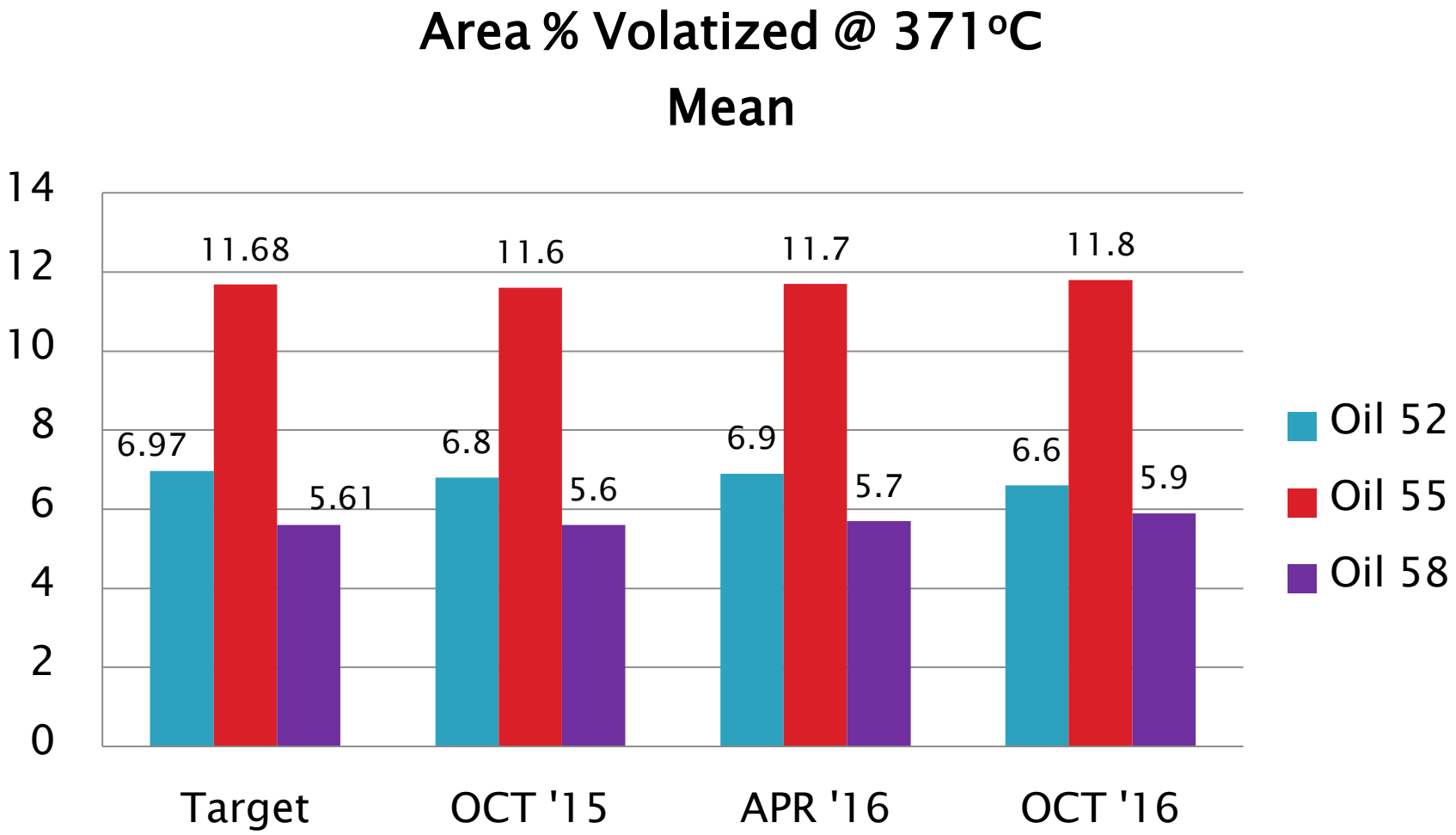
D6417: Estimation of Engine Oil Volatility by Capillary GC

Area % Volatized @ 371°C
Performance by Oil

	Targets			4/1/15 - 9/30/15				10/1/15 - 3/31/16				4/1/16 - 9/30/16			
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	7	6.8	0.61	-0.69	4	6.9	0.24	-0.23	2	6.6	0.35	-1.03
55	18	11.68	0.51	4	11.6	0.76	-0.11	5	11.7	0.15	0.12	4	11.8	0.47	0.14
58	18	5.61	0.30	5	5.6	0.28	-0.10	4	5.7	0.19	0.22	5	5.9	0.18	0.83

D6417 Performance by Oil



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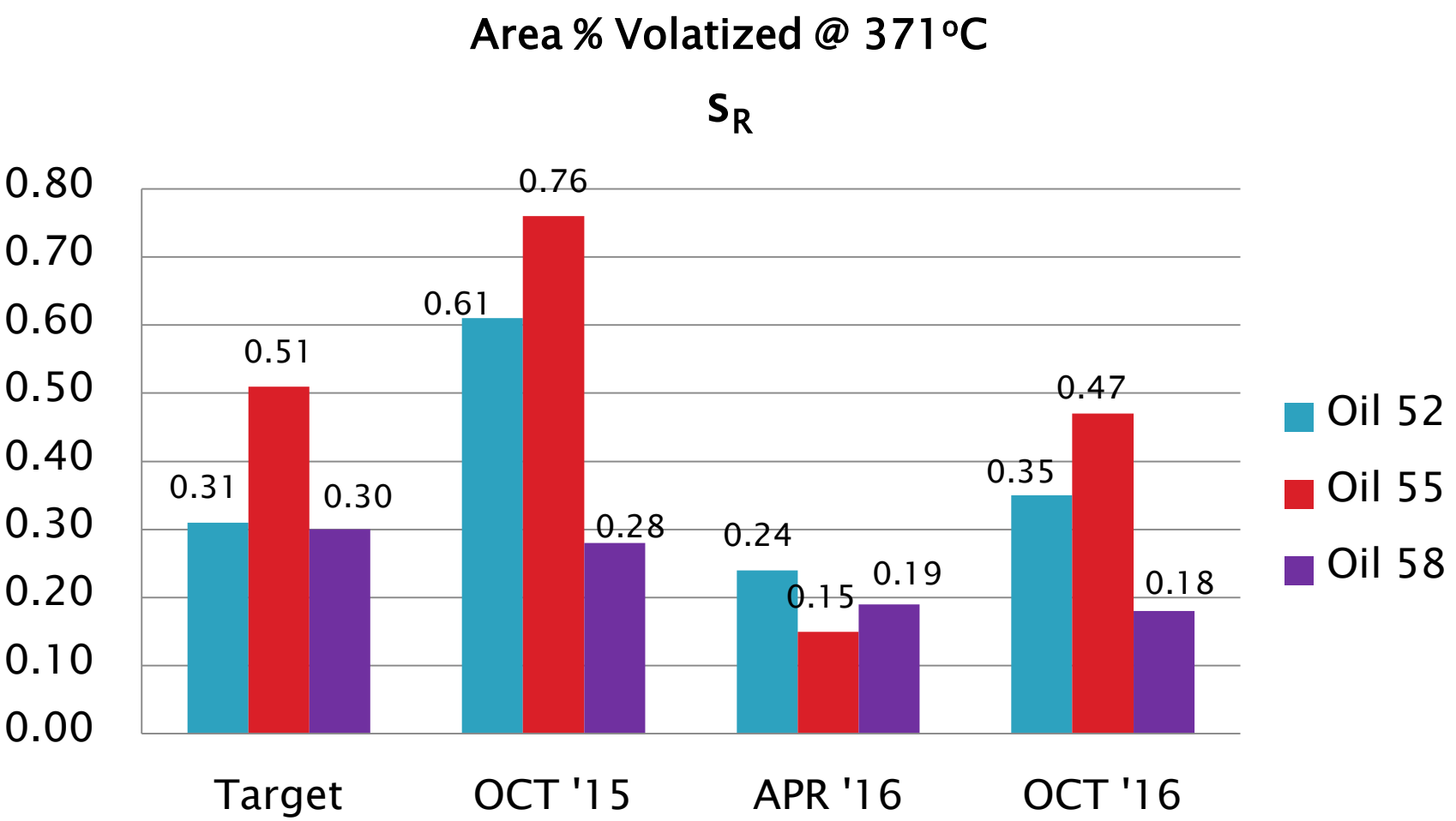
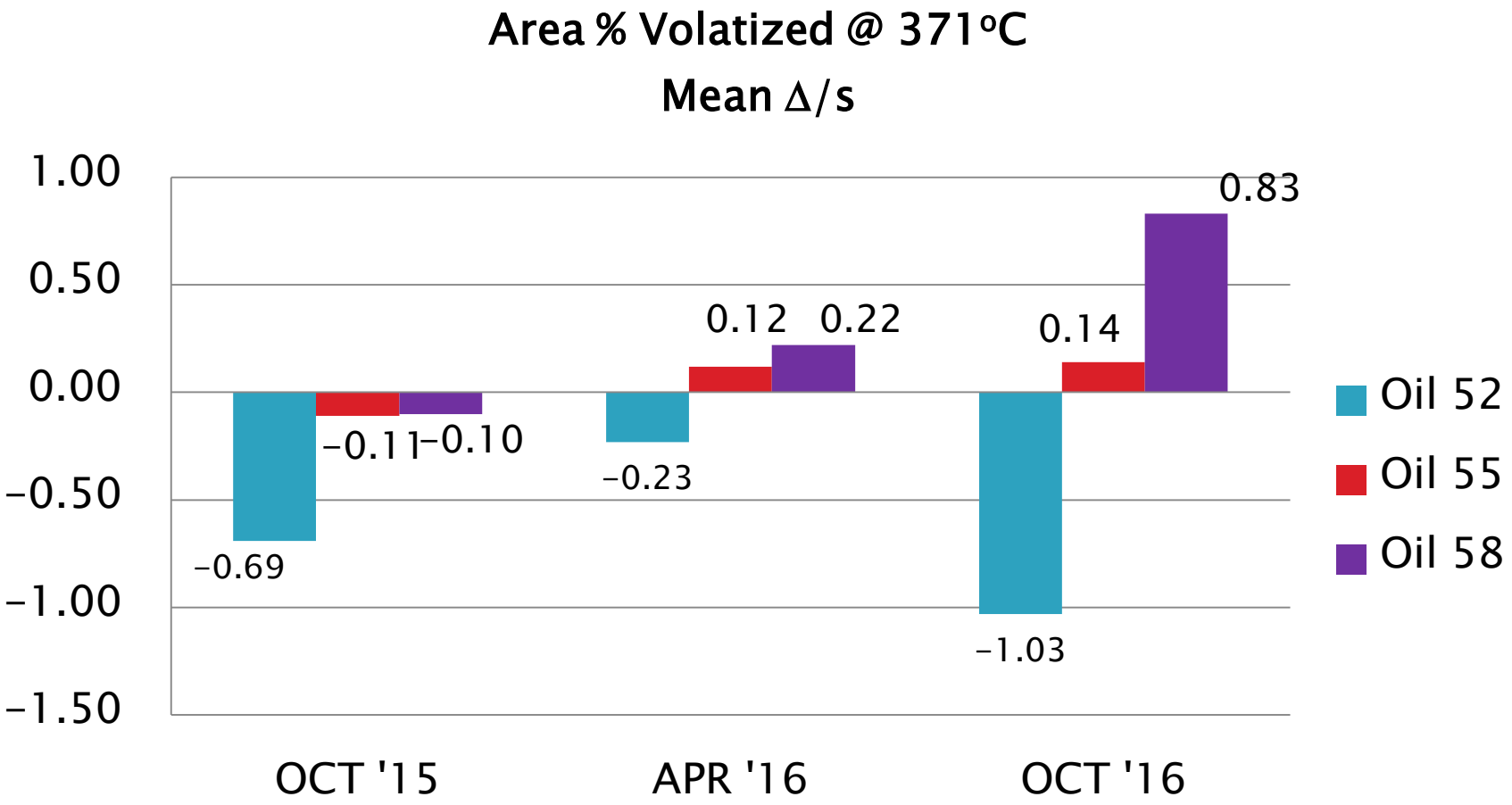
D6417 Performance by Oil



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	46
Failed Calibration Test	OC	16
Operationally Invalidated by Lab	LC, XC	1
Operationally Invalidated After Initially Reported as Valid	RC	0
Excluded from Statistics (New Rig)	MC	1
Non-Blind Instrument Shakedown	NN	1
Total		**65**

Number of Labs Reporting Data: 9
Fail Rate of Operationally Valid Tests: 26%

D5800: Evaporation Loss of Lubricating Oil by Noack Method

Statistically Unacceptable Tests (OC)	No. Of Tests
Evaporation Loss Mild	1
Evaporation Loss Severe	15

- Failing results are across multiple labs, instruments and oils.
  - Four rigs at four separate labs had 2 or 3 consecutive statistically failing runs before finally passing calibration this period.

- Number of operationally valid results reported by oil:
  - VOLC12: 16 AC, 13 OC (1 mild, 12 severe)
  - VOLD12: 19 AC, 3 OC (severe)
  - VOLE12: 11 AC, 0 OC

D5800: Evaporation Loss of Lubricating Oil by Noack Method

- There were two technical updates issued this report 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 10/1/2013	78	75	0.50	-----
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
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

*Extreme OC result included and excluded

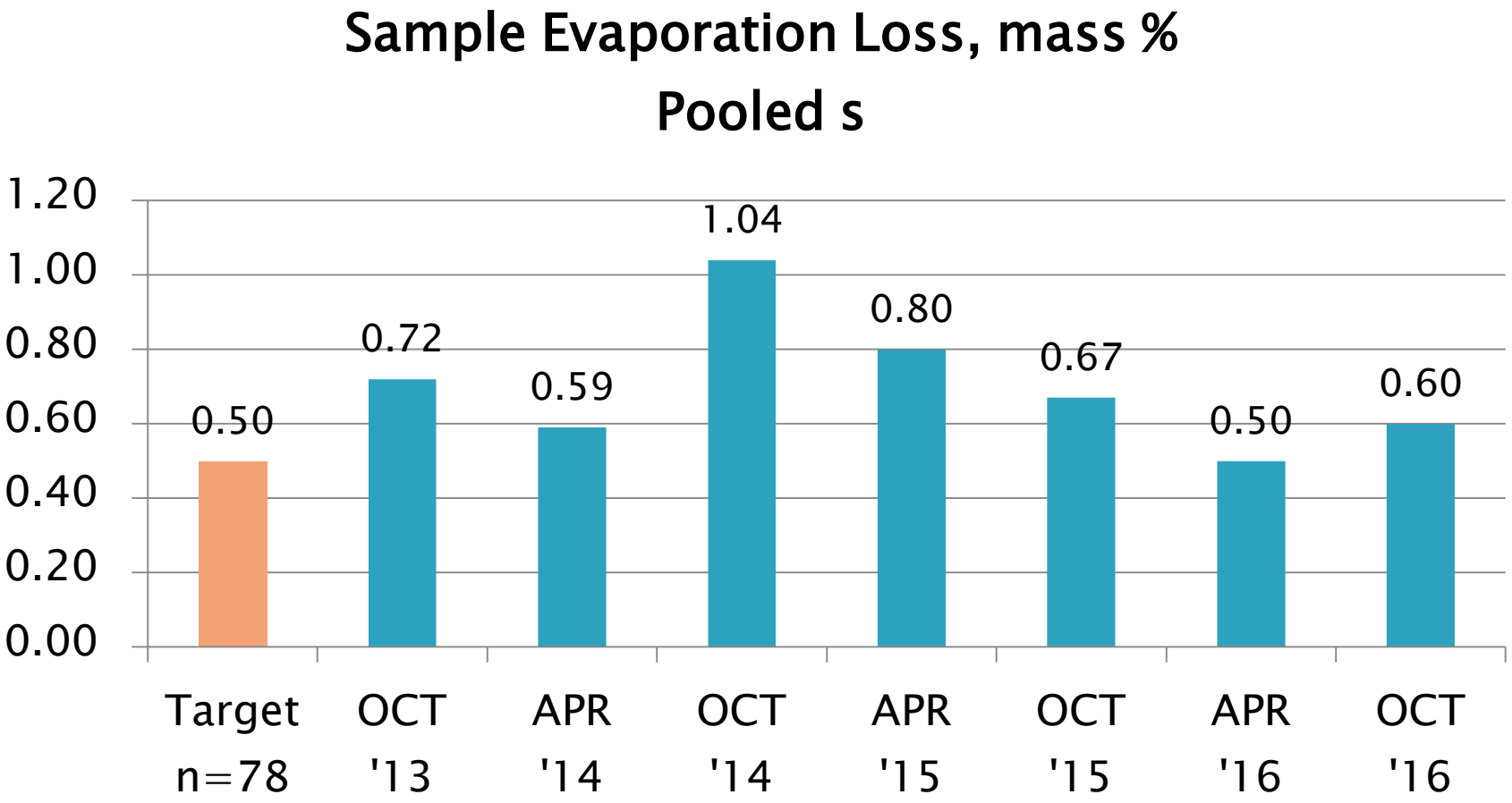
D5800: Evaporation Loss of Lubricating Oil by Noack Method

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

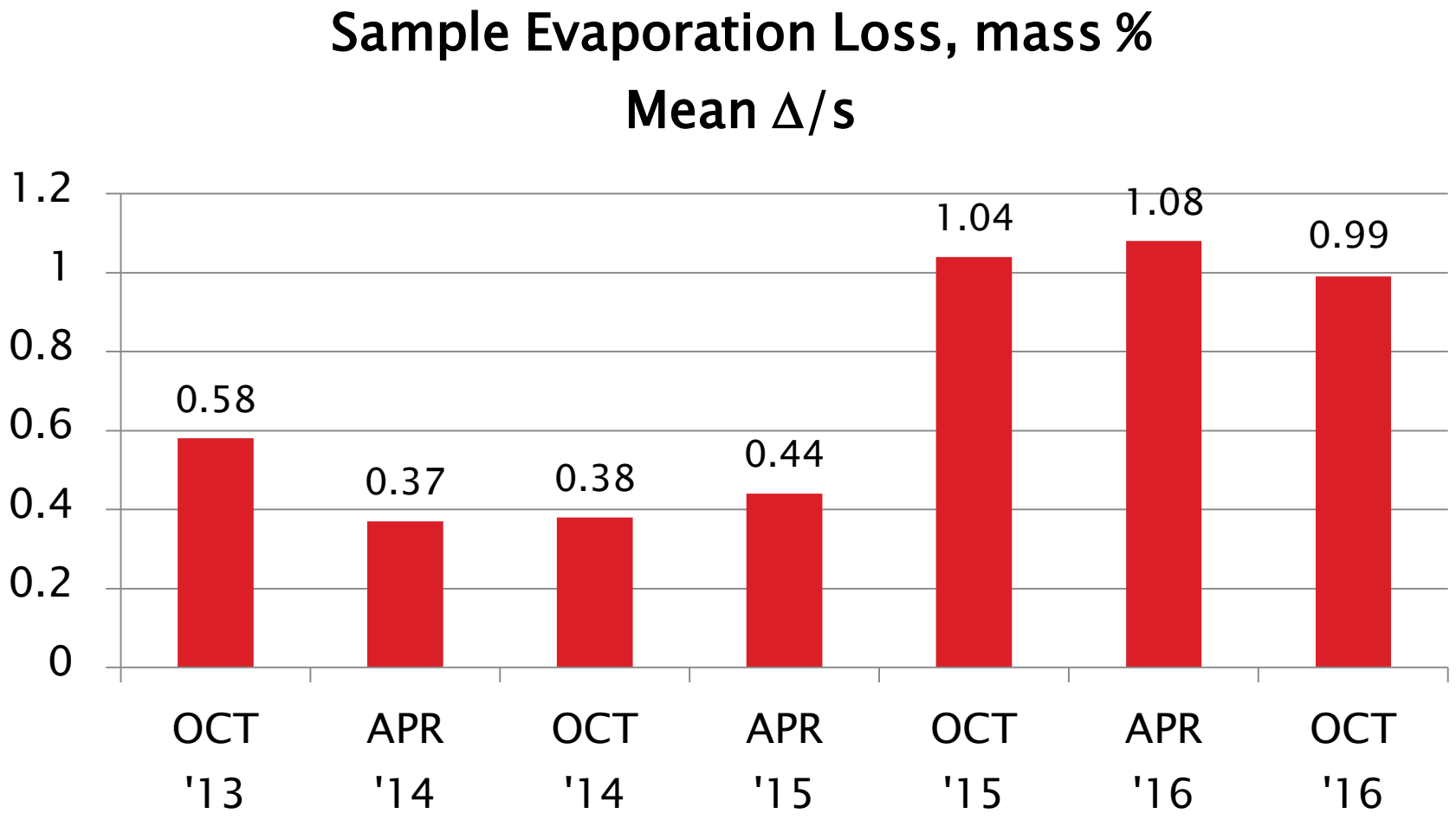
	n	df	Pooled s	Mean Δ/s
Procedure B	54	51	0.59	0.97
Procedure C	8	6	0.79	1.12

Model	n	df	Pooled s	Mean Δ/s
NCK2	11	8	0.49	0.31
NCK25G	43	40	0.61	1.14
SVT1	8	6	0.79	1.12

D5800 Precision Estimates



D5800 Severity Estimates



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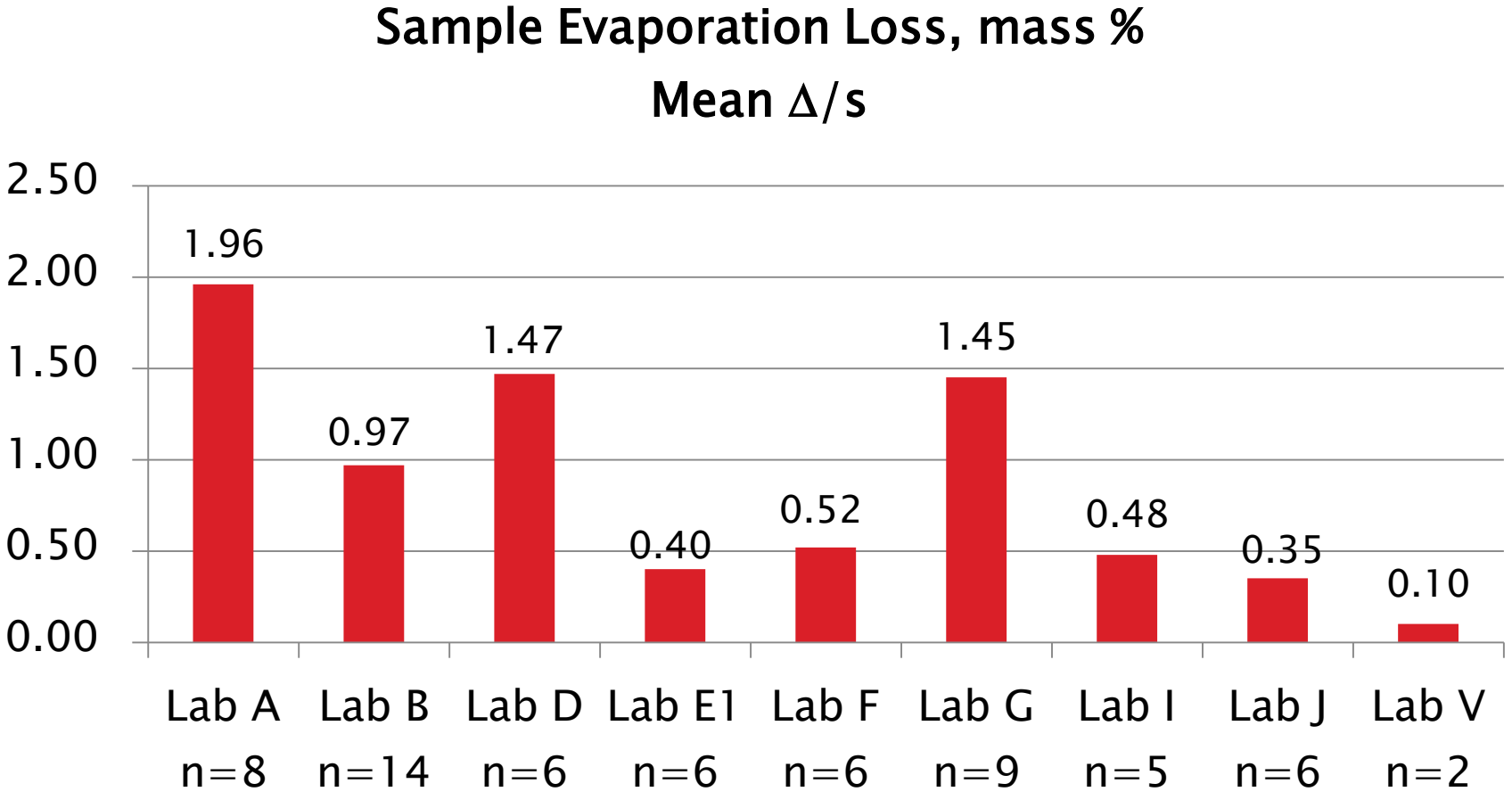
D5800: Evaporation Loss of Lubricating Oil by Noack Method

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

	n	Mean Δ/s
Lab A	8	1.96
Lab B	14	0.97
Lab D	6	1.47
Lab E1	6	0.40
Lab F	6	0.52
Lab G	9	1.45
Lab I	5	0.48
Lab J	6	0.35
Lab V	2	0.10

D5800 Lab Severity Estimates



D5800: Evaporation Loss of Lubricating Oil by Noack Method

- Precision (Pooled s), at 0.60 mass %, is less precise than prior period and less precise than the target precision.
- Performance (Mean Δ/s) is 0.99 s severe and comparable to the last two report periods.
- Fail rate of operationally valid tests (AC & OC) is 26% (fail rate of the four prior periods was 20%, 27% , 36% and 19%).
- Historical long-term severe trend continues with only a modest decrease in severity following the introduction of the new reference oils (3Q 2013), and an increase in severity to approximately 1 s for the past three report periods.

D5800: Evaporation Loss of Lubricating Oil by Noack Method

- Breakdown of tests reported this period by severity of results:
  - 2 < and < 3 s mild or severe of targets:
    - 9 tests (one passed on acceptance bands due to rounding)
    - models NCK2 and NCK25G.
  - 3 < and $\leq$ 4 s severe of targets:
    - 7 tests
    - models NCK25G and SVT1
- VOLC12 is again performing most severe at 1.4 s, but oil VOLE12 performing nearly on-target this period at 0.09 s severe (last period VOLE12 was 0.92 s severe).

D5800 VOLATILITY BY NOACK INDUSTRY OPERATIONALLY VALID DATA

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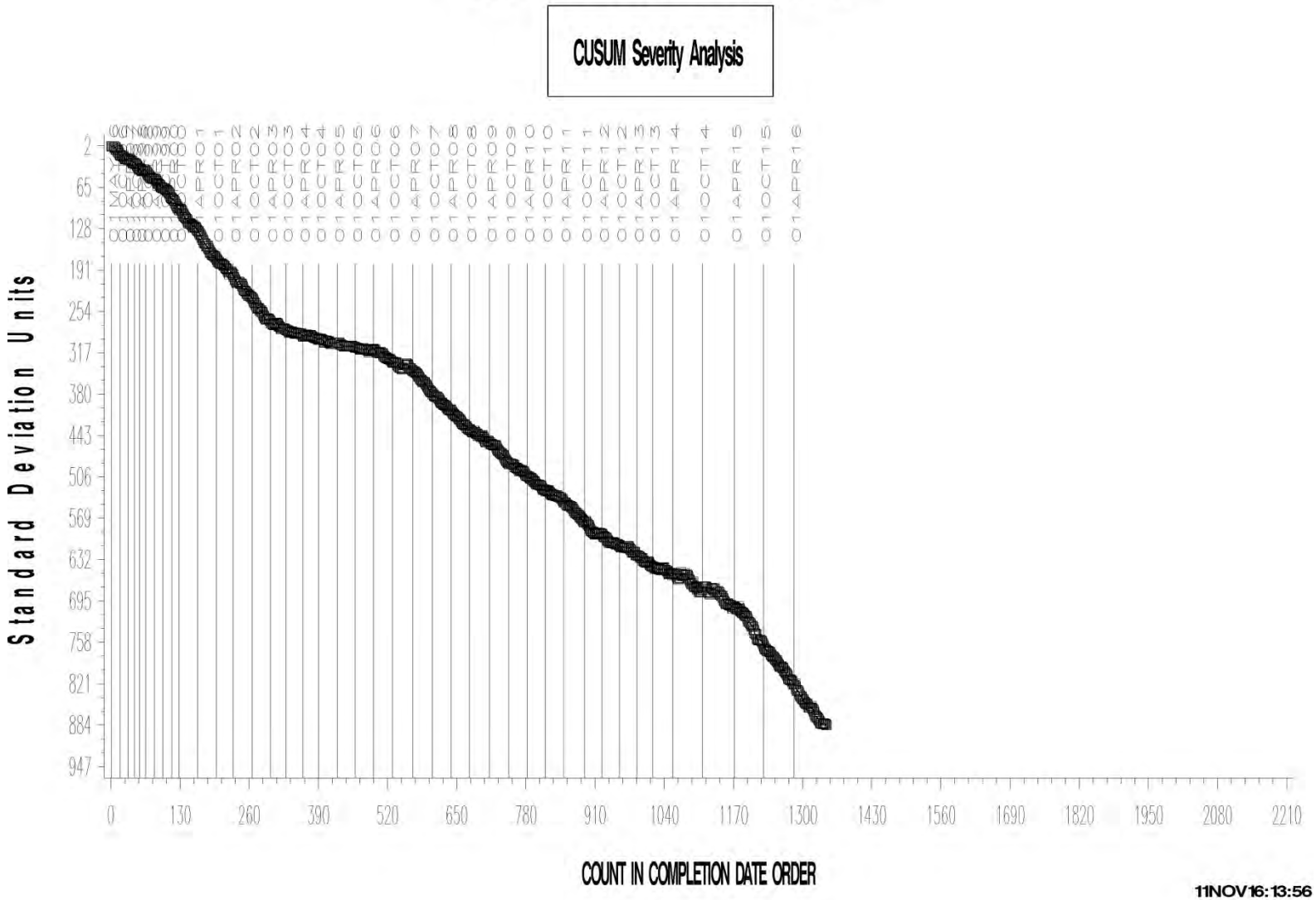
EVAPORATION LOSS, MASS%



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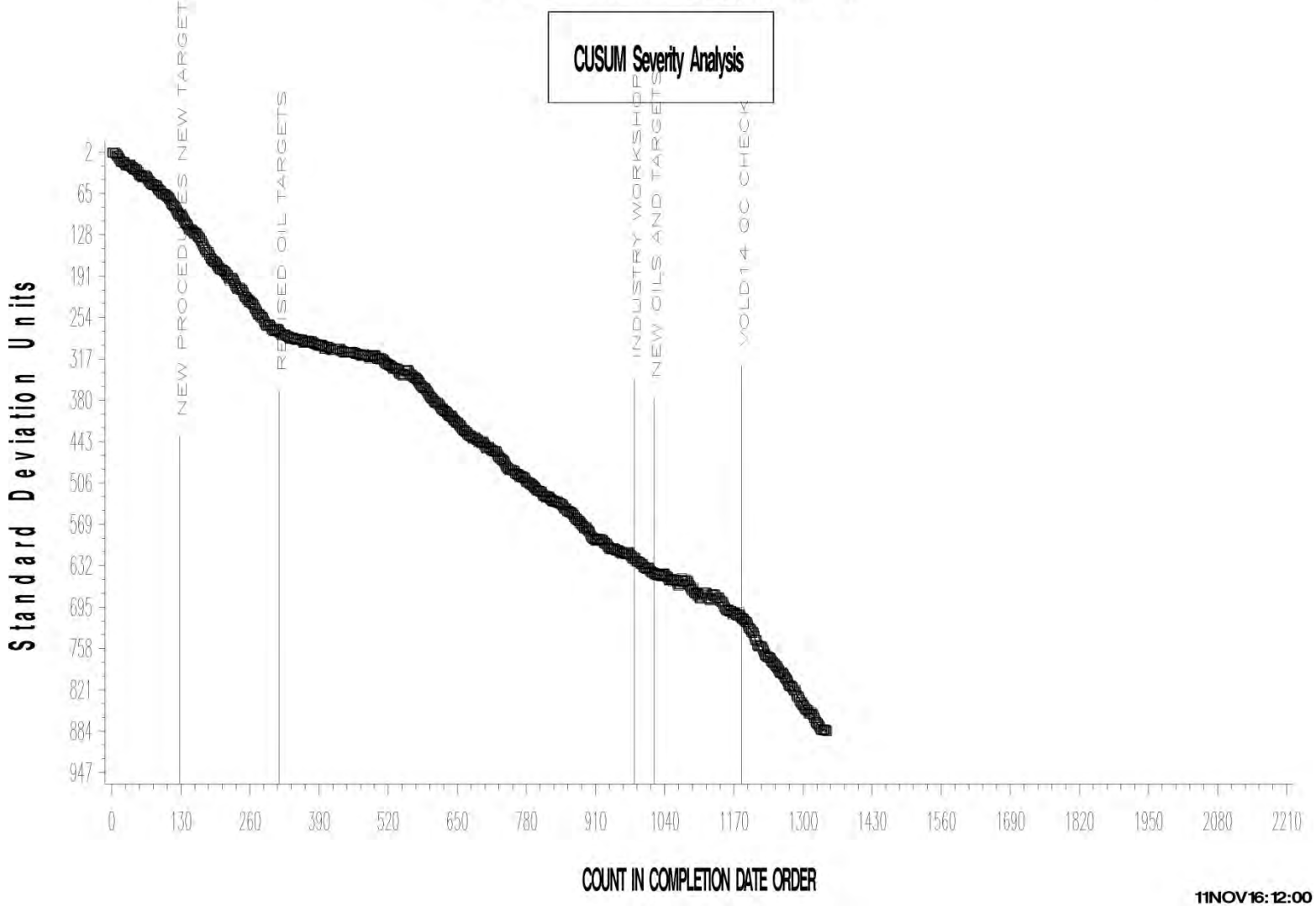
D5800 VOLATILITY BY NOACK INDUSTRY OPERATIONALLY VALID DATA

DTCOMP< = '20160930'

EVAPORATION LOSS, MASS%



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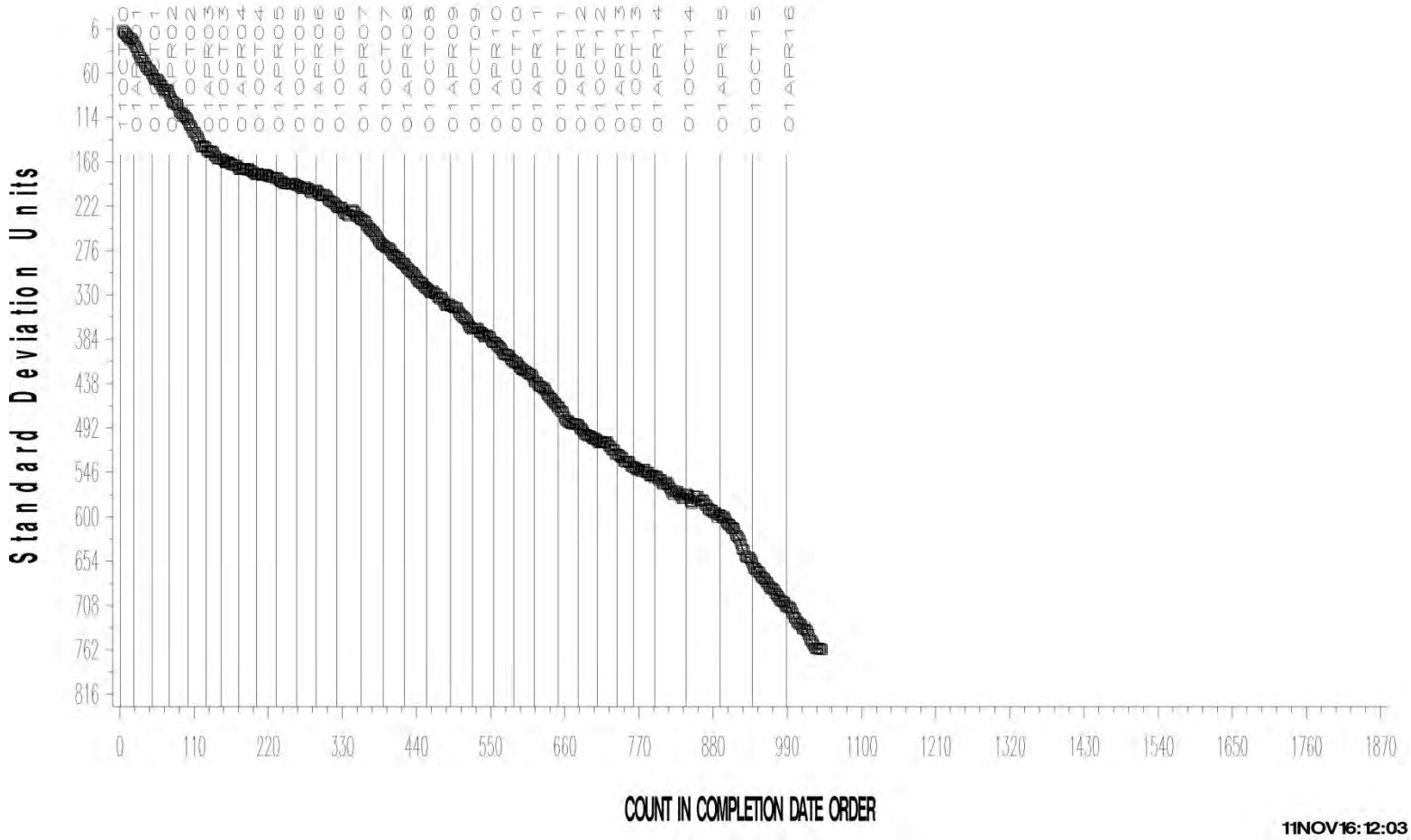
D5800 VOLATILITY BY NOACK INDUSTRY OPERATIONALLY VALID DATA
(DTCOMP< ='20160930') and (PRCDR='B')
EVAPORATION LOSS, MASS%

CUSUM Severity Analysis



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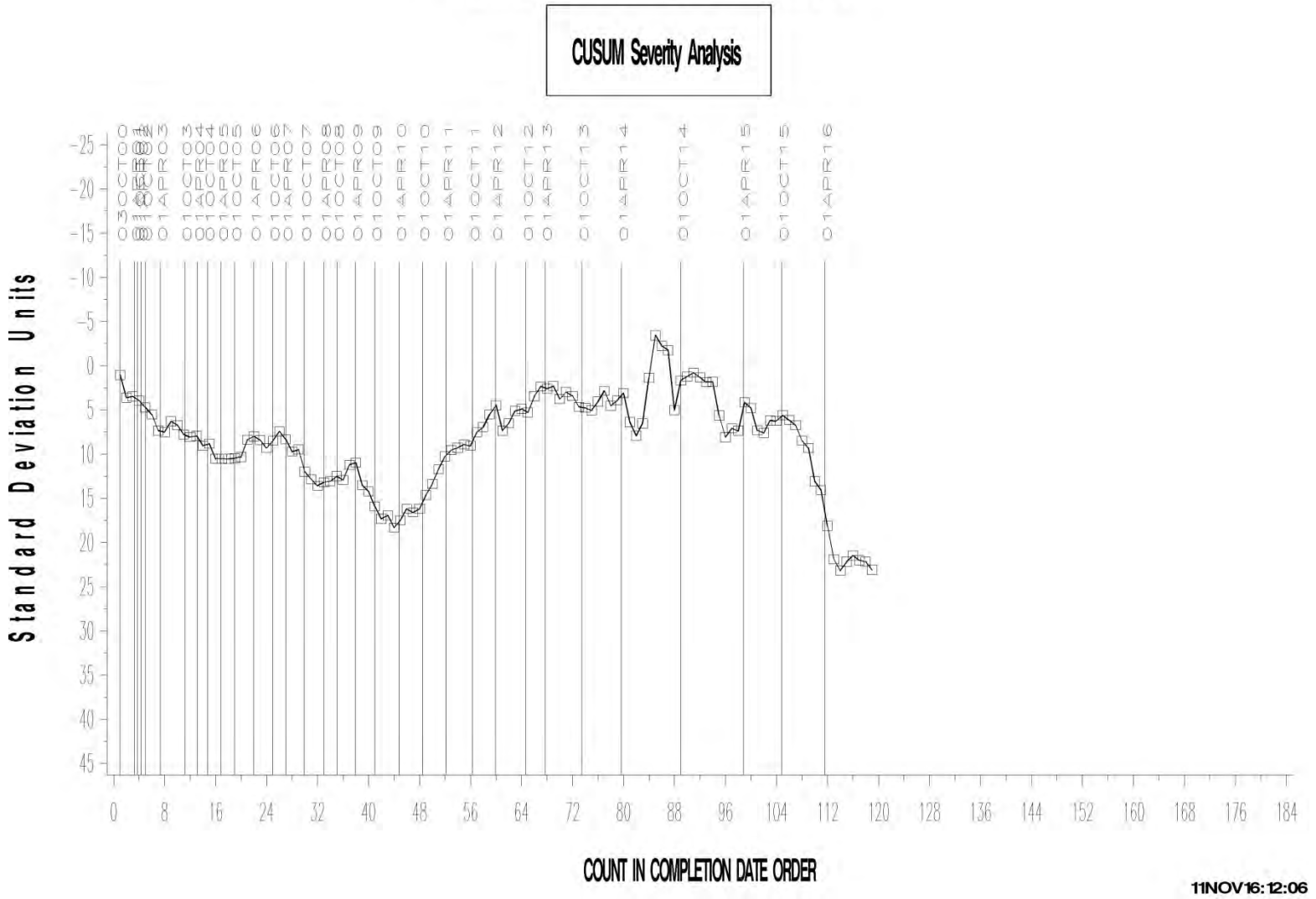
D5800 VOLATILITY BY NOACK INDUSTRY OPERATIONALLY VALID DATA
(DTCOMP< ='20160930') and (PRCDR='C')
EVAPORATION LOSS, MASS%



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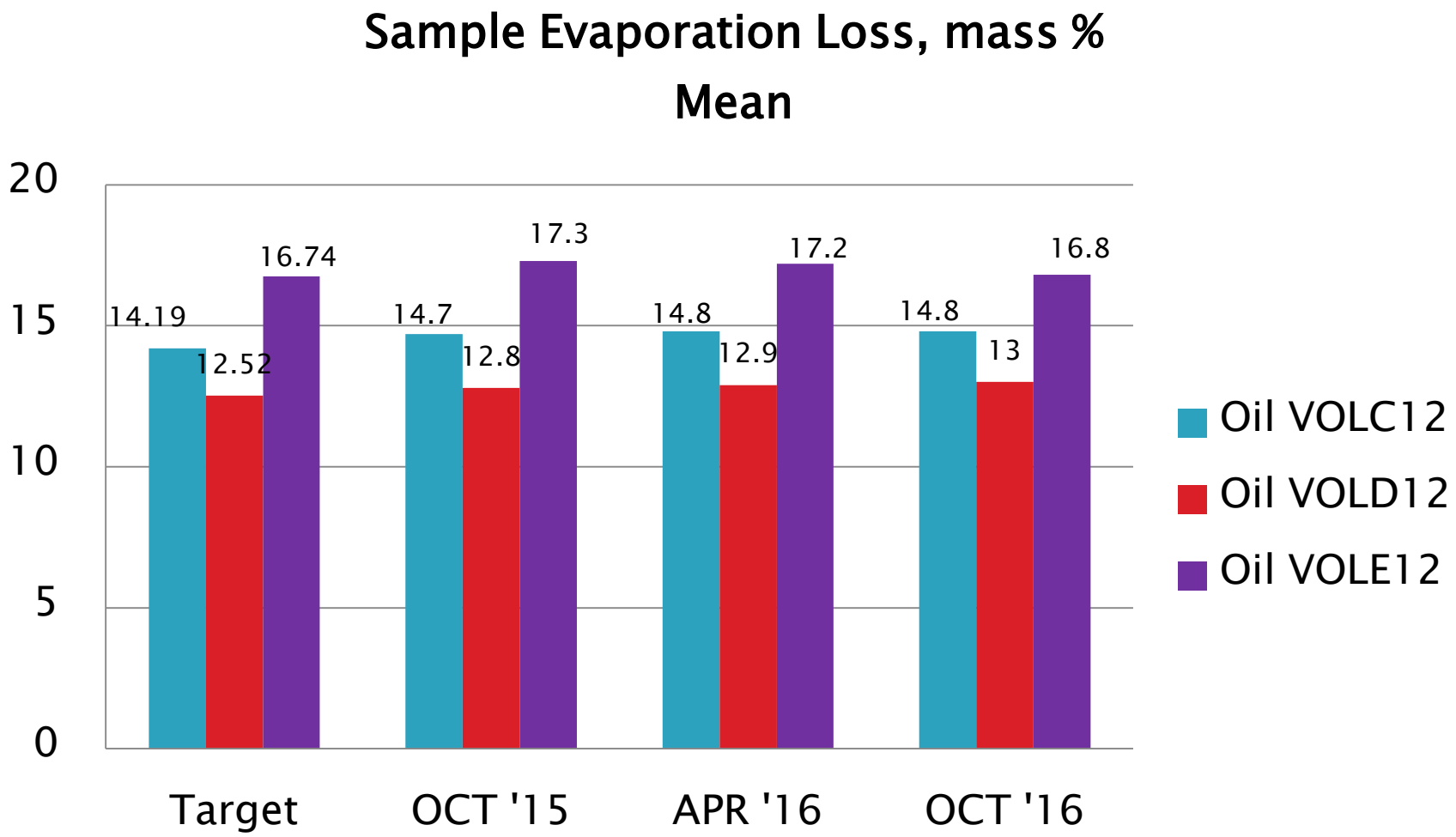
D5800: Evaporation Loss of Lubricating Oil by Noack Method

Sample Evaporation Loss, mass %
Performance by Oil

	Targets			4/1/135– 9/30/15				10/1/15 – 3/31/16				4/1/16 – 9/30/16			
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	25	14.7	0.75	1.32	18	14.8	0.44	1.57	29	14.8	0.72	1.40
VOLD12	27	12.52	0.52	16	12.8	0.65	0.57	16	12.9	0.62	0.77	22	13.0	0.44	0.89
VOLE12	27	16.74	0.55	14	17.3	0.52	1.10	23	17.2	0.45	0.92	11	16.8	0.55	0.09

D5800 Performance by Oil



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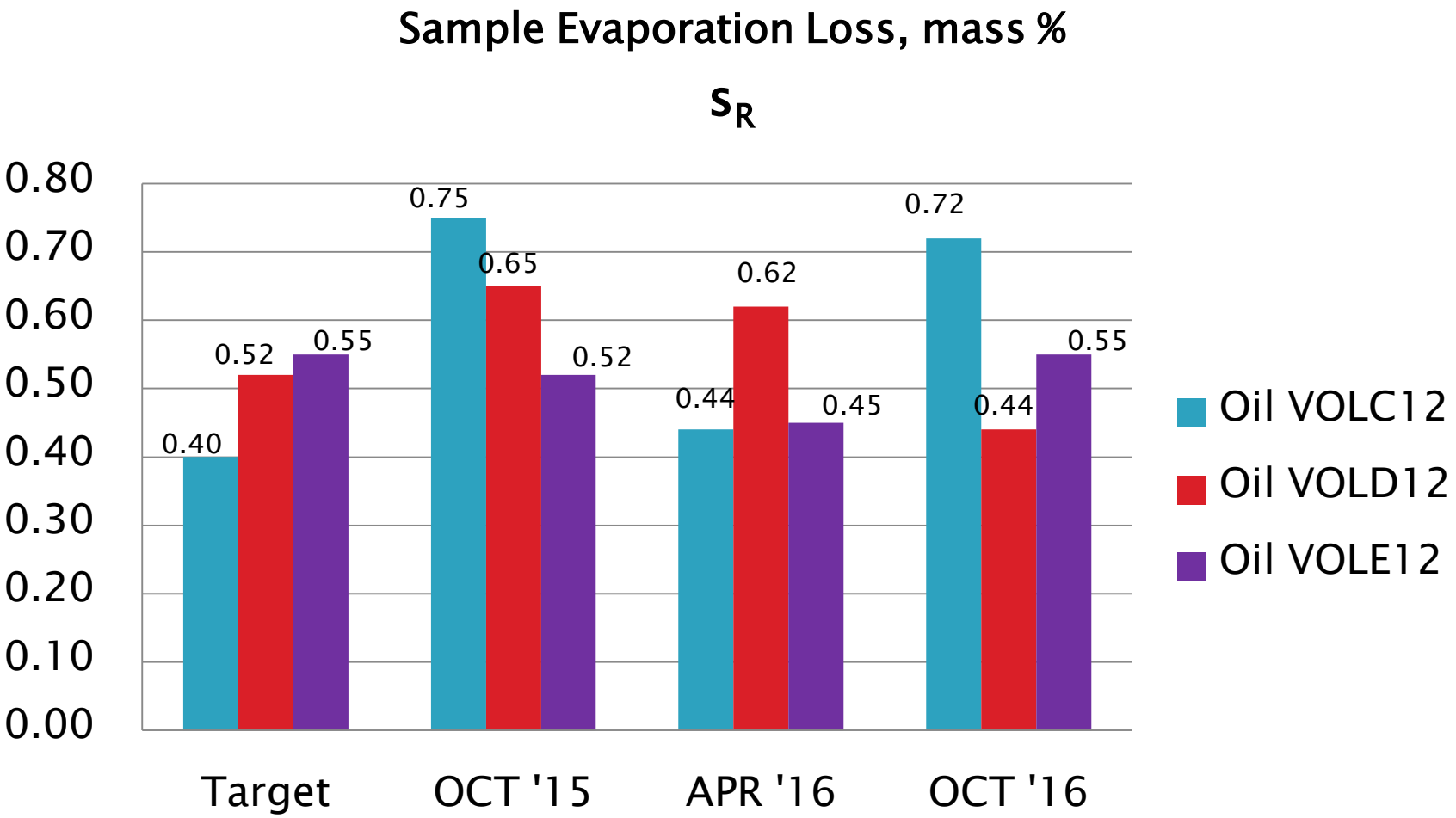
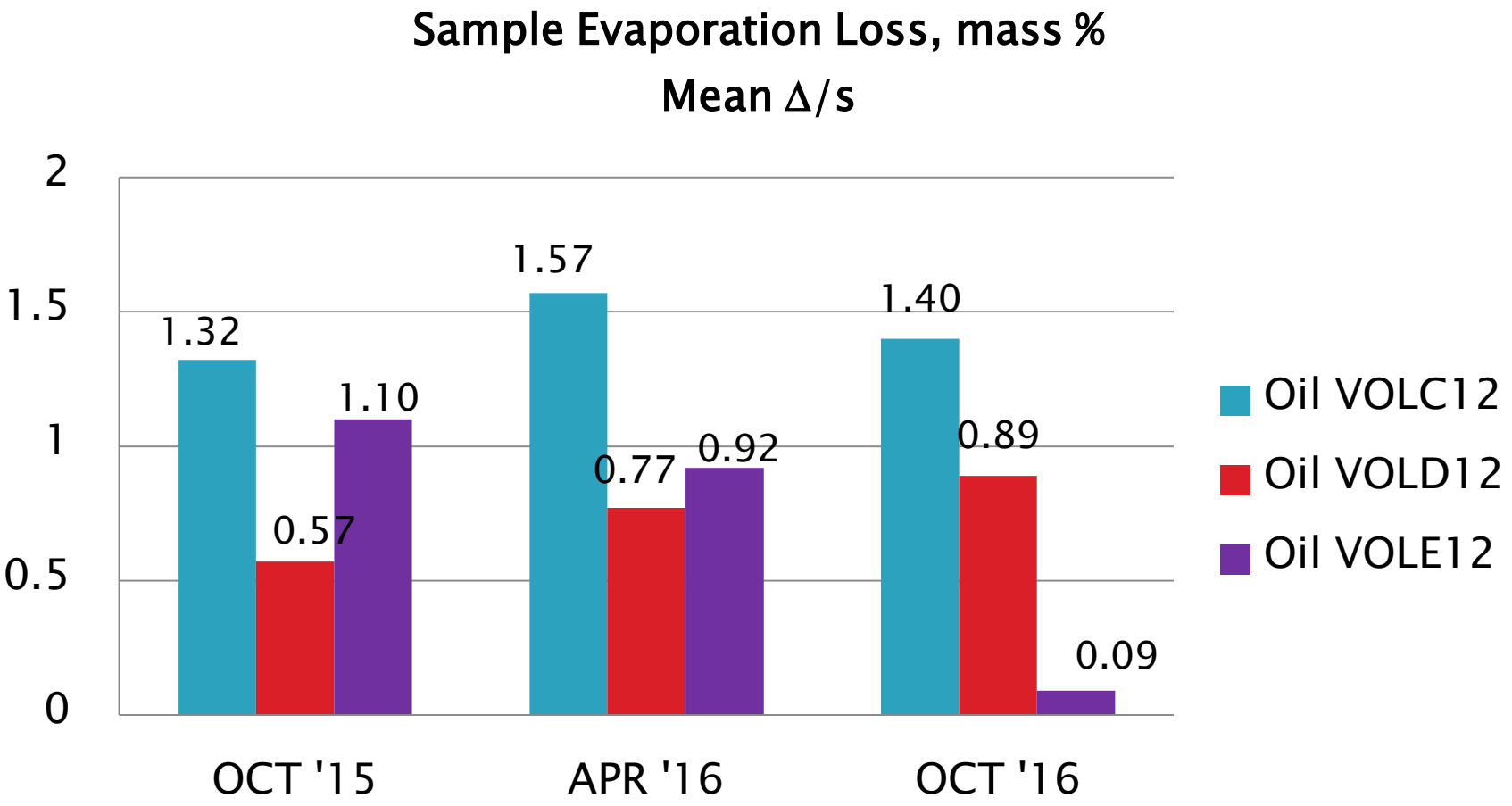
D5800 Performance by Oil



D5800 Performance by Oil



Return to Executive Summary

D5133: Gelation Index

Test Status	Validity Code	No. Tests
Acceptable Calibration Test	AC	29
Failed Calibration Test	OC	2
Operationally Invalidated by Lab	LC, XC	1
Operationally Invalidated After Initially Reported as Valid	RC	0
Total		**32**

Number of Labs Reporting Data: 8
Fail Rate of Operationally Valid Tests: 6%

D5133: Gelation Index

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

- One operationally invalid test reported this period:
  - Power failure (XC)

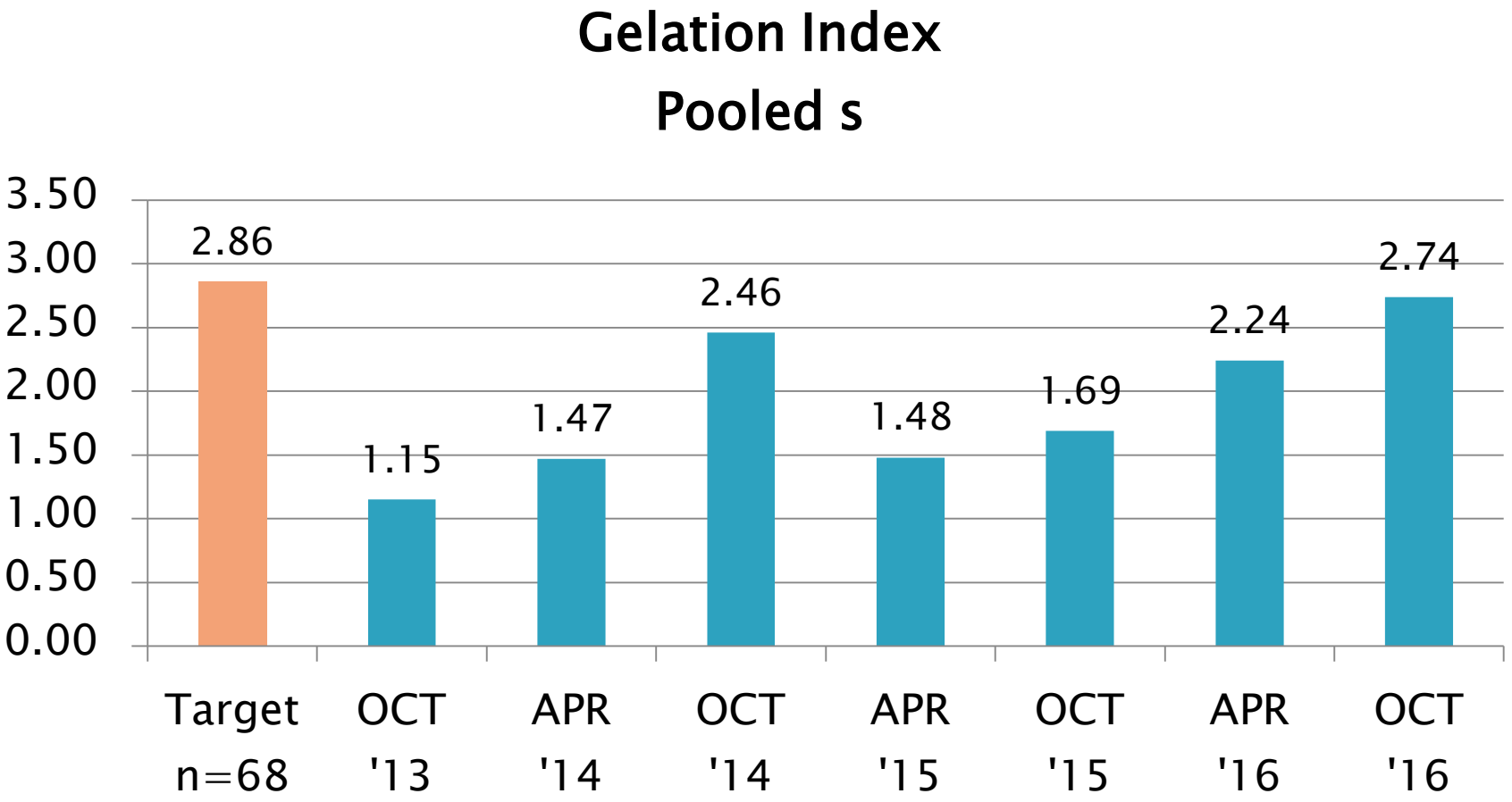
- No TMC technical updates issued this period

D5133: Gelation Index

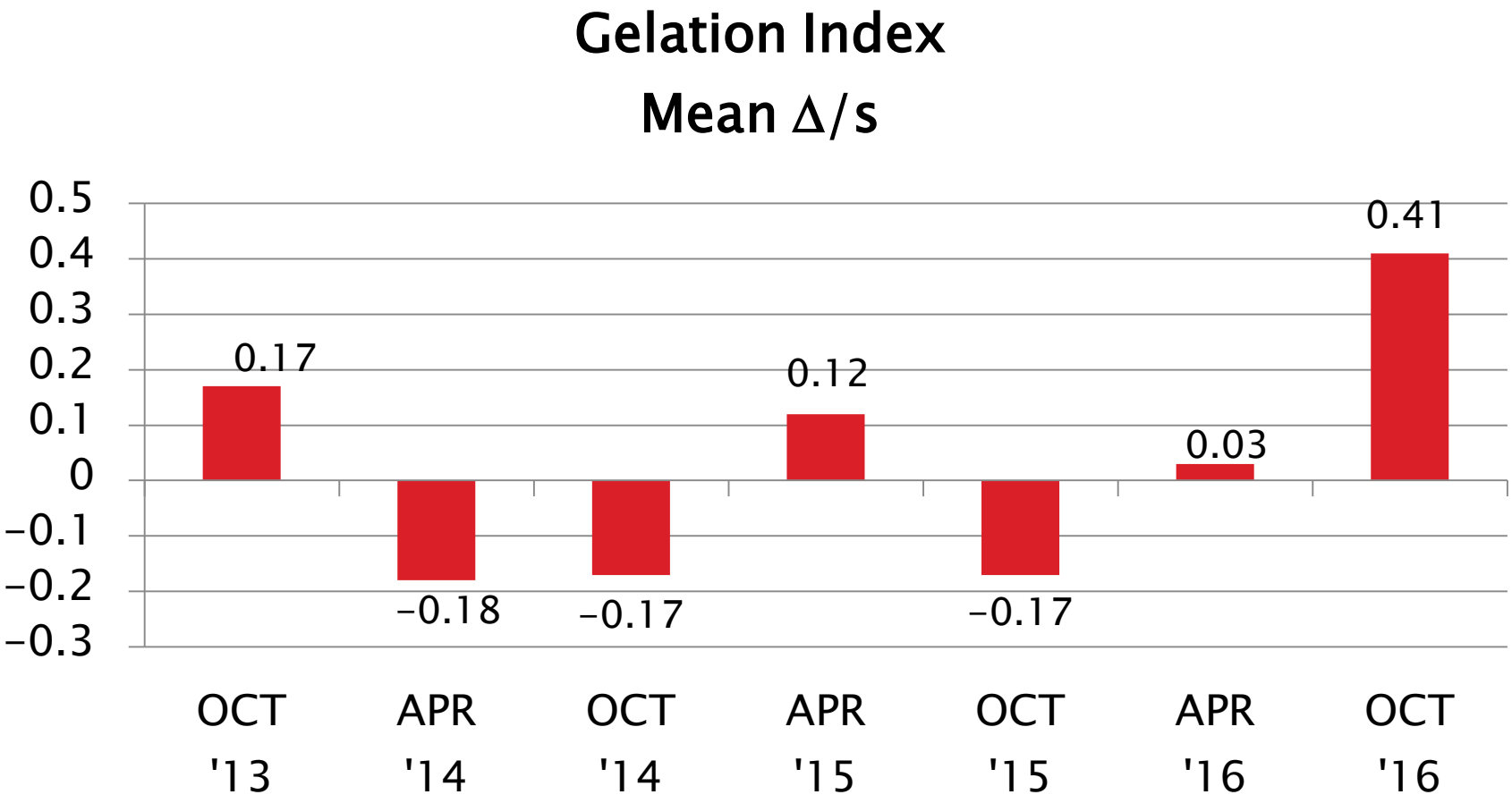
Period Precision and Severity Estimates

Gelation Index	n	df	Pooled s	Mean Δ/s
Current Targets 7/15/2003	68	65	2.86	-----
4/1/13 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
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

D5133 Precision Estimates



D5133 Severity Estimates



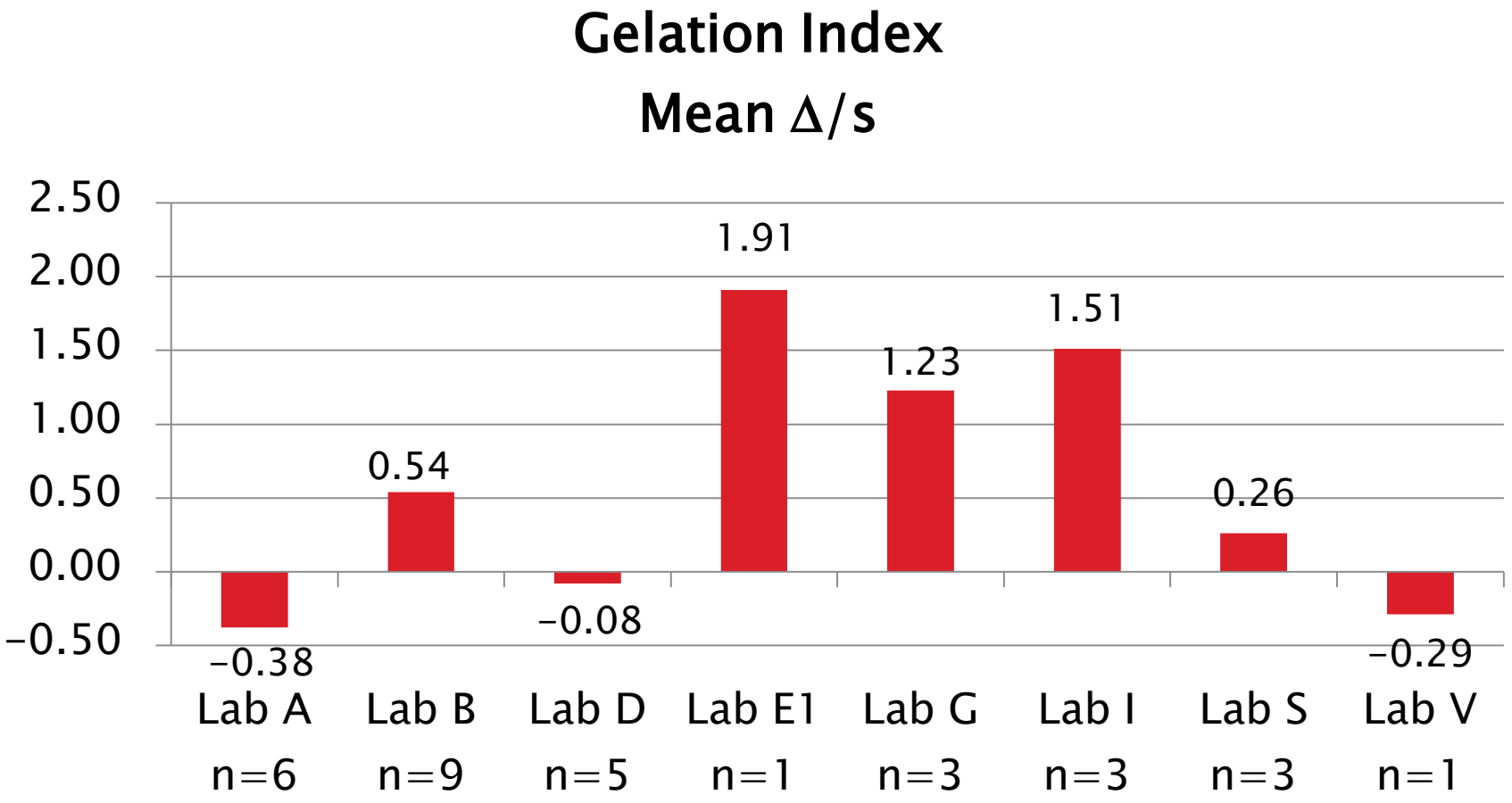
D5133: Gelation Index

Current Period Severity Estimates by Lab

Gelation Index

	n	Mean Δ/s
Lab A	6	-0.38
Lab B	9	0.54
Lab D	5	-0.08
Lab E1	1	1.91
Lab G	3	1.23
Lab I	3	1.51
Lab S	3	0.26
Lab V	1	-0.29

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 0.41 s severe
  - Considerably more severe than prior periods
  - Three labs performing more than 1 s severe
- Reference oil 62 inventory is down to 0.9 gallons remaining (but only 0.1 gallon shipped prior 12 months).

D5133 GELATION INDEX INDUSTRY OPERATIONALLY VALID DATA

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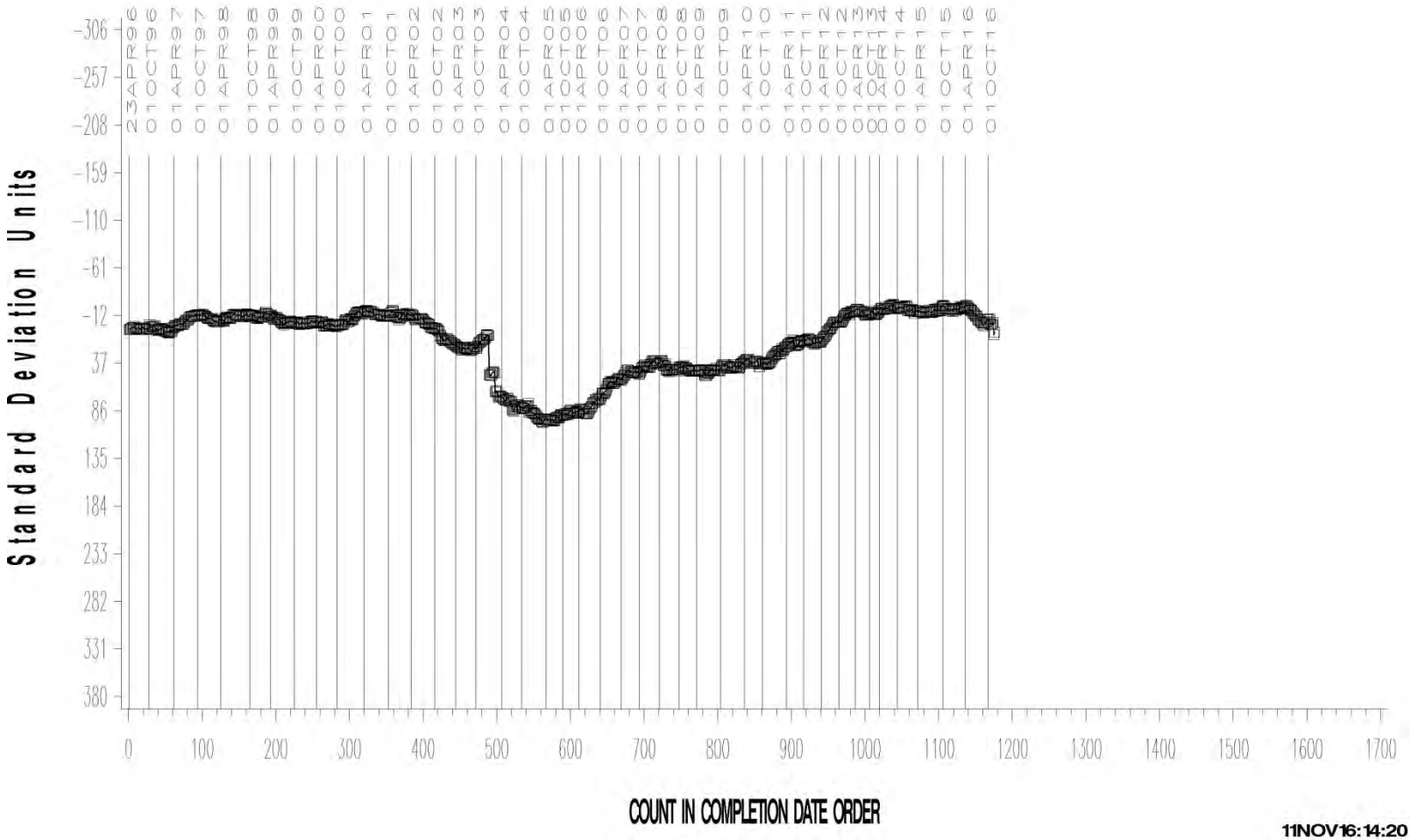
GELATION INDEX

CUSUM Severity Analysis



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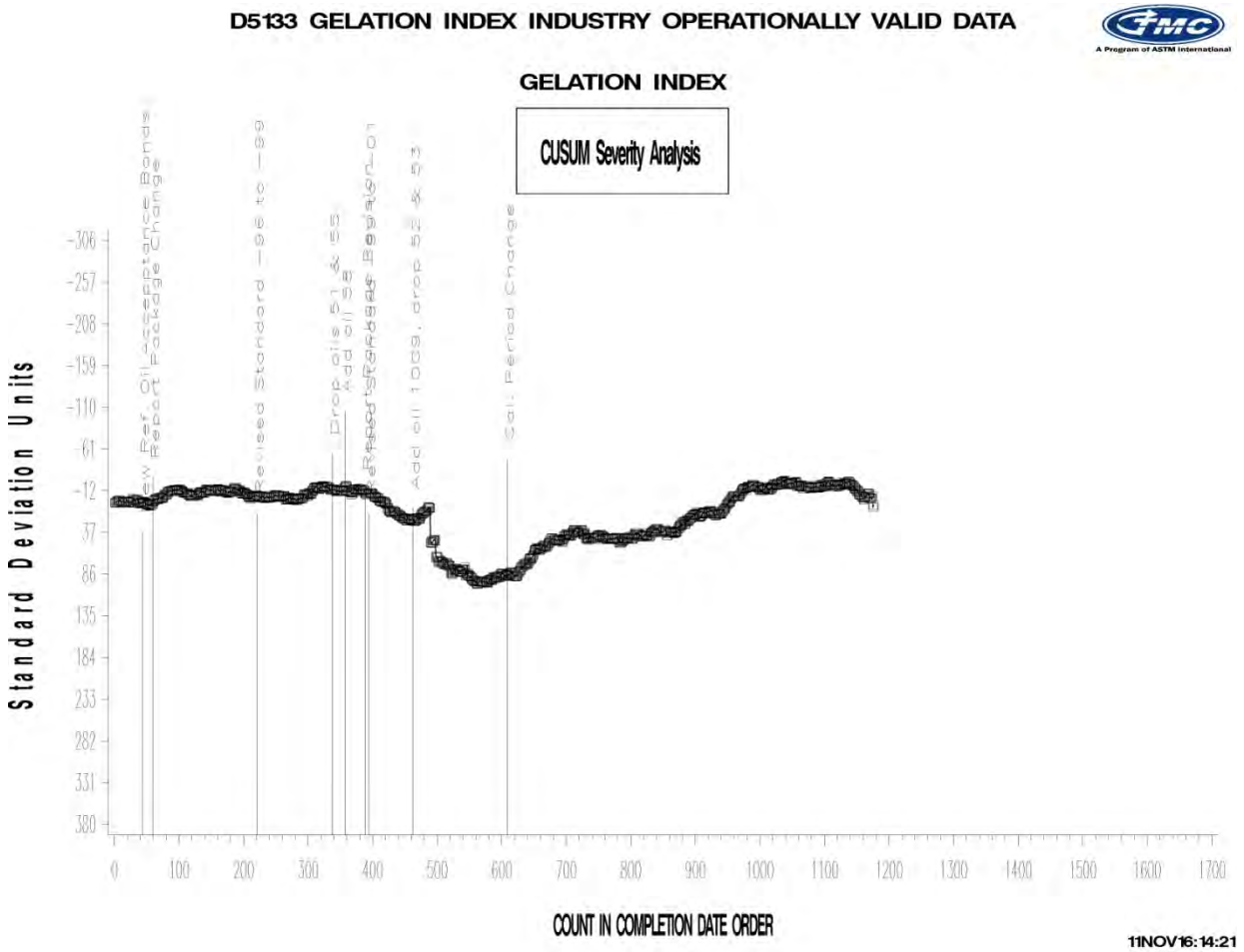
D5133: Gelation Index

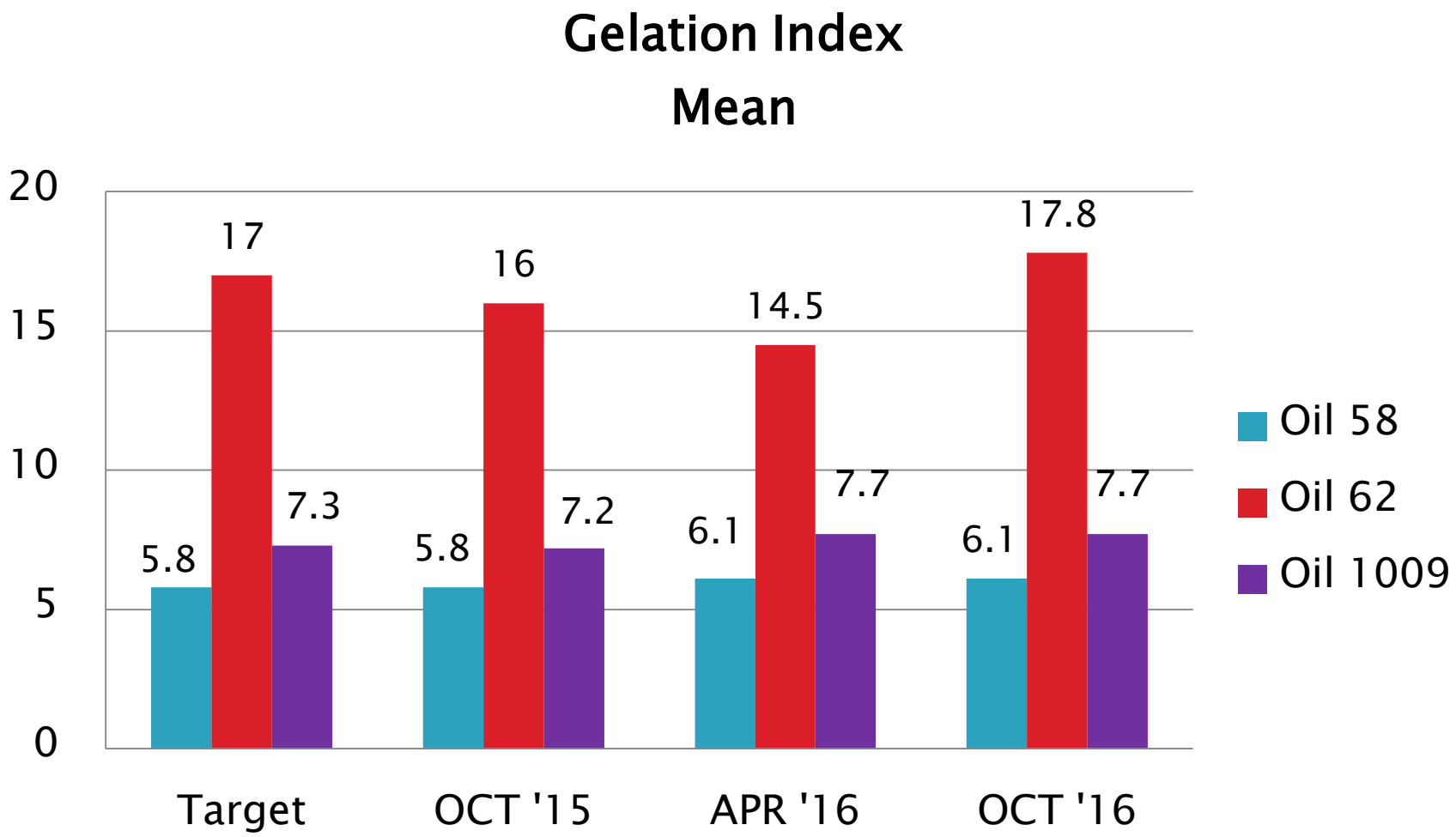


D5133 Performance by Oil

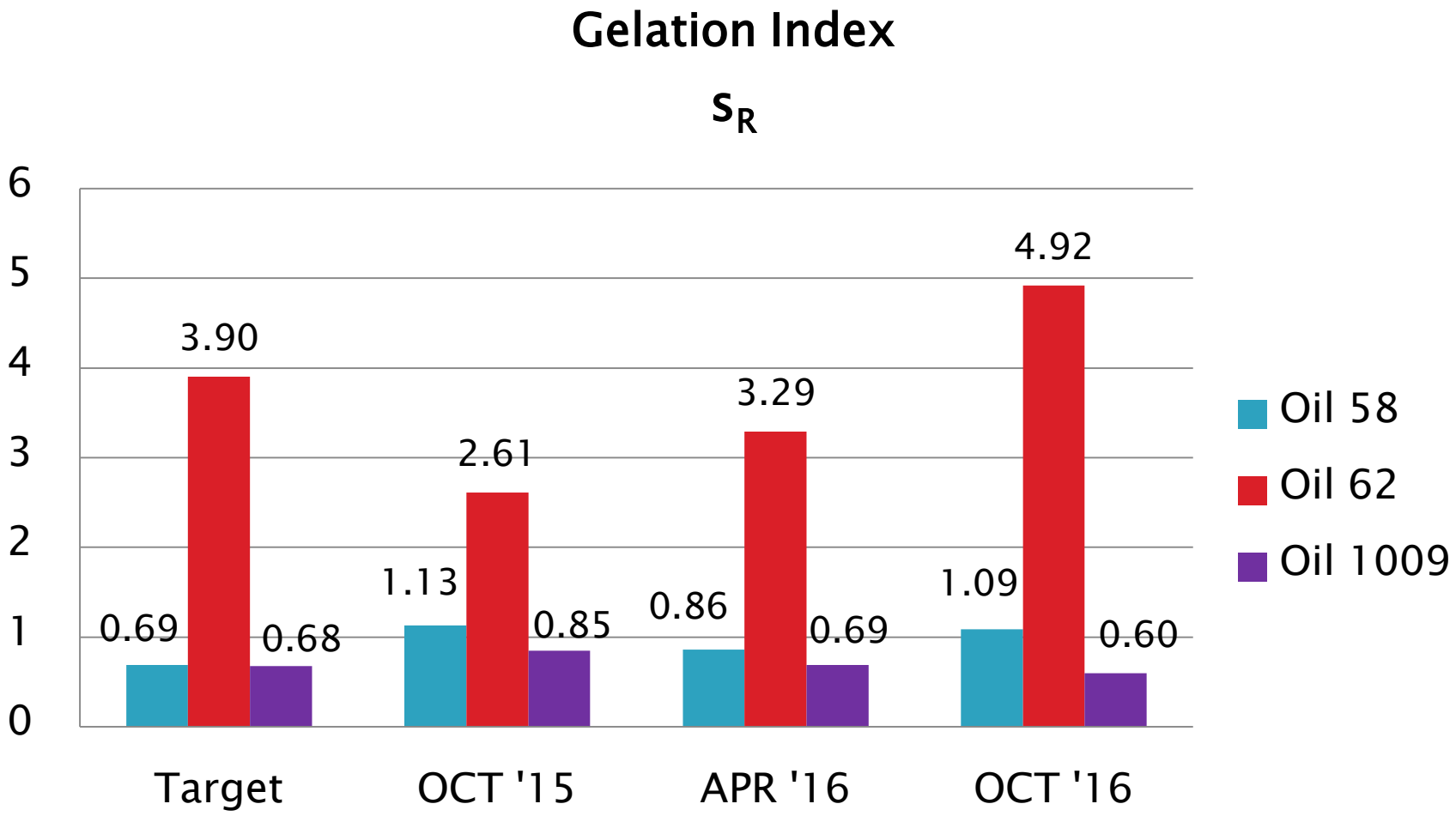
Gelation Index
Performance by Oil

	Targets			4/1/145– 9/30/15				10/1/15 – 3/31/16				4/1/16 – 9/30/16			
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	5.8	1.13	-0.03	11	6.1	0.86	0.46	11	6.1	1.09	0.47
62	35	17.0	3.90	11	16.0	2.61	-0.26	13	14.5	3.29	-0.64	9	17.8	4.92	0.21
1009	16	7.30	0.68	12	7.2	0.85	-0.22	7	7.7	0.69	0.61	11	7.7	0.60	0.52

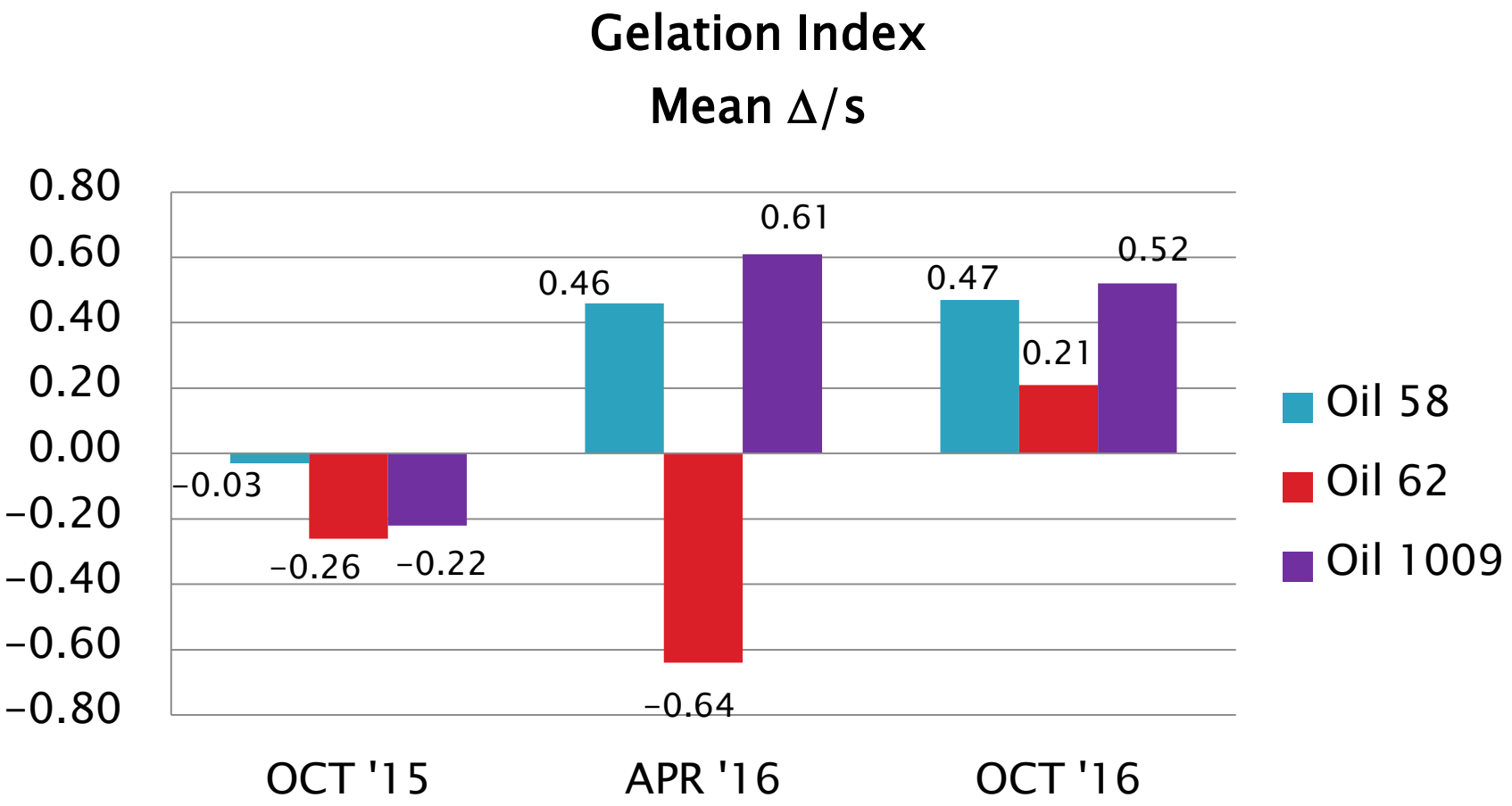
D5133 Performance by Oil



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	17
Failed Calibration Test	OC	4
Operationally Invalidated by Lab	LC, XC	2
Operationally Invalidated After Initially Reported as Valid	RC	0
Instrument Shakedown	NN	1
Total		**24**

Number of Labs Reporting Data: 6
Fail Rate of Operationally Valid Tests: 19%

D6335: Deposits by TEOST-33C

Statistically Unacceptable Tests (OC)	No. Of Tests
Total Deposits Mild	4
Total Deposits Severe	0

- Two operationally invalid tests reported this period:
  - Initial rod weight not recorded (XC)
  - Incorrect power setting (LC)

- One shakedown run on instrument G2 after two consecutive statistically failing runs reported

D6335: Deposits by TEOST-33C

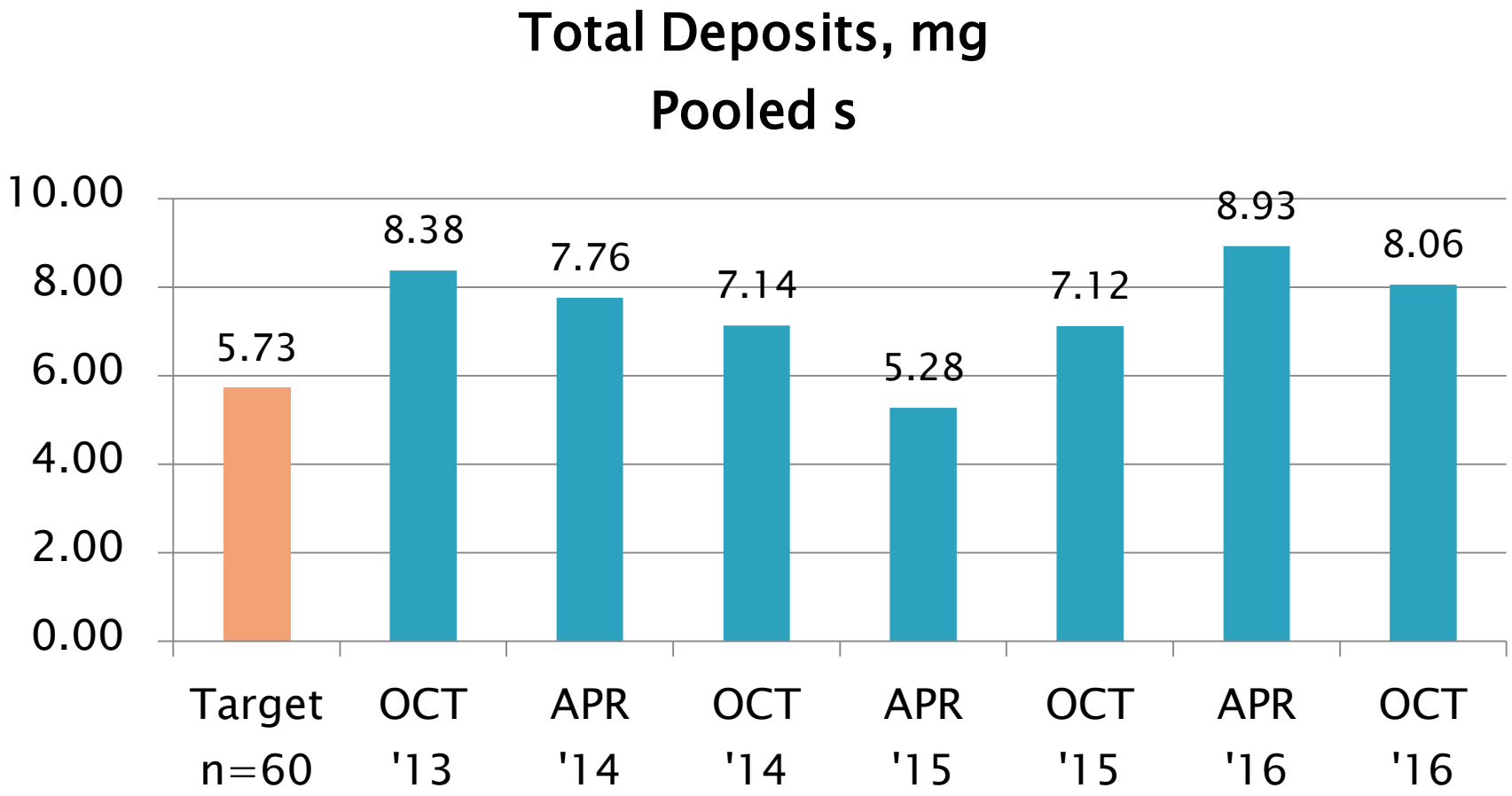
- No TMC technical updates issued this period.
- One TMC technical update was issued shortly after the end of this report period:
  - Memo 16-034, October 18, 2016, New TMC Calibration Requirements Effective November 14, 2016

D6335: Deposits by TEOST-33C

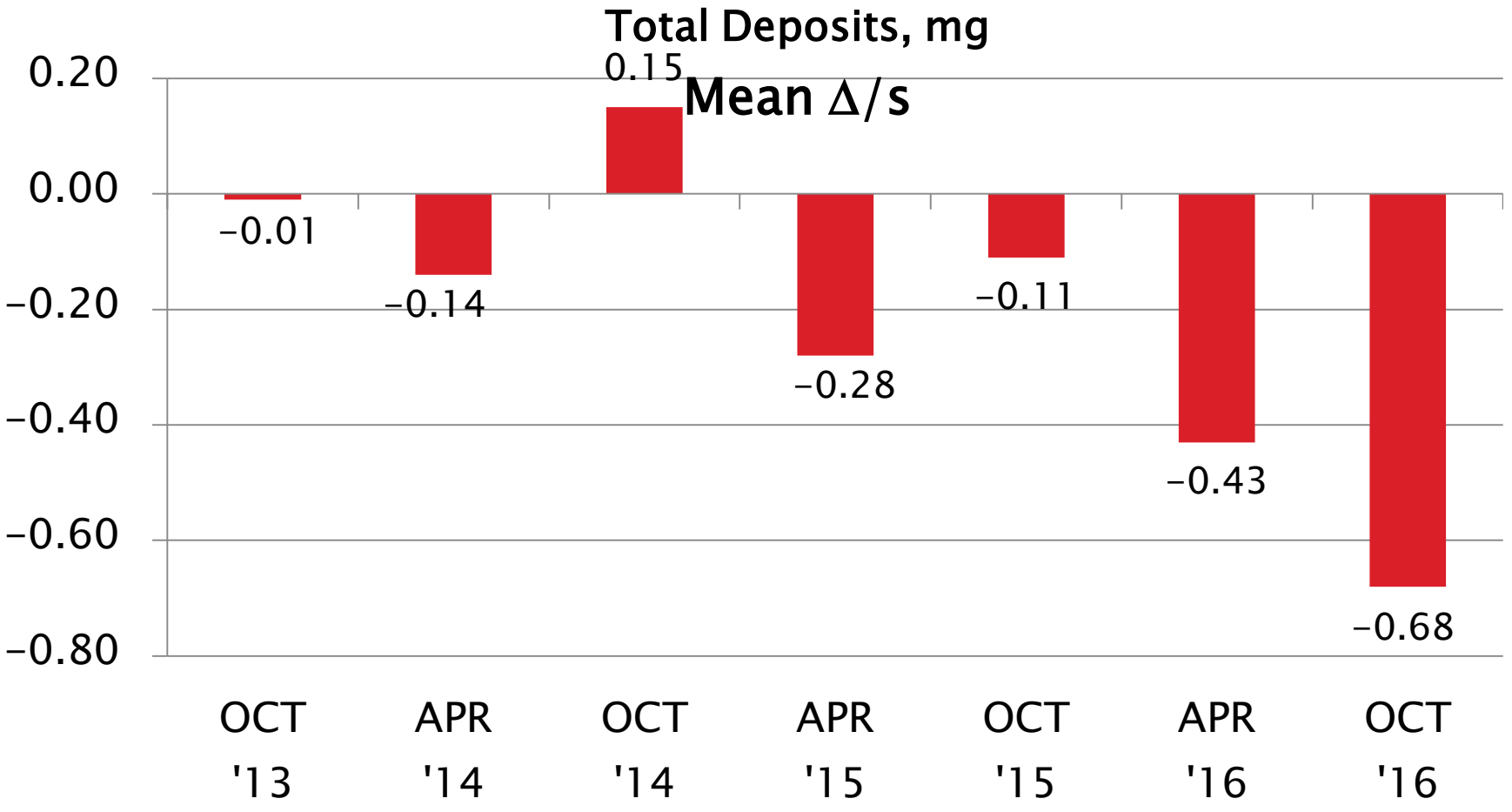
Period Precision and Severity Estimates

Total Deposits, mg	n	df	Pooled s	Mean Δ/s
Updated Targets 20130415	60	58	5.73	-----
4/1/13 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
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

D6335 Precision Estimates



D6335 Severity Estimates

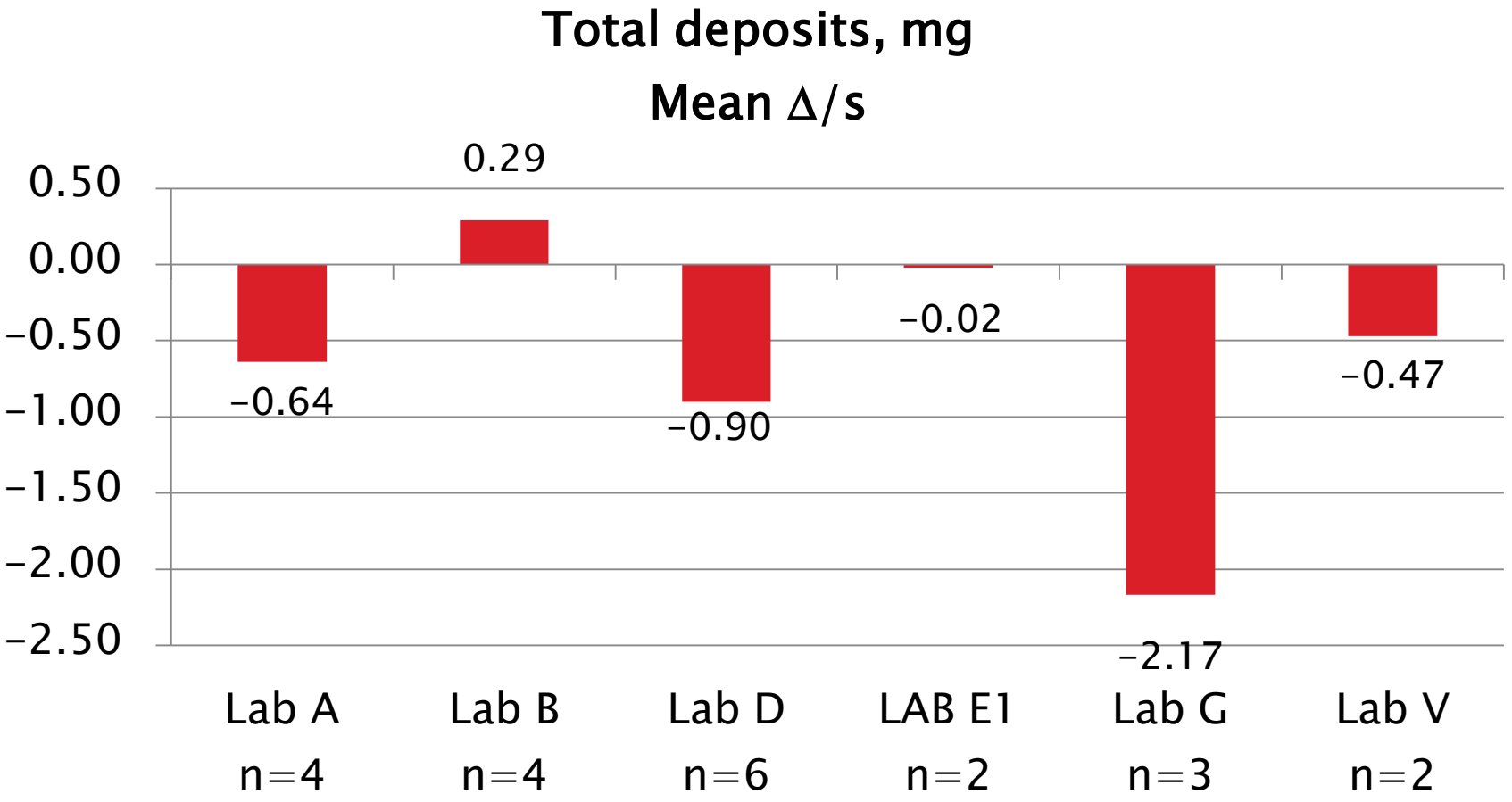


D6335: Deposits by TEOST-33C

Current Period Severity Estimates by Lab
Total Deposits, mg

	n	Mean Δ/s
Lab A	4	-0.64
Lab B	4	0.29
Lab D	6	-0.90
Lab E1	2	-0.02
Lab G	3	-2.17
Lab V	2	-0.47

D6335 Lab Severity Estimates



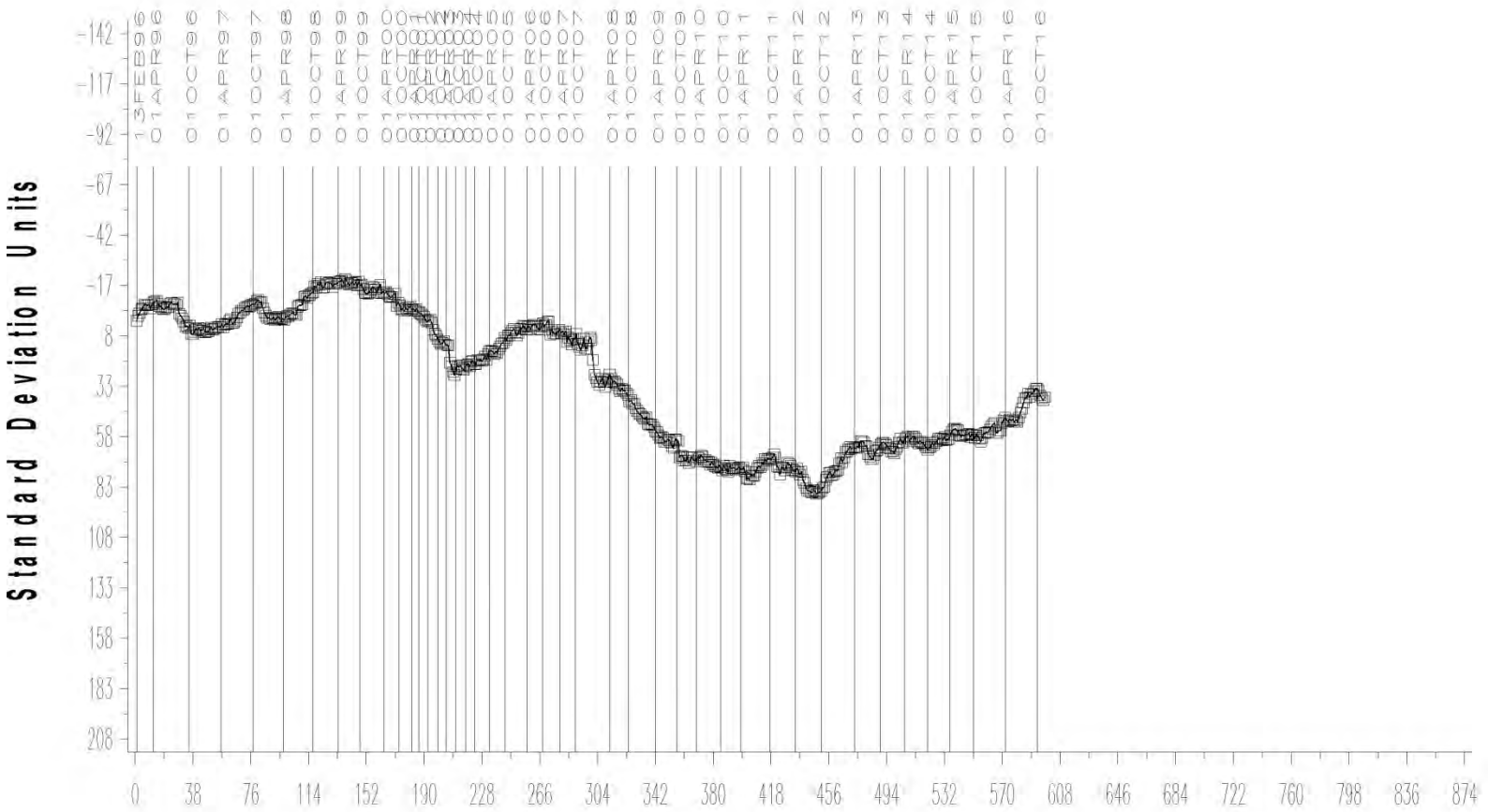
D6335: Deposits by TEOST-33C

- Precision (Pooled s) is more precise than prior period
  - Less precise than target precision
- Performance (Mean Δ/s) is -0.68 s mild
  - Most mild period since at least October 2013
  - Instrument G2 reported results contributing to the overall poor precision last period and continues to bias both precision and severity this period with three very mild tests.
- All tests this period report using Rod Batch M

TEOST—33C INDUSTRY OPERATIONALLY VALID DATA

TOTAL DEPOSITS MG

CUSUM Severity Analysis



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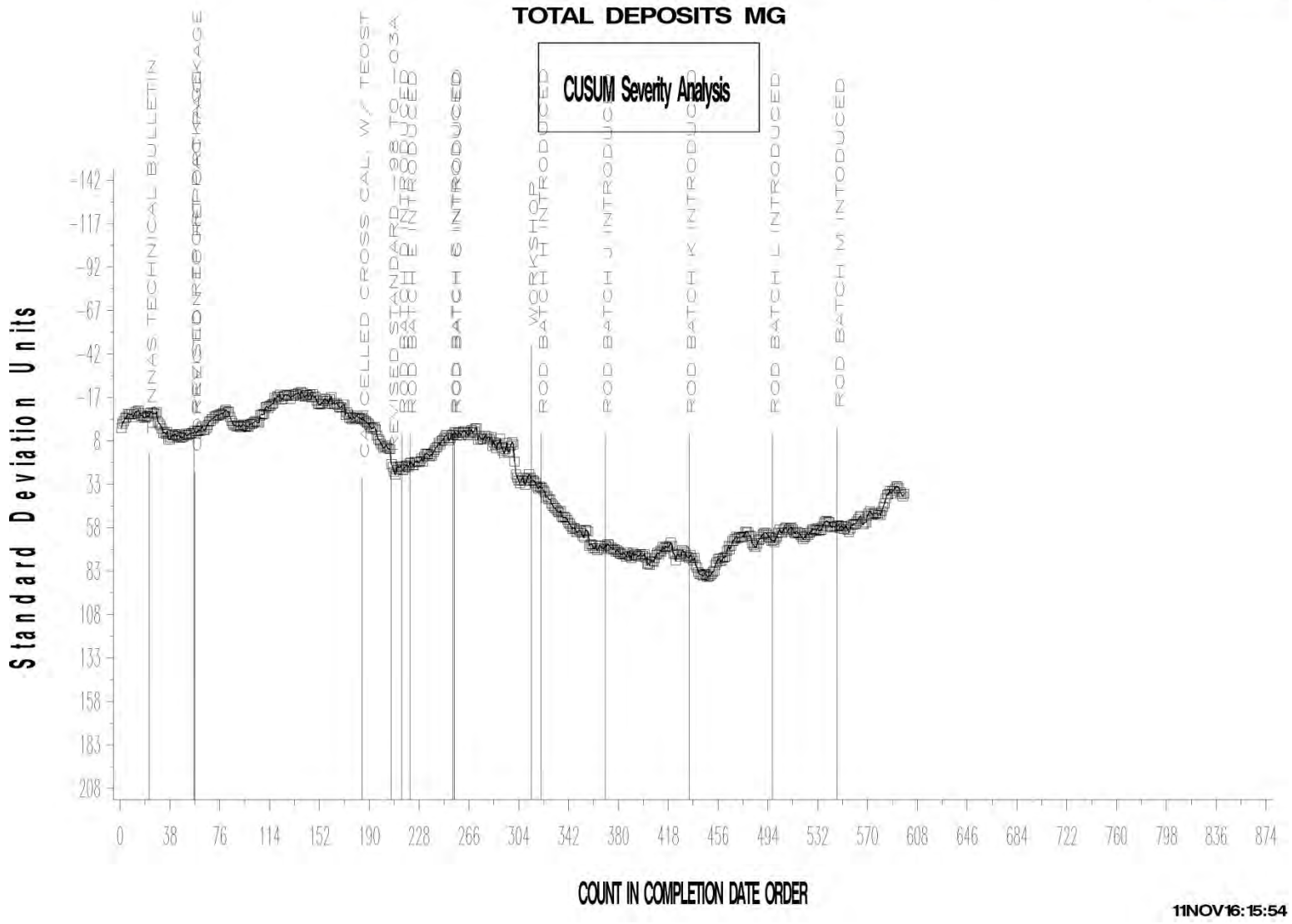
TEOST–33C INDUSTRY OPERATIONALLY VALID DATA



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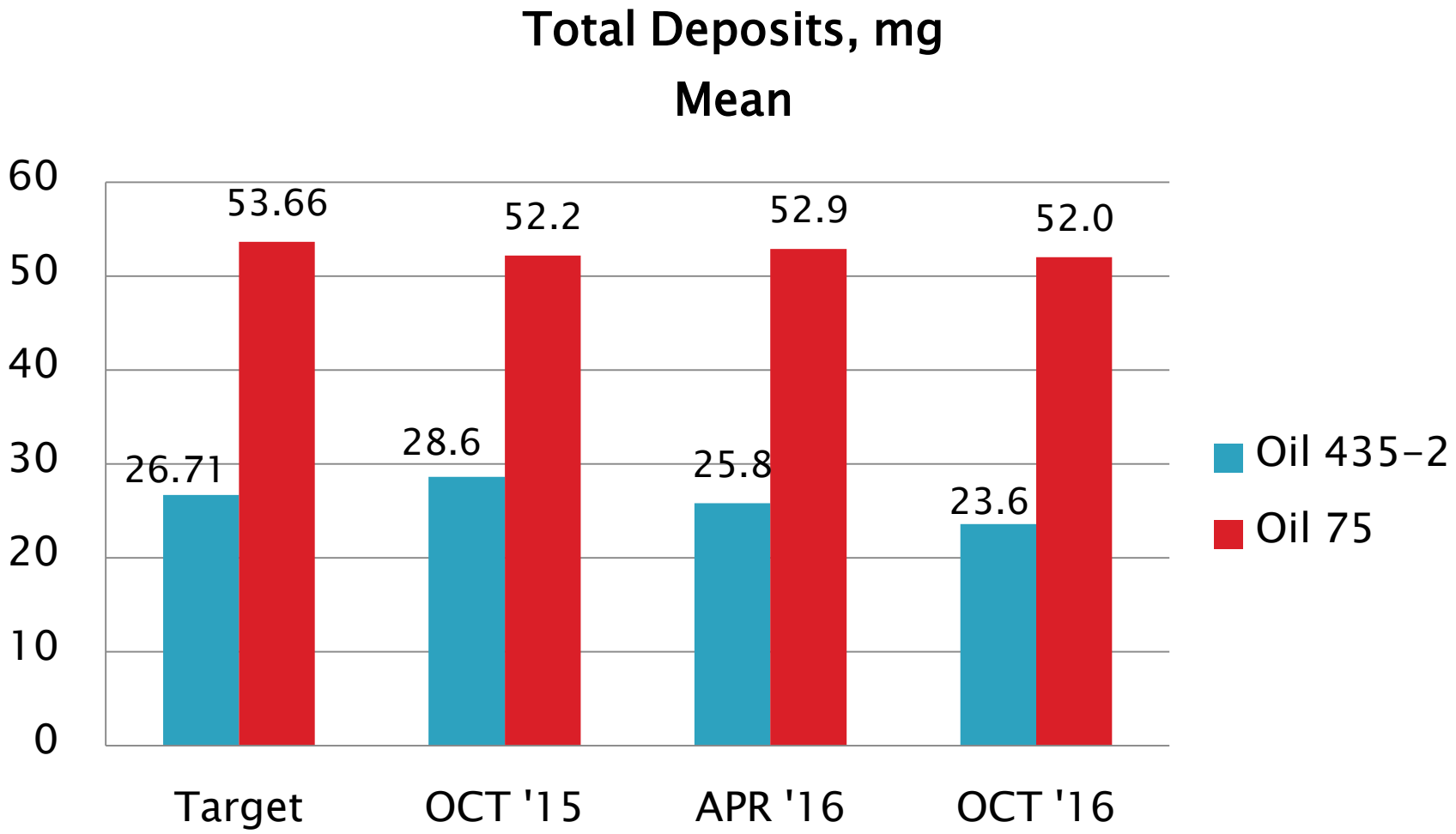
D6335 Performance by Oil

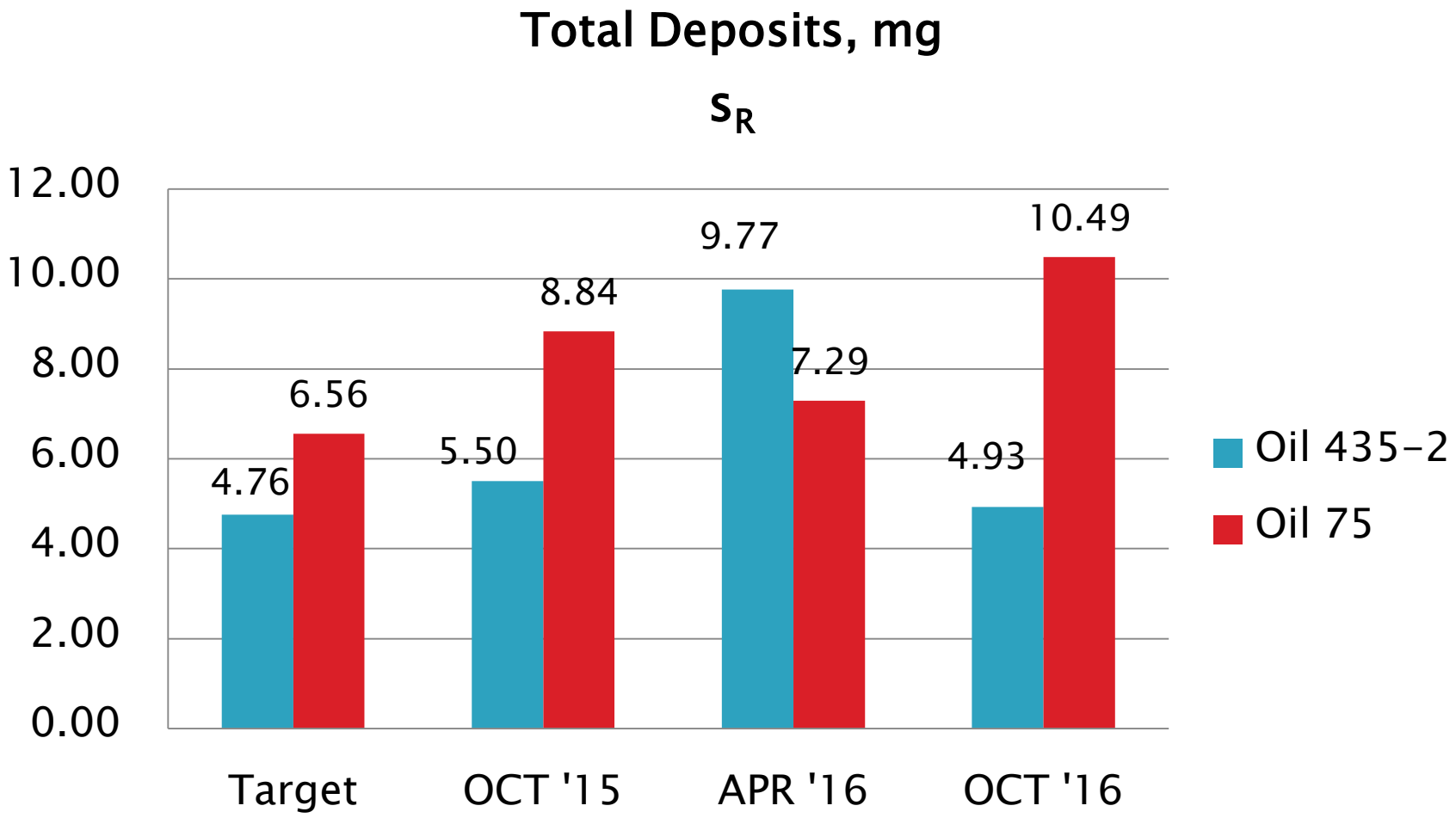
Total Deposits, mg
Performance by Oil

	Targets 20130415			4/1/15 – 9/30/15				10/1/15 – 3/31/16				4/1/16– 9/30/16			
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	9	28.6	5.50	-0.01	13	25.8	9.8	-0.62	11	23.6	4.93	-1.07
75	30	53.66	6.56	7	52.2	8.84	-0.22	8	52.9	7.3	-0.11	10	52.0	10.49	-0.25

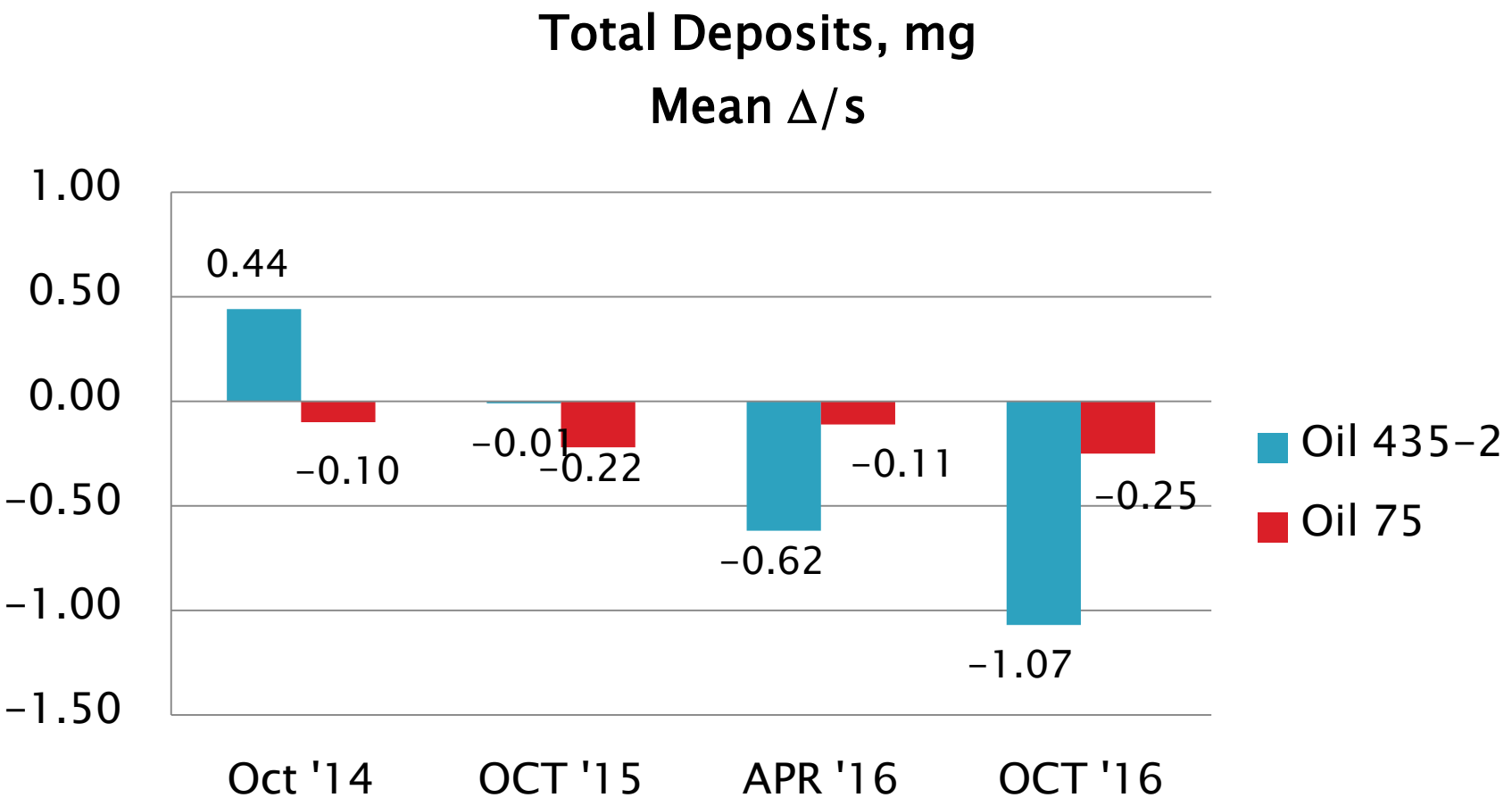
D6335 Performance by Oil



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	86
Failed Calibration Test	OC	10
Operationally Invalidated by Lab	LC, XC	8
Operationally Invalidated After Initially Reported as Valid	RC	1
Excluded from Statistics (New Rig)	MC	1
Total		**106**

Number of Labs Reporting Data: 12
Fail Rate of Operationally Valid Tests: 10%

D7097: Deposits by MHT TEOST

Statistically Unacceptable Tests (OC)	No. Of Tests
Total Deposits Mild	2
Total Deposits Severe	8

- Nine operationally invalid calibration tests this period:
  - Total Sample Weight off-spec, one test (RC)
  - Broken flowmeter, one test (LC)
  - Rod weight not recorded before test start, one test (LC)
  - Sample completely volatized before EOT, one test (XC)
    - Unexplained phenomena
  - Operating temperature off-spec, three tests (LC, XC)
  - Heater failure during run, one test (XC)
  - Misaligned airflow restrictor, one test (LC)
- One test excluded from statistics (MC), new rig, reported as operationally valid but failed to calibrate.

D7097: Deposits by MHT TEOST

- One TMC technical update issued this period:
  - Memo 16-031, September 20, 2016, Updated Test method D7097-16A
  - This update requires the use of new flask air seals.
  - One test reported/completed at end of this period using the new flask seal
  - Two runs given shortened, conditional calibration periods to allow them time to obtain the new flask seals

- One TMC technical update was issued shortly after the end of this report period:
  - Memo 16-033, October 18, 2016, New TMC Calibration Requirements Effective November 14, 2016

D7097: Deposits by MHT TEOST

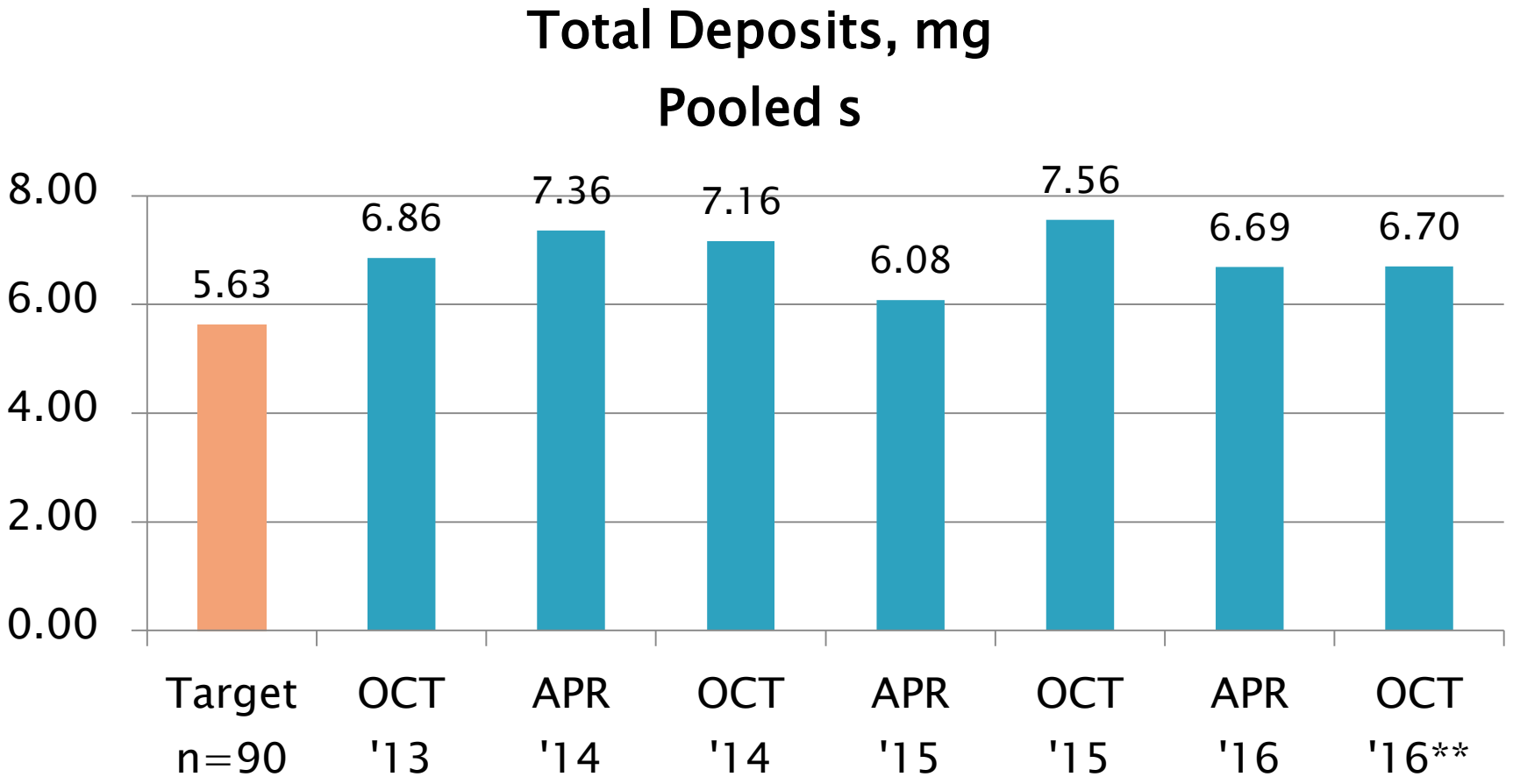
Period Precision and Severity Estimates

Total Deposits, mg	n	df	Pooled s	Mean Δ/s
Current Targets 7/31/2006	90	87	5.63	-----
10/1/13 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*	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

*Four severe OC tests from instrument G1 included and excluded

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

D7097 Precision Estimates



**Three severe OC tests from instrument P1 excluded

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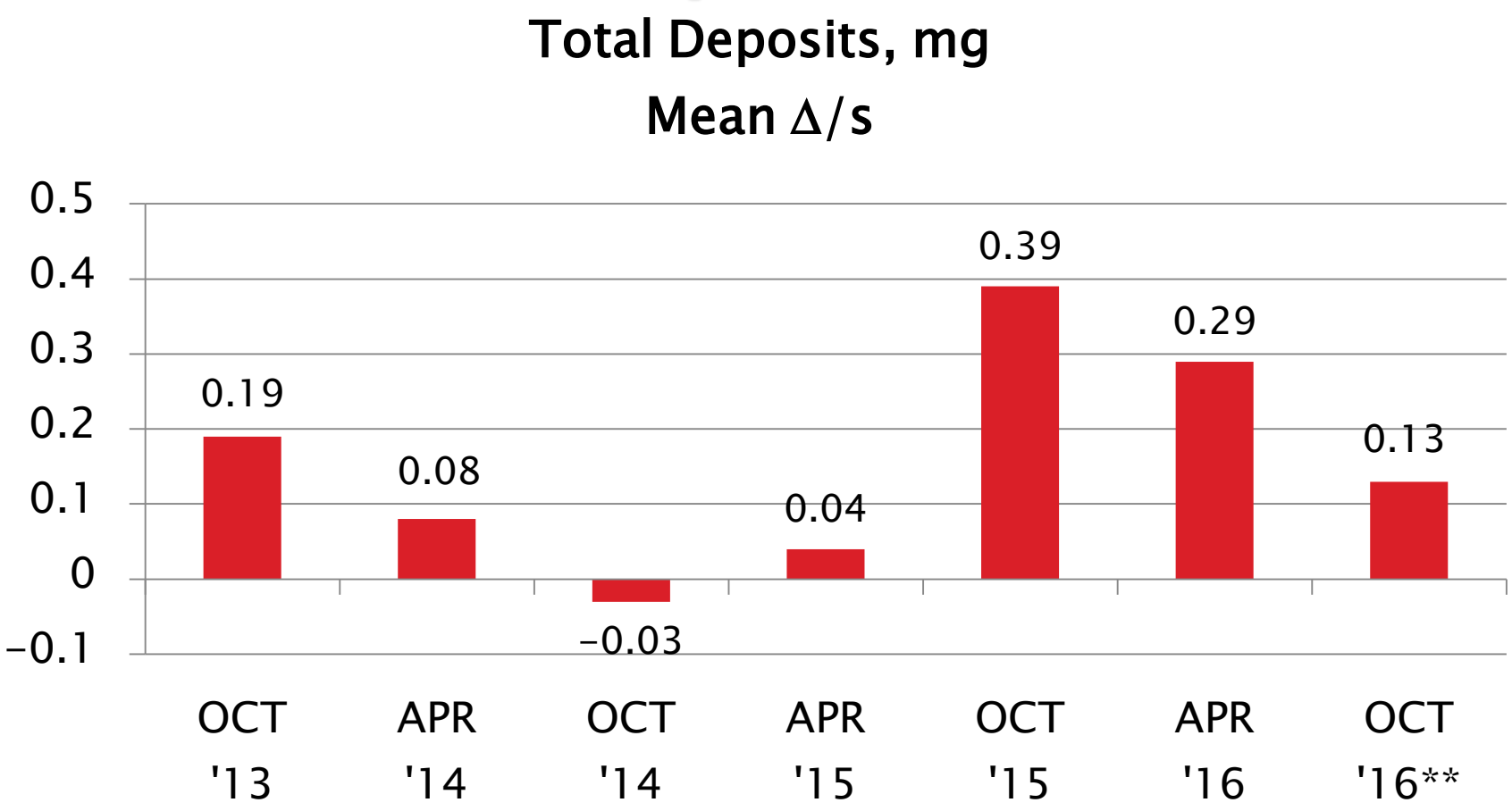
D7097 Severity Estimates



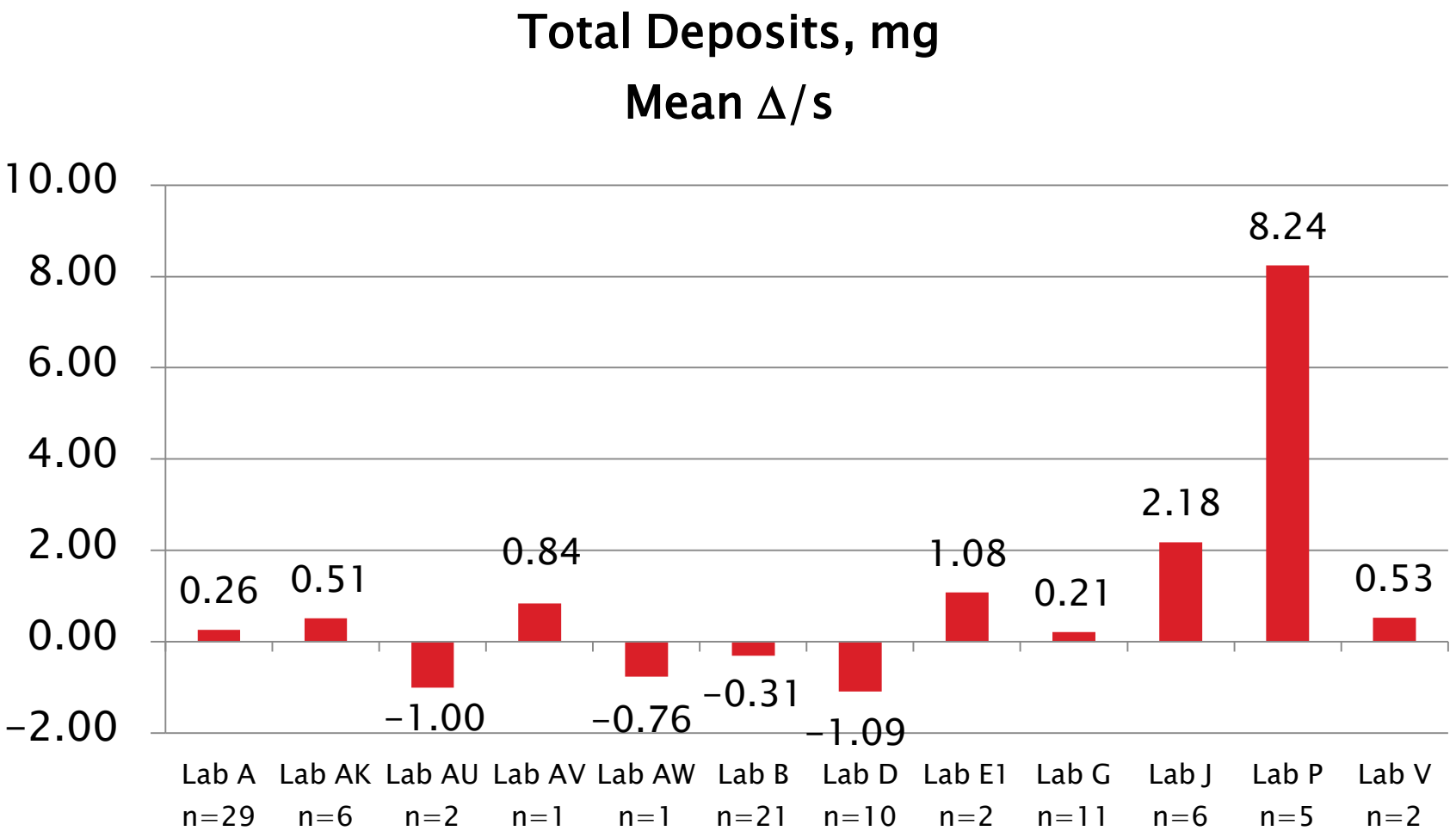
**Three severe OC tests from instrument P1 excluded

D7097: Deposits by MHT TEOST

Current Period Severity Estimates by Lab
Total Deposits, mg

Lab	n	Mean Δ/s	Lab	n	Mean Δ/s
Lab A	29	0.26	Lab D	10	-1.09
Lab AK	6	0.51	LAB E1	2	1.08
Lab AU	2	-1.00	Lab G	11	0.21
Lab AV	1	0.84	Lab J	6	2.18
Lab AW	1	-0.76	Lab P	5	8.24
Lab B	21	-0.31	Lab V	2	0.53

D7097 Lab Severity Estimates



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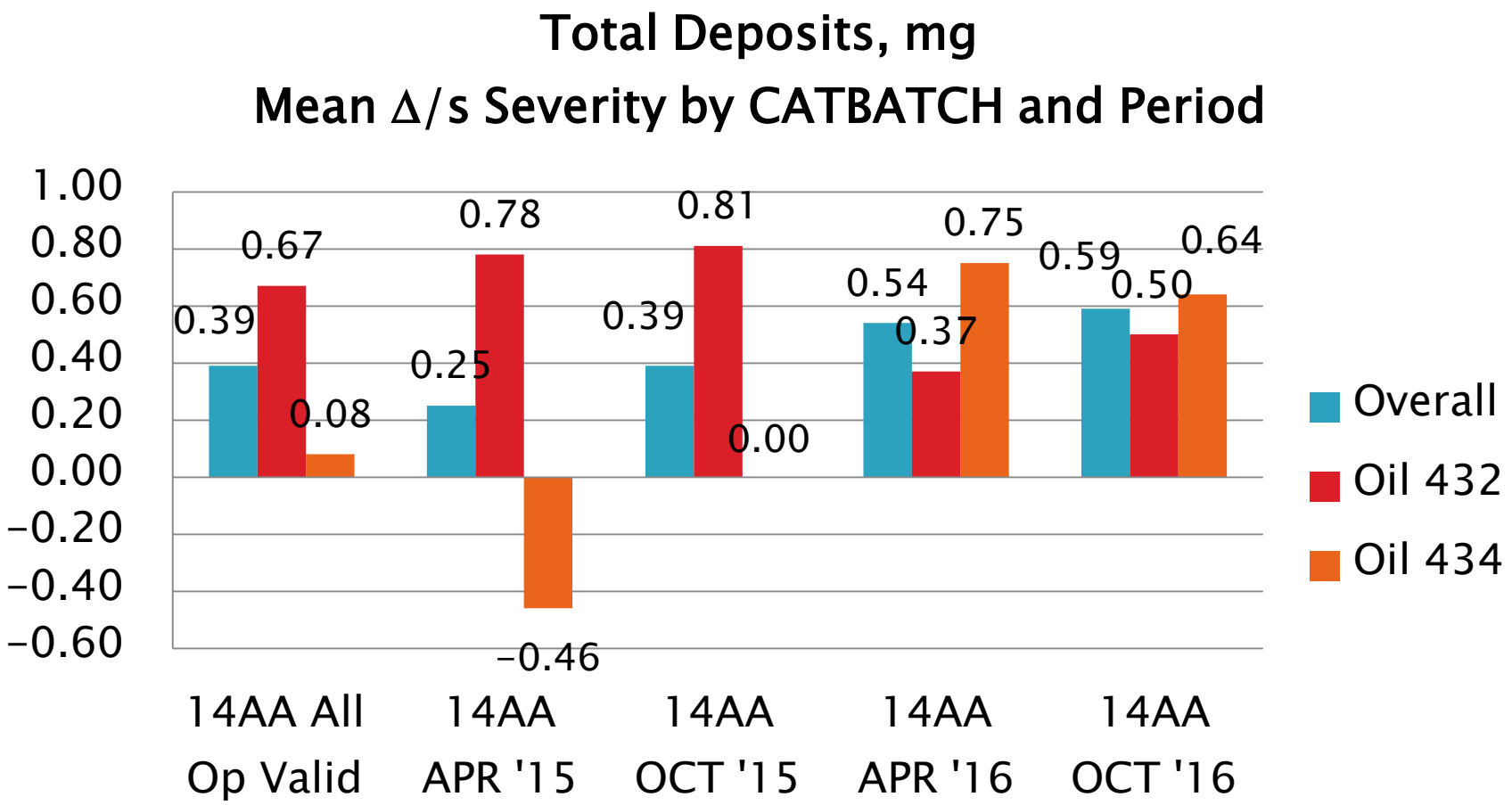
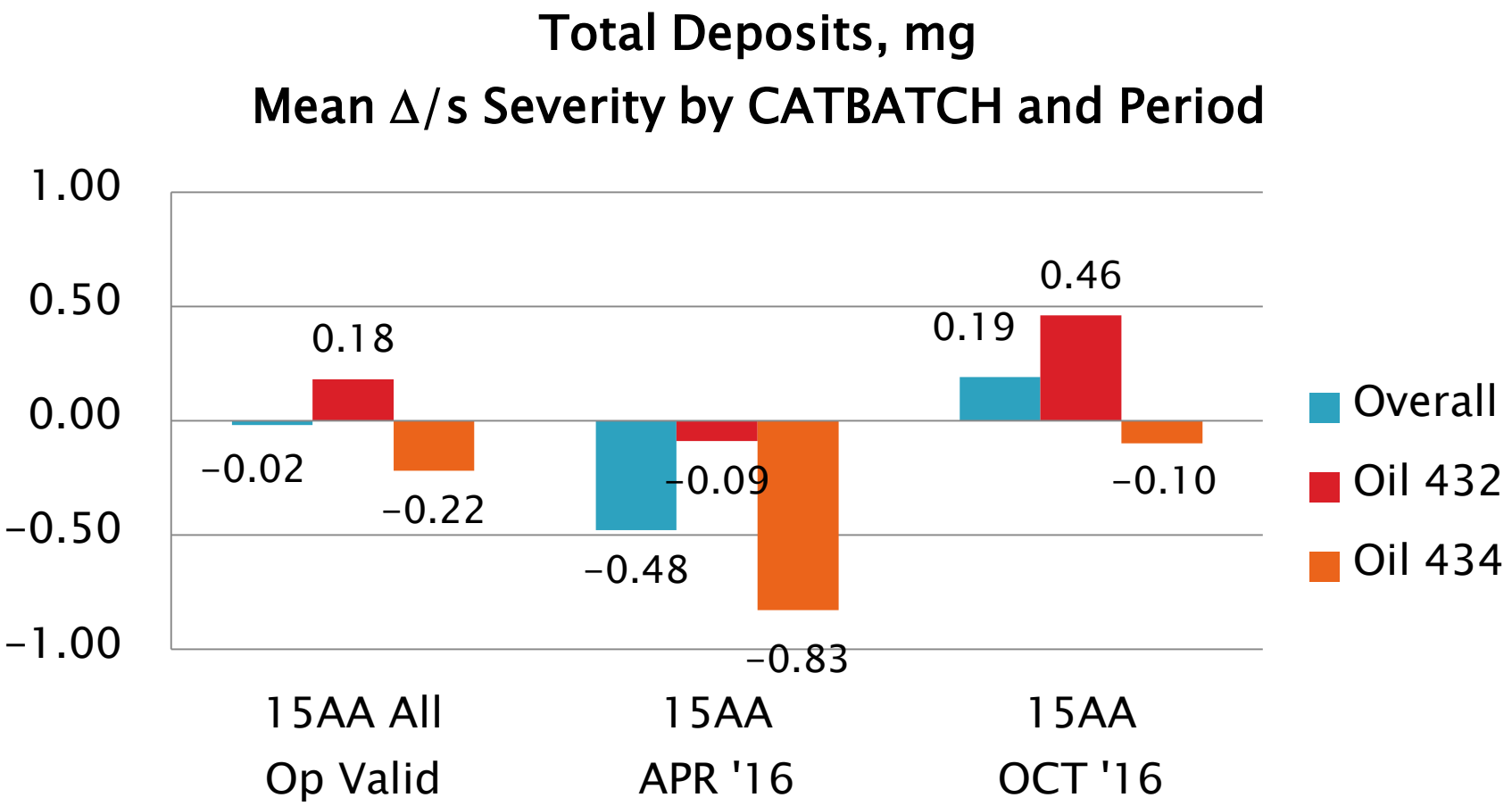
D7097: Deposits by MHT TEOST



D7097: Deposits by MHT TEOST



D7097: Deposits by MHT TEOST

- Instrument P1 reported three consecutive severe fails (3s, 4s & 31s) as operationally valid, all are excluded from the period statistics. Lab successfully calibrated the instrument on 4th try but had no explanation for the failing runs.
- Precision (Pooled s) is comparable to prior period
  - Remains less precise than target precision
- Performance (Mean Δ/s) is 0.13 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 1307 (n=1), 14AA (n=10) or 15AA (n=94)

D7097: Deposits by MHT TEOST

- CUSUM severity plot shows some leveling this period (except for a single very severe result)
  - However, lab performance differences persist
- Precision on oil 432 has improved compared to the last two periods, while precision on oil 434 has worsened.
- 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

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TOTAL DEPOSITS MG

CUSUM Severity Analysis

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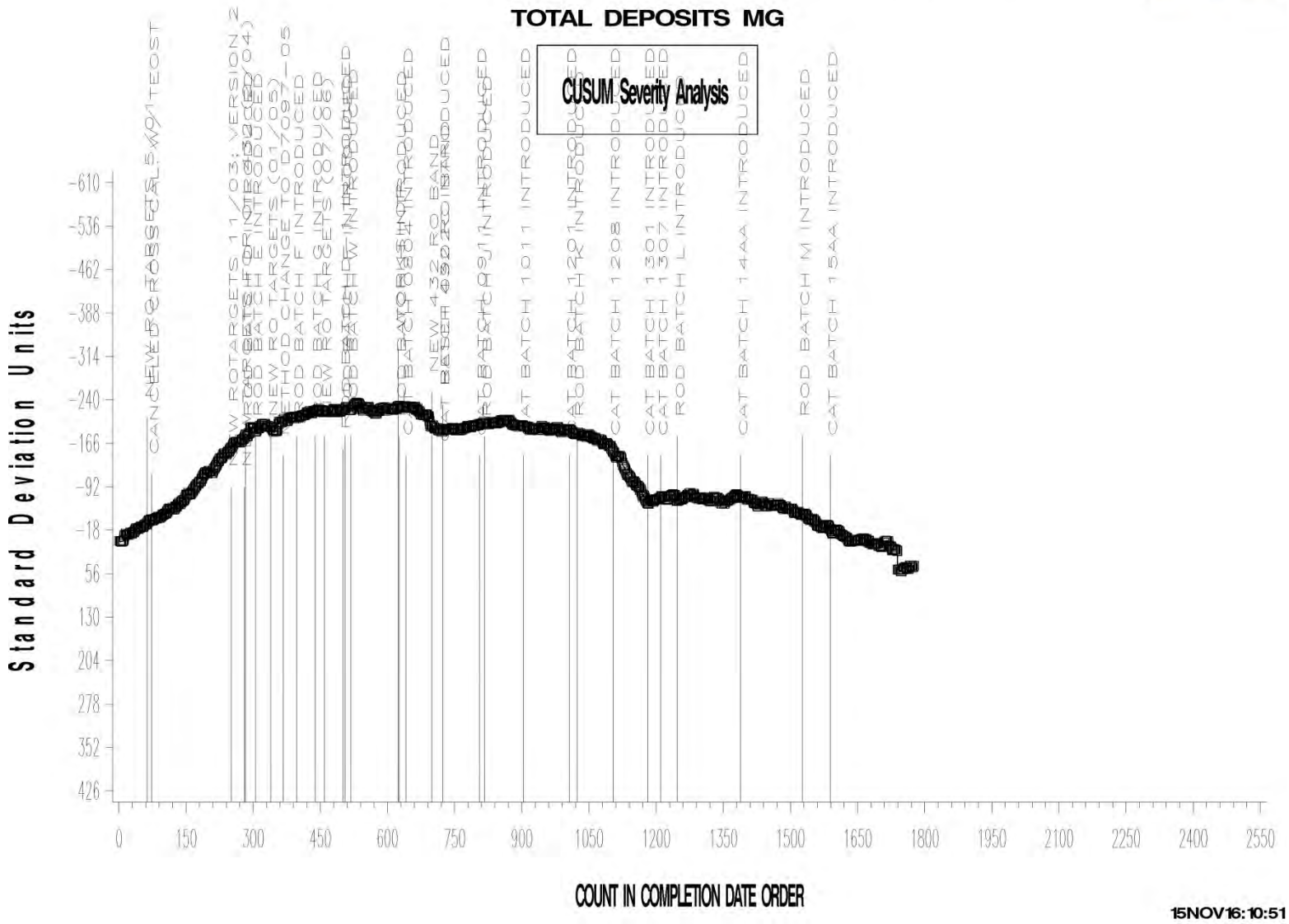
MHT—4 TEOST INDUSTRY OPERATIONALLY VALID DATA

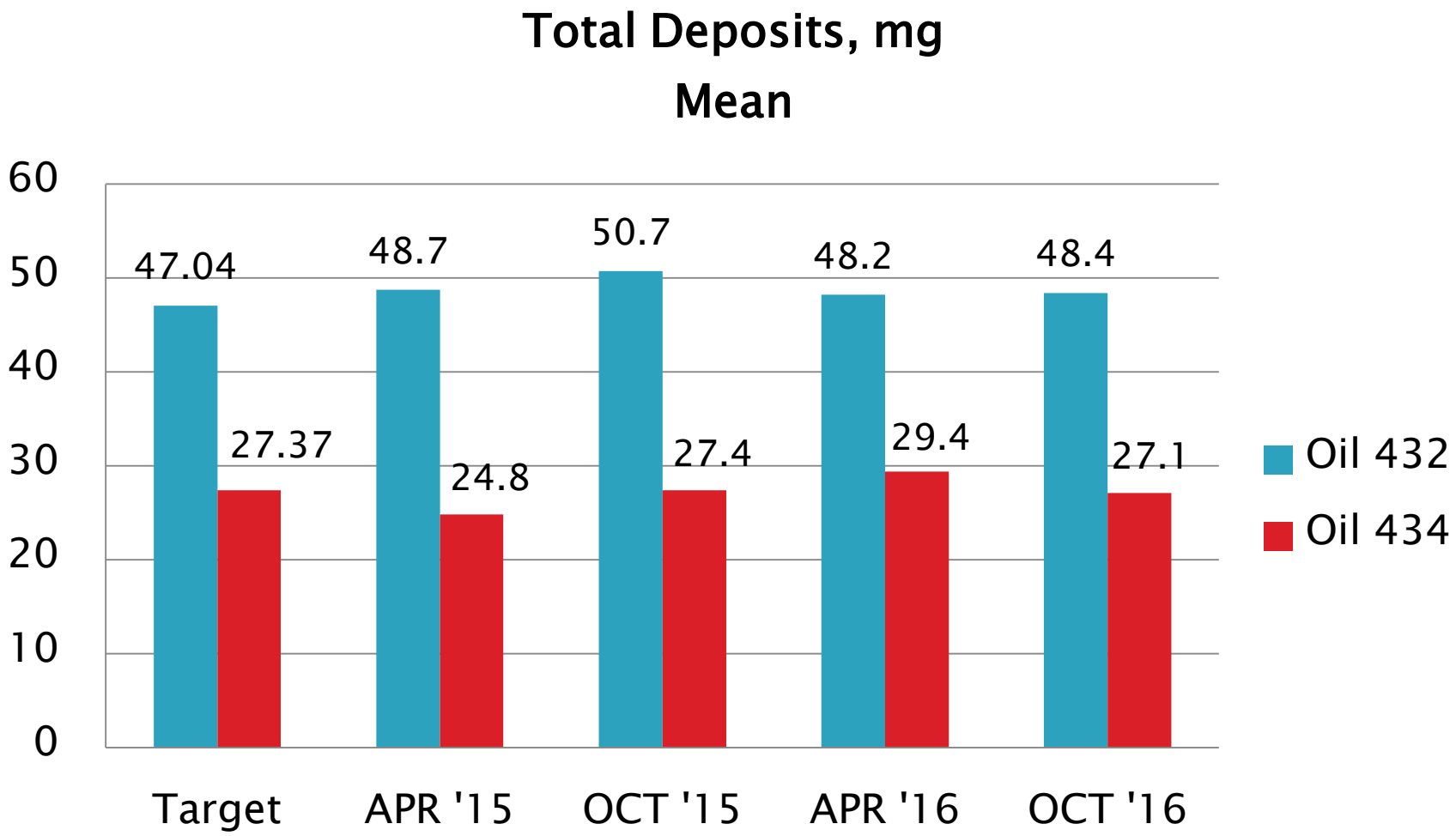


D7097 Performance by Oil

Total Deposits, mg
Performance by Oil

	Targets			4/1/15 – 9/30/15				10/1/15 – 3/31/16				4/1/16– 9/30/16			
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	40	50.7	5.60	0.81	44	48.2	4.84	0.27	45	48.4	6.84	0.31
434	30	27.37	6.57	44	27.4	8.98	0.00	40	29.4	8.27	0.31	48	27.1	6.58	-0.04

D7097 Performance by Oil



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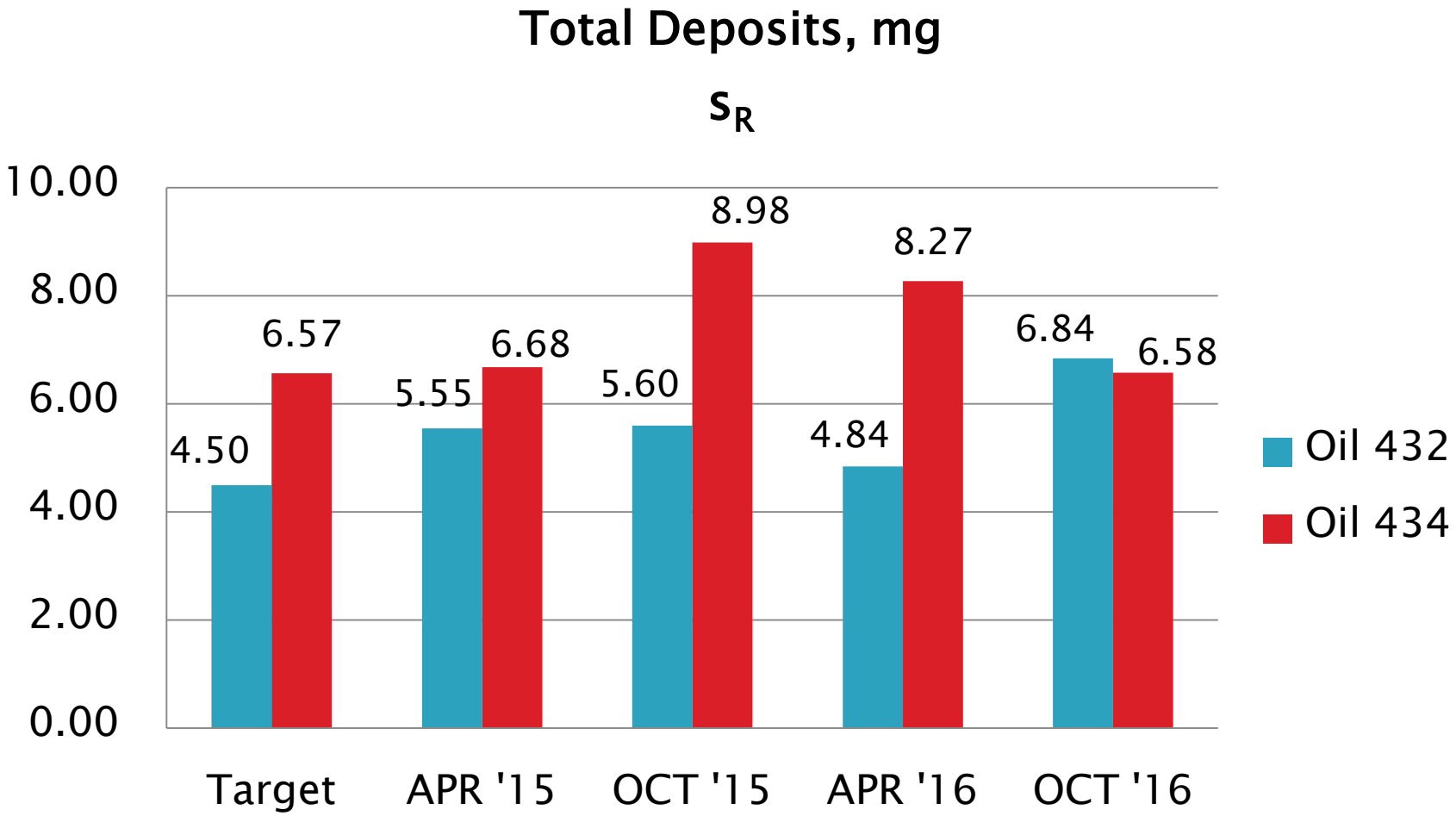
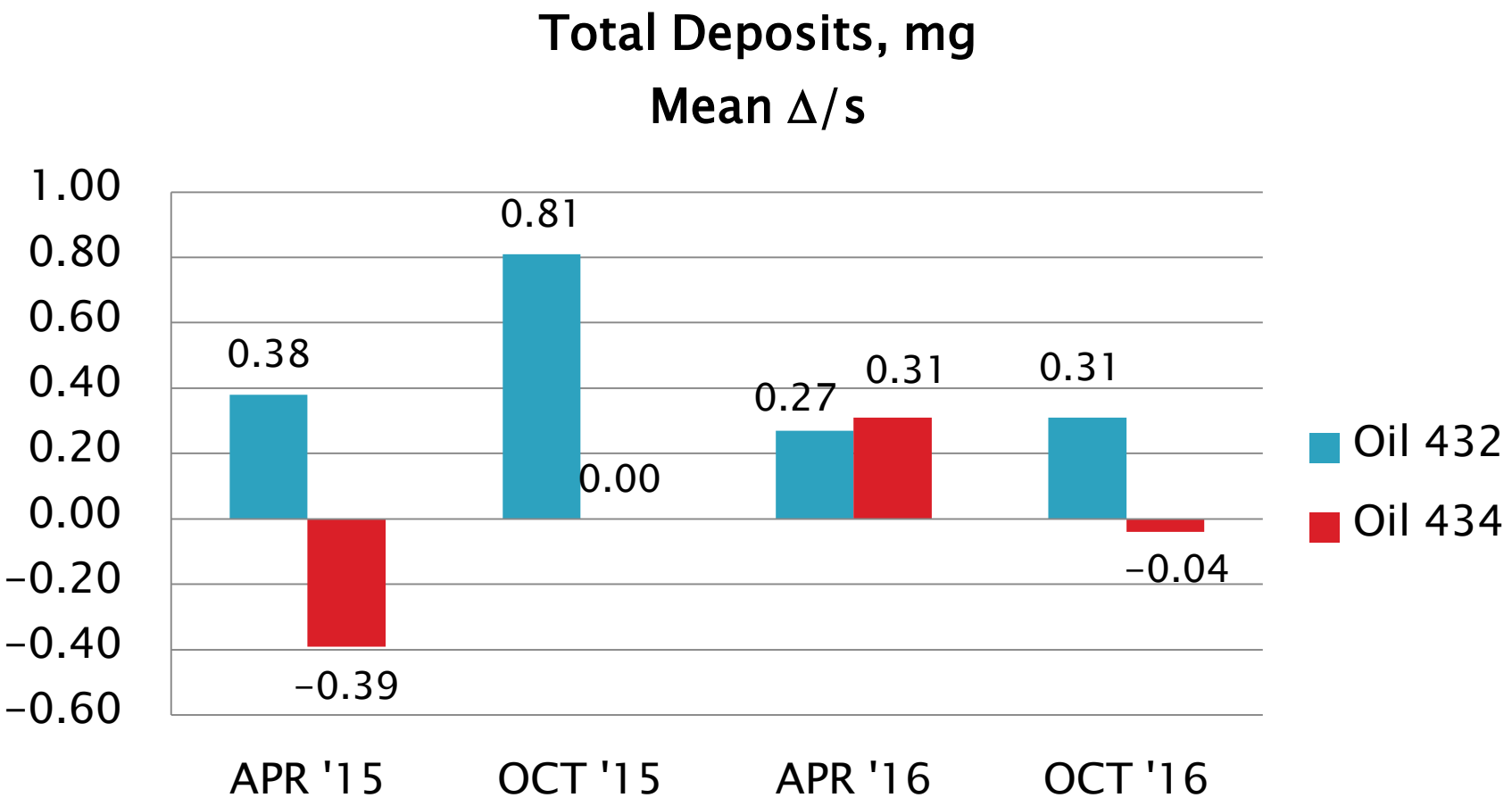
D7097: Deposits by MHT TEOST



D7097: Deposits by MHT TEOST



Return to Executive Summary

D6082: High Temperature Foam

Test Status	Validity Code	No. Tests
Acceptable Calibration Test	AC	12
Acceptable Discrimination Test	AS	5
Failed Calibration Test	OC	0
Operationally Invalidated by Lab	LC, XC	0
Operationally Invalidated After Initially Reported as Valid	RC	0
Total		**17**

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

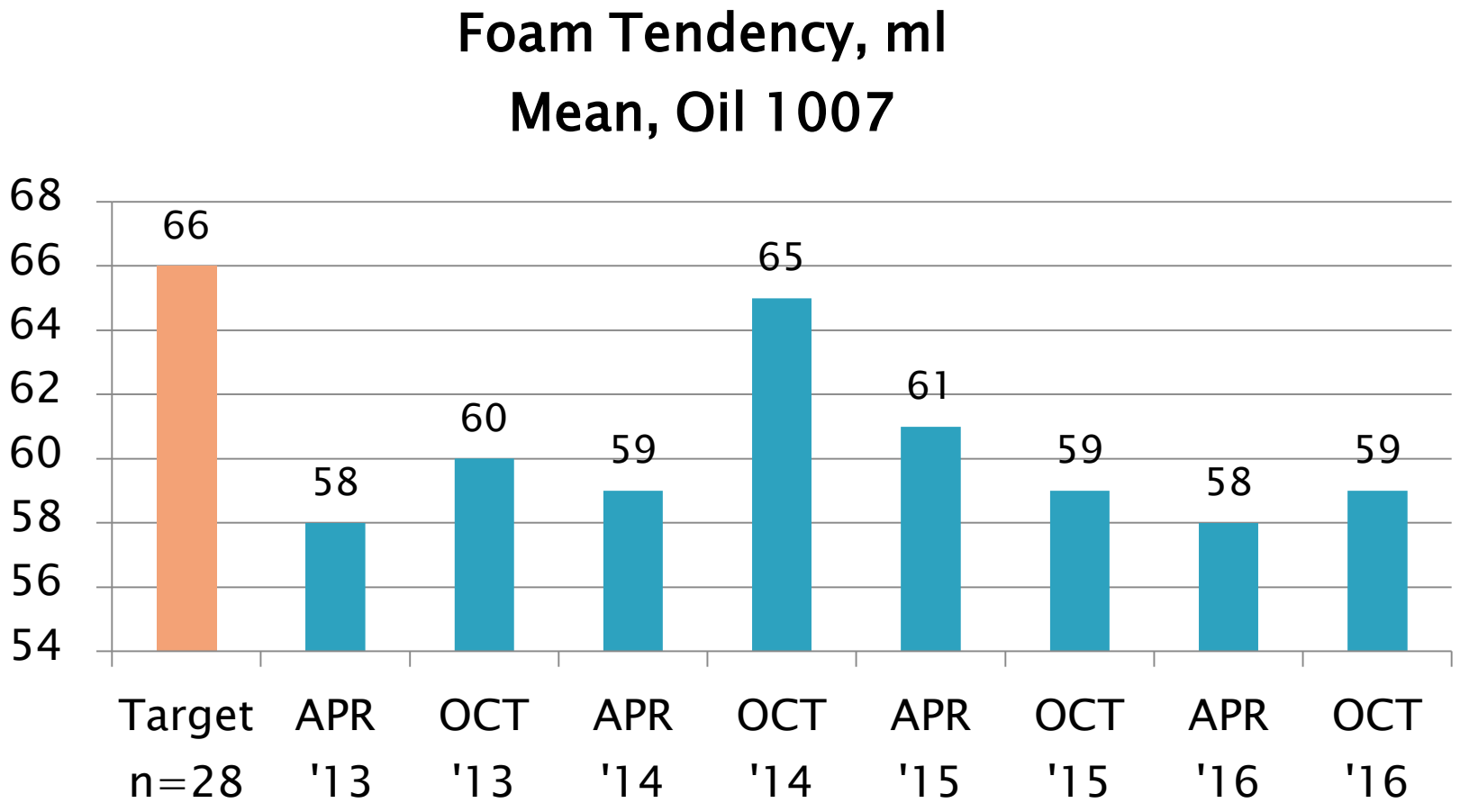
Foam Tendency, ml	n	Mean	Pooled s	Mean Δ/s
Current Targets	28	65.71	19.28	-----
10/1/12 through 3/31/13	8	58	10	-0.45
4/1/13 through 9/30/13	9	60	7	-0.32
10/1/13 through 3/31/14	11	59	8	-0.39
4/1/14 through 9/30/14	11	65	22	-0.05
10/1/14 through 3/31/15	10	61	12	-0.26
4/1/15 through 9/30/15	11	59	16	-0.36
10/1/15 through 3/31/16	8	58	10	-0.45
4/1/16 through 9/30/16	12	59	18	-0.38

D6082: High Temperature Foam

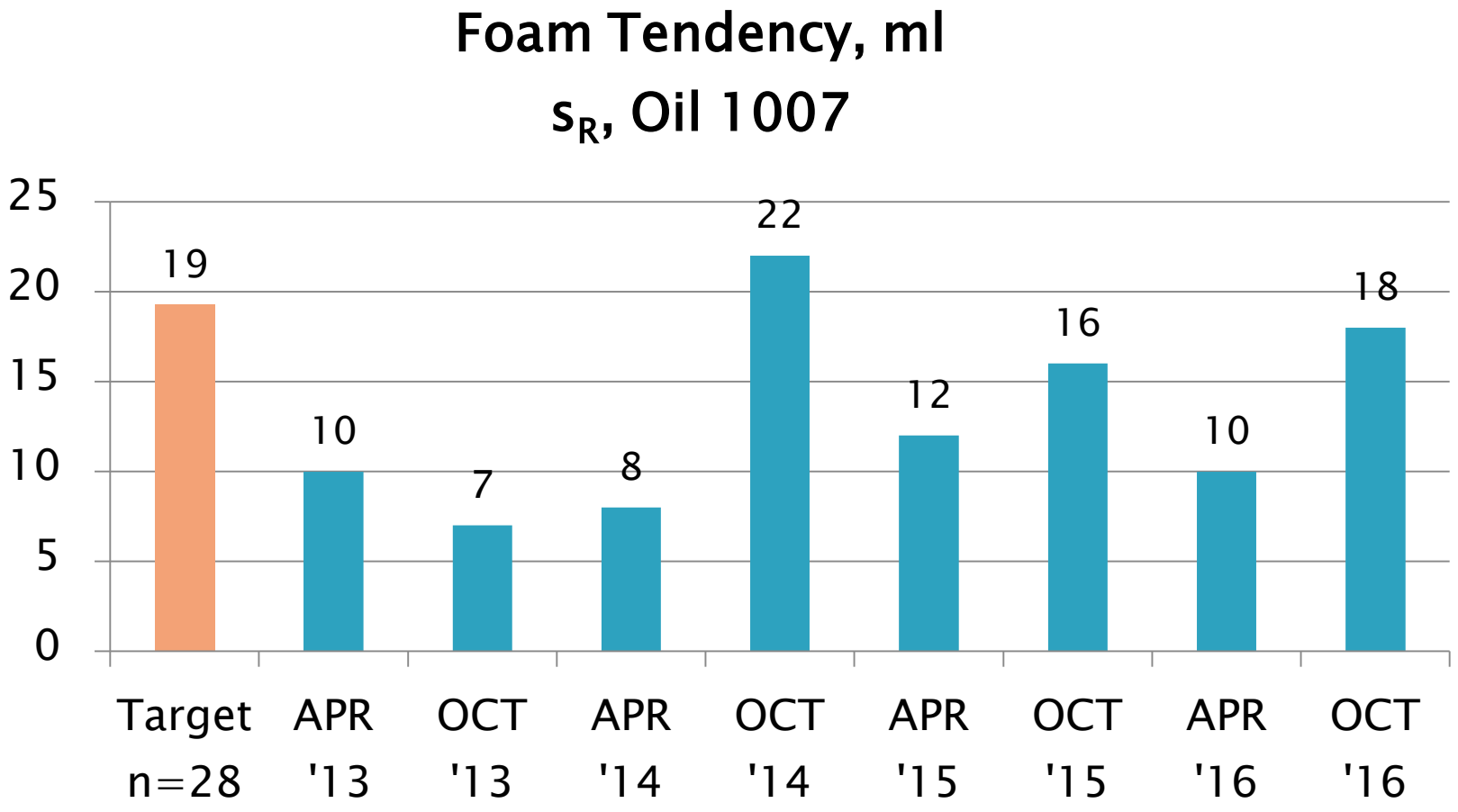
Period Precision and Severity Estimates Oil 1007

Foam Stability @ 1 min, ml	n	Mean	s
Current Targets	28	0.00	0.00
10/1/12 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	
10/1/15 through 3/31/16	8	No non-zero occurrences	
4/1/16 through 9/30/16	5	No non-zero occurrences	

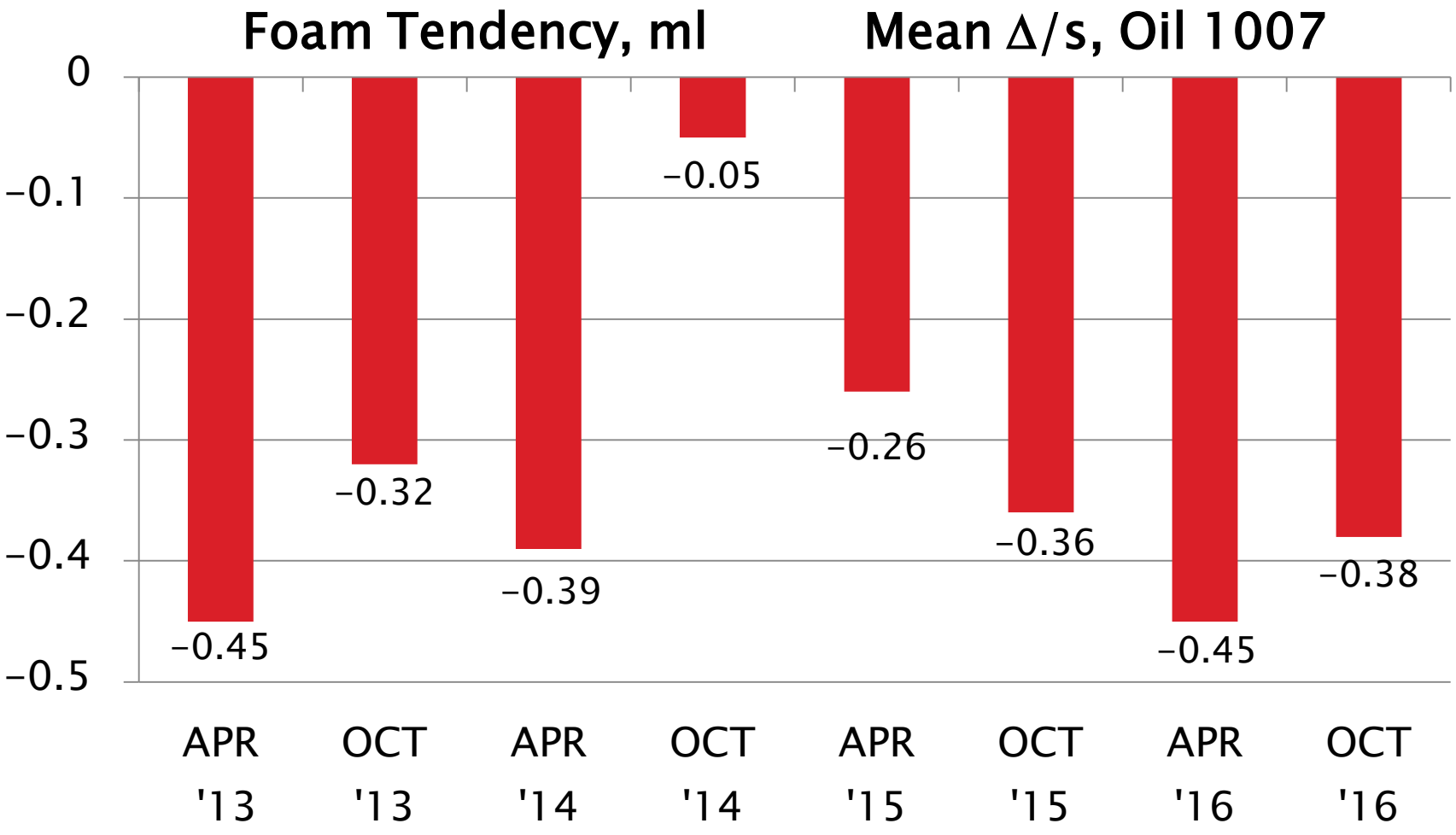
D6082: High Temperature Foam



D6082: High Temperature Foam



D6082: High Temperature Foam

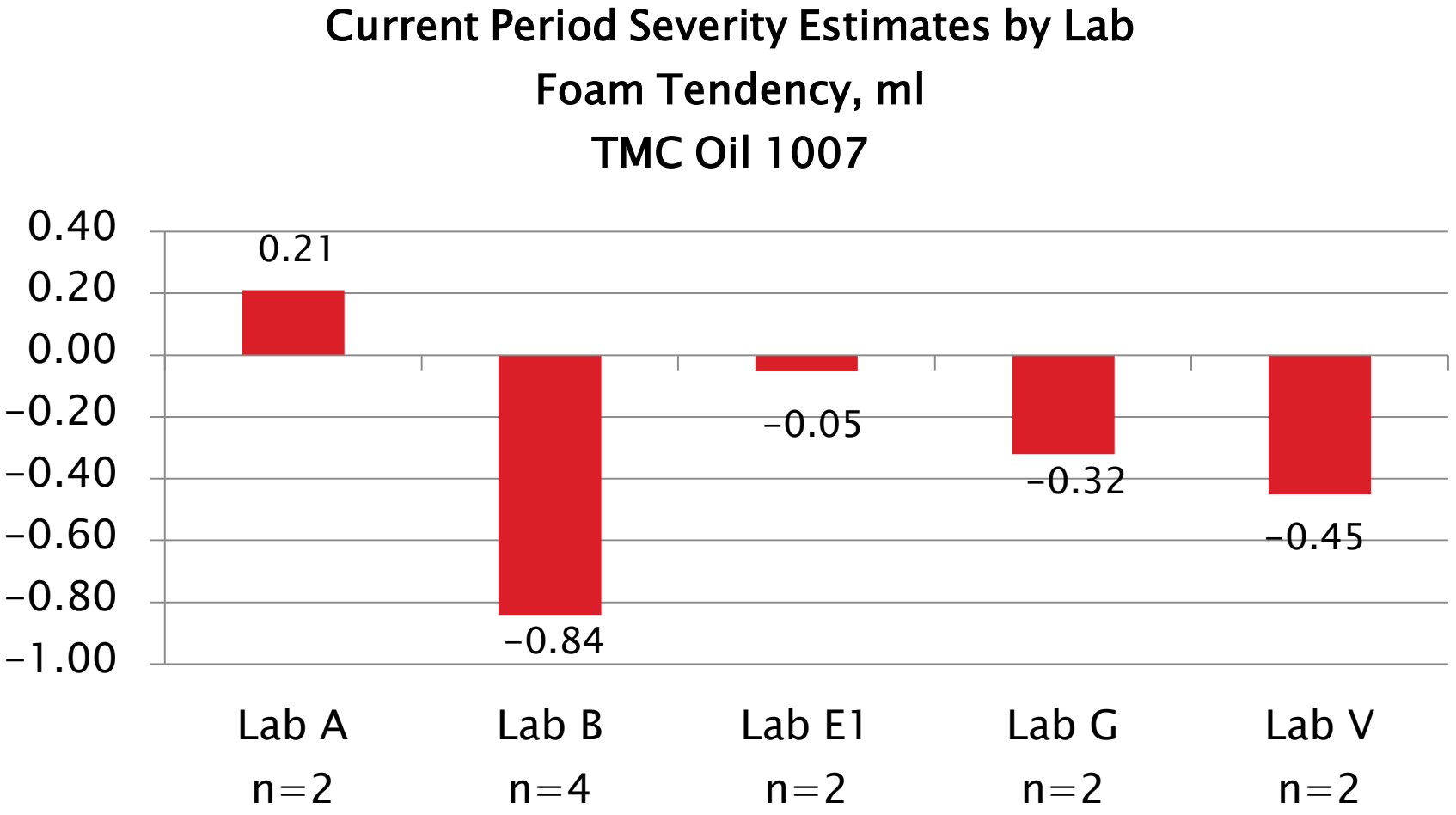


D6082: High Temperature Foam

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

	n	Mean Δ/s
Lab A	2	0.21
Lab B	4	-0.84
Lab E1	2	-0.05
Lab G	2	-0.32
Lab V	2	-0.45

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 -0.38 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

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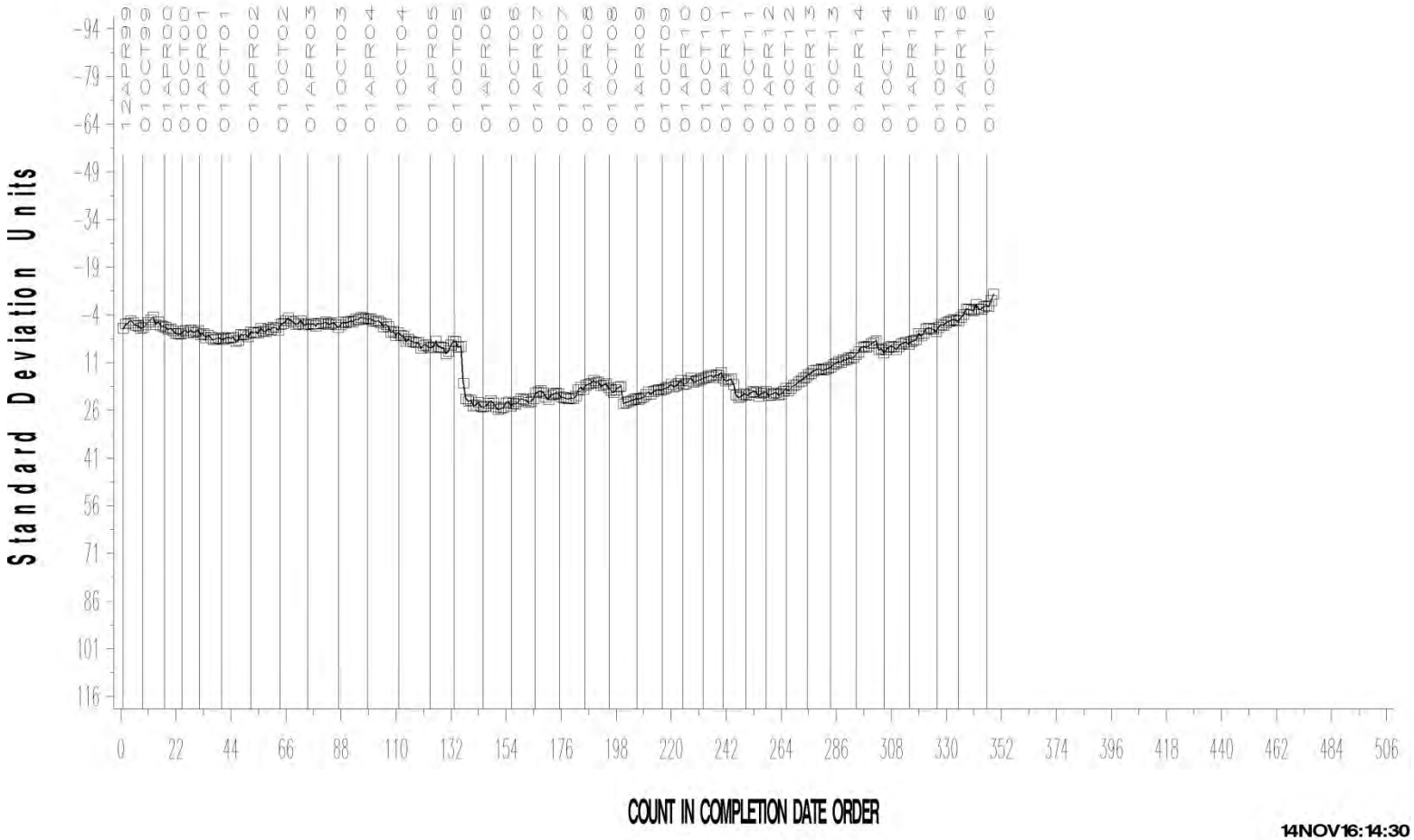
FOAM TENDENCY

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	0
Operationally Invalidated by Lab	LC, XC	0
Operationally Invalidated After Initially Reported as Valid	RC	0
Total		**6**

Number of Labs Reporting Data: 3
Fail Rate of Operationally Valid Tests: 0%

D874: Sulfated Ash

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

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

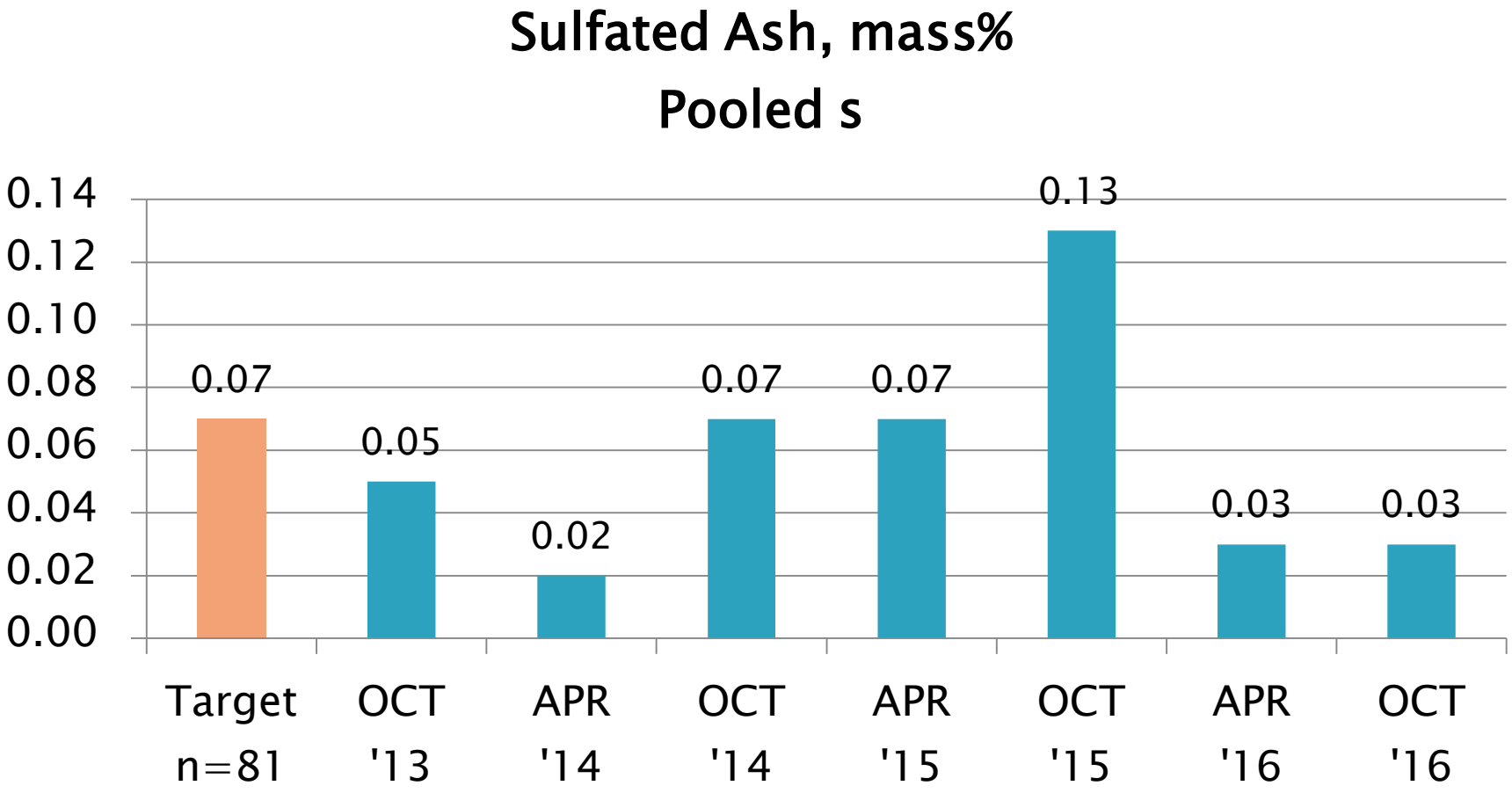
D874: Sulfated Ash

Period Precision and Severity Estimates

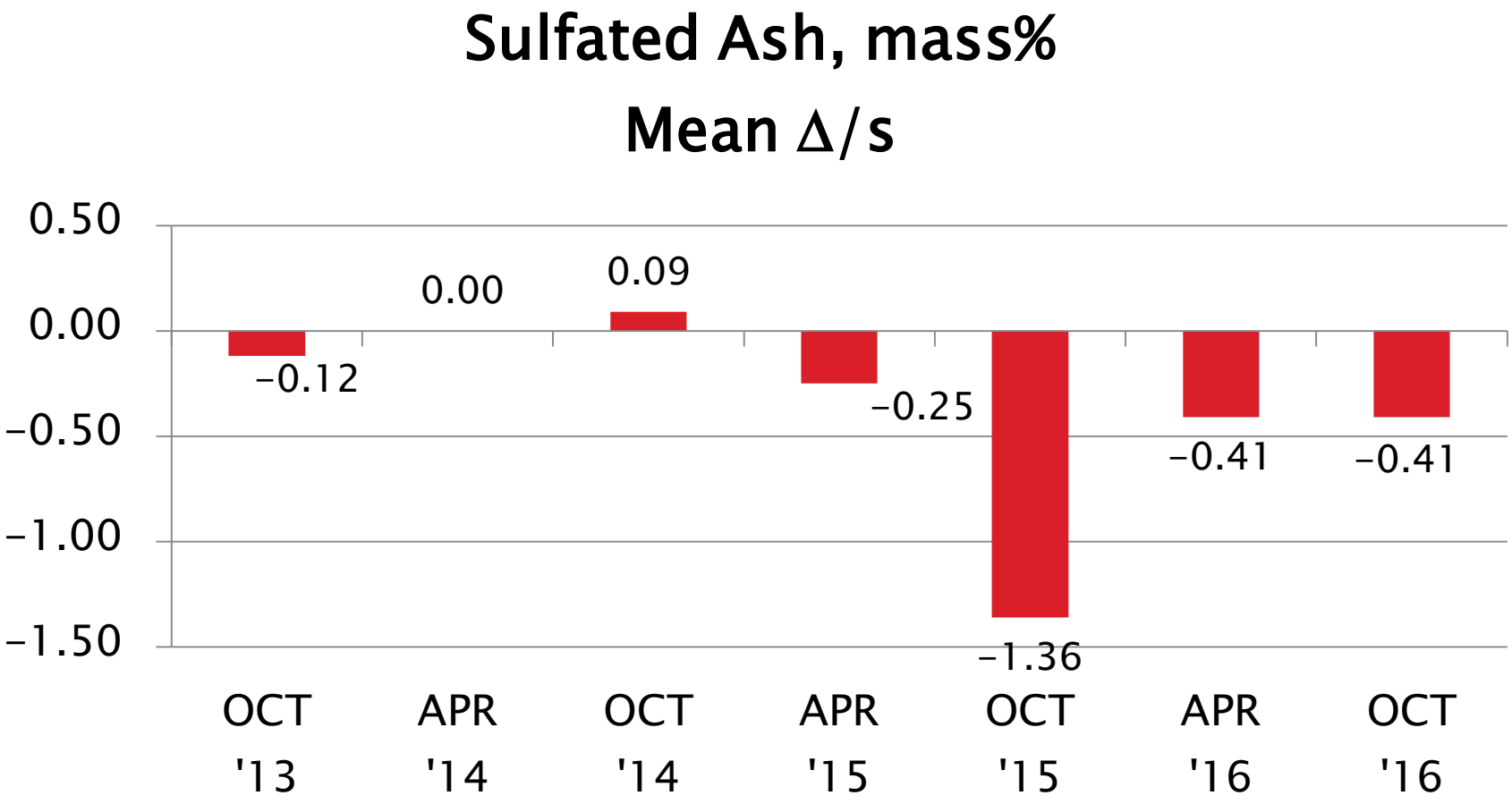
Total Deposits, mg	n	df	Pooled s	Mean Δ/s
Current Targets	81	78	0.07	-----
4/1/13 through 9/30/13	6	3	0.05	-0.12
10/1/13 through 3/31/14	5	2	0.02	0.00
4/1/14 through 9/30/14	6	3	0.07	0.09
10/1/14 through 3/31/15	6	4	0.07	-0.25
4/1/15 through 9/30/15*	8	5	0.13	-1.36
4/1/15 through 9/30/15*	7	4	0.05	-0.36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

*Period statistics with and without extreme result included

D874: Sulfated Ash



D874: Sulfated Ash

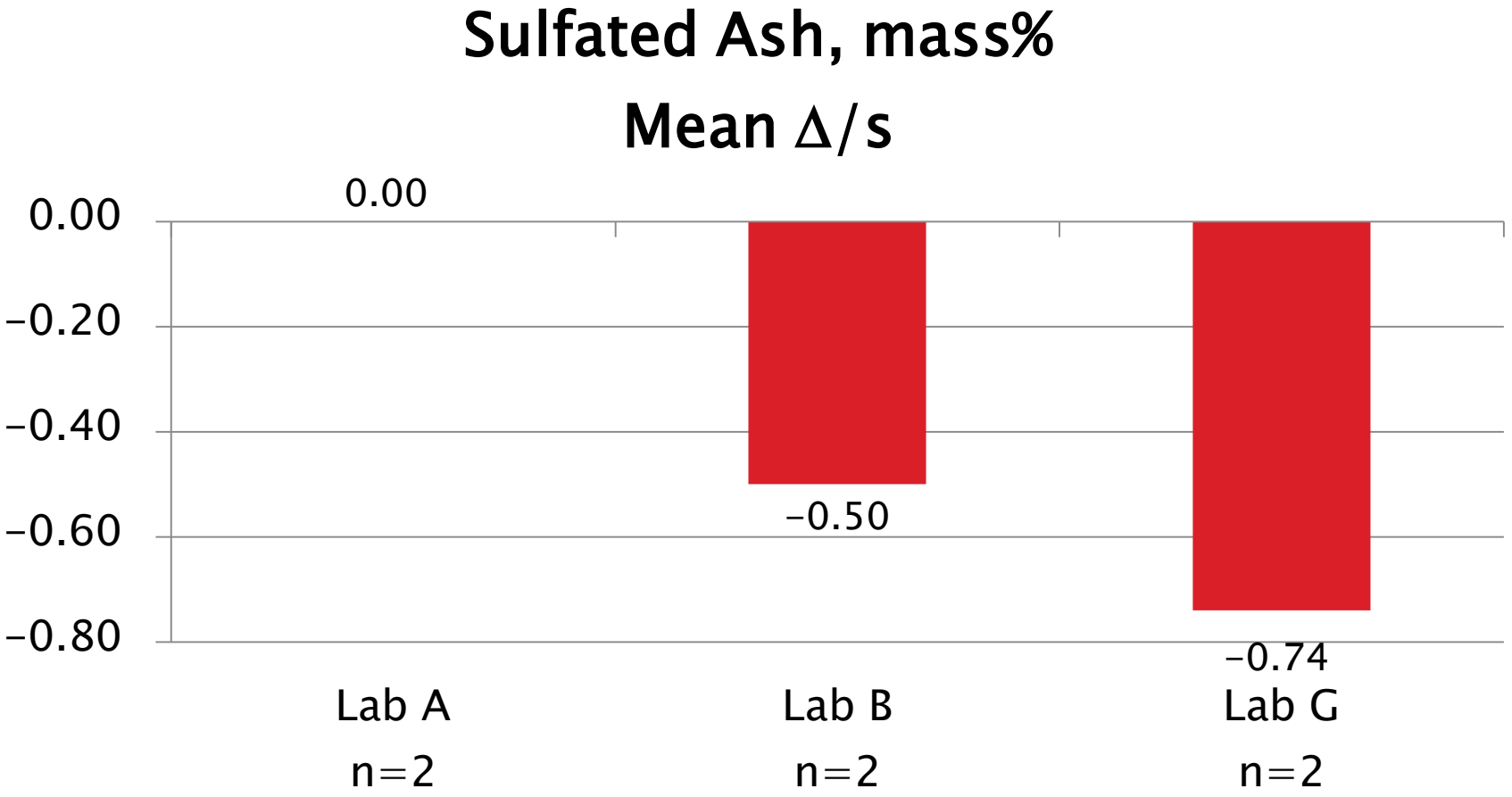


D874: Sulfated Ash

Current Period Severity Estimates by Lab
Sulfated Ash, mass%

	n	Mean Δ/s
Lab A	2	0.00
Lab B	2	-0.50
Lab G	2	-0.74

D874: Sulfated Ash



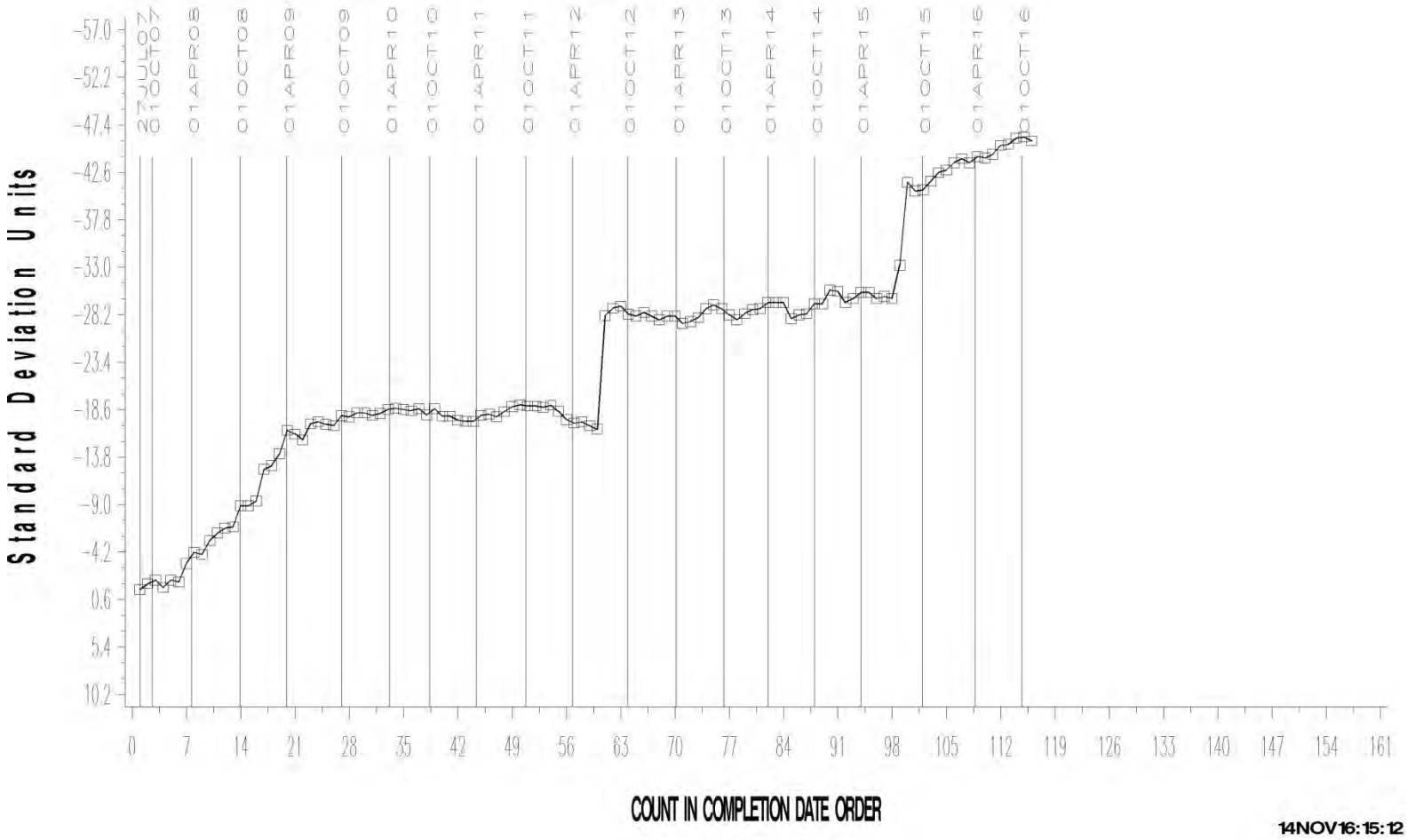
D874: Sulfated Ash

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

D874 INDUSTRY OPERATIONALLY VALID DATA

TEST SAMPLE PERCENT SULFATED ASH

CUSUM Severity Analysis



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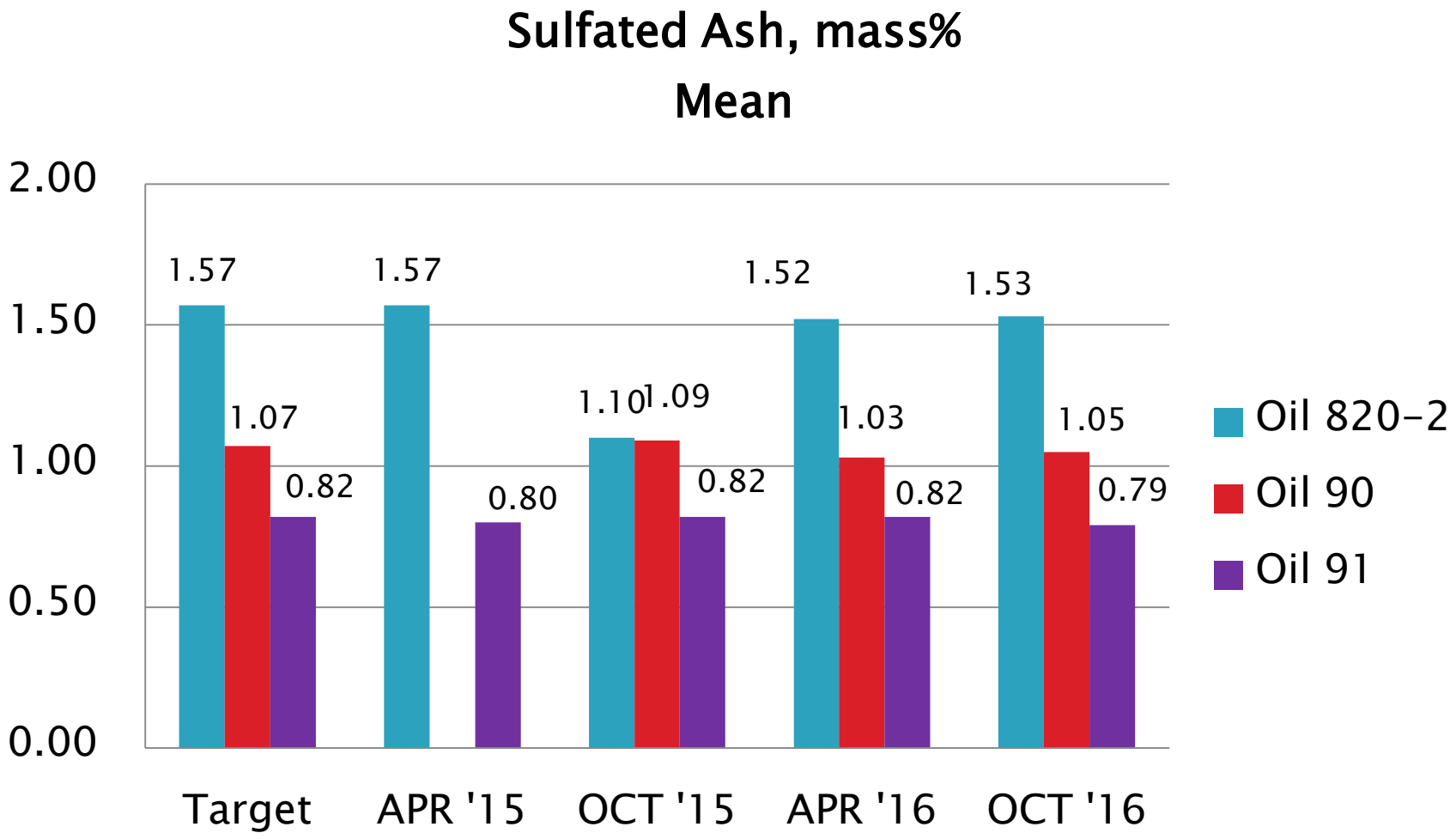
D874: Sulfated Ash

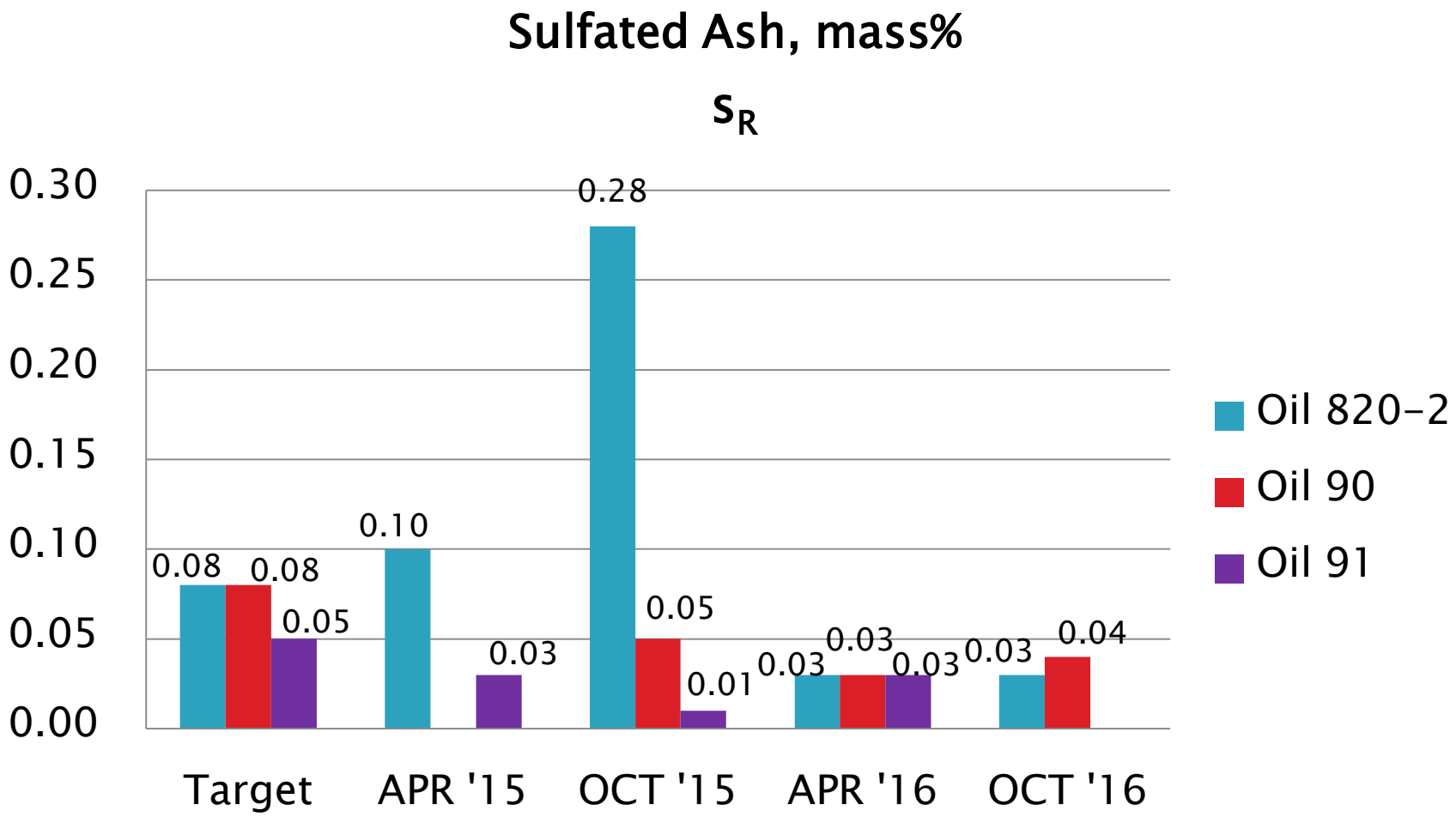
Performance by Oil
Sulfated Ash, mass%

	Targets			4/1/15 – 9/30/15				10/1/15 – 3/31/16				4/1/16 – 9/30/16			
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	2	1.10	0.28	-5.88	3	1.52	0.03	-0.62	3	1.53	0.03	-0.46
90	27	1.07	0.08	4	1.09	0.05	0.22	2	1.03	0.03	-0.50	2	1.05	0.04	-0.25
91	27	0.82	0.05	2	0.82	0.01	0.00	2	0.82	0.03	0.00	1	0.79	---	-0.60

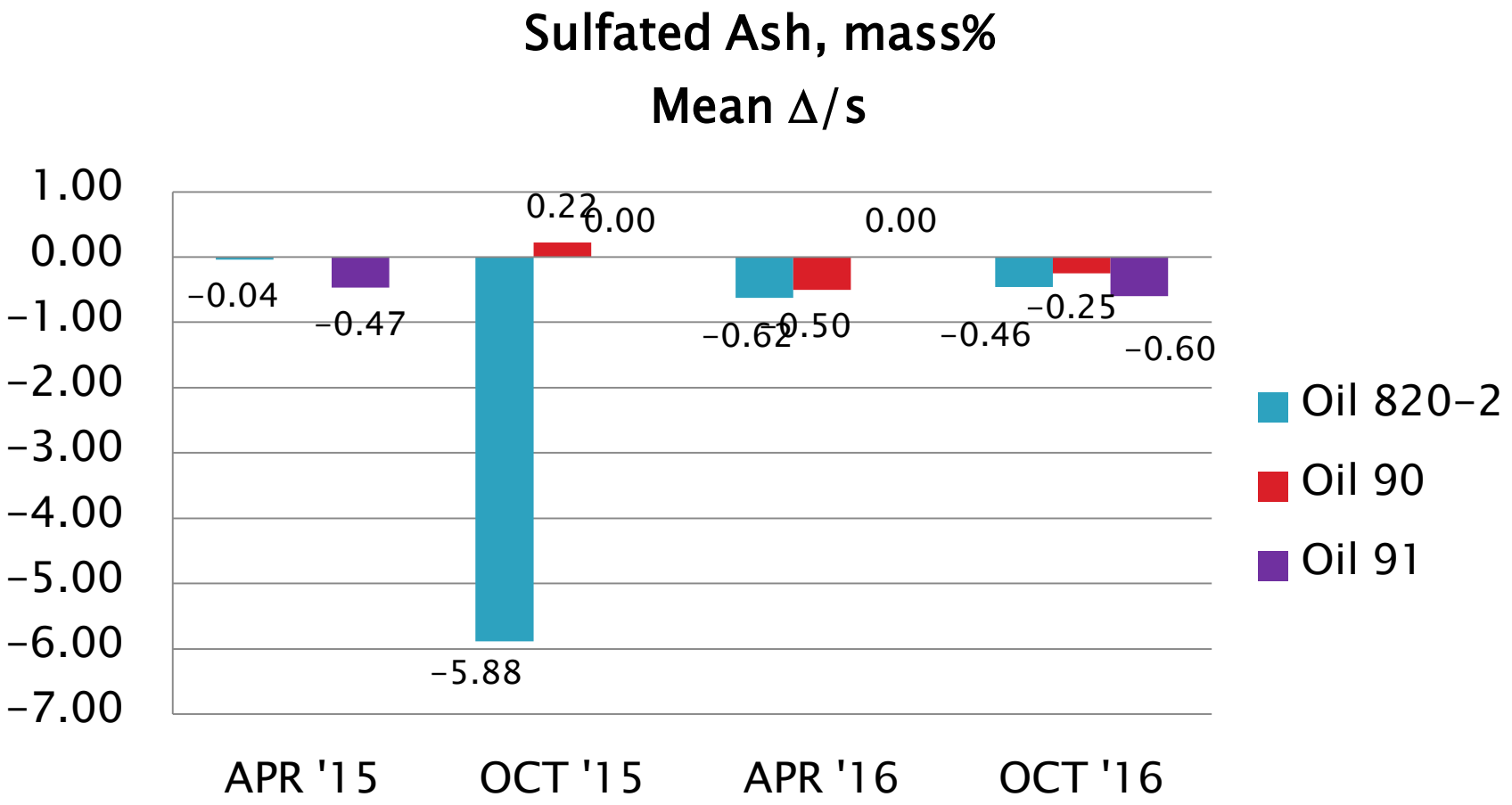
D874: Sulfated Ash



D874: Sulfated Ash



D874: Sulfated Ash



Return to Executive Summary

D7528: Oxidation by ROBO

Test Status	Validity Code	No. Tests
Acceptable Calibration Test	AC	64
Failed Calibration Test	OC	10
Operationally Invalidated by Lab	LC, XC	9
Operationally Invalidated After Initially Reported as Valid	RC	4
Total		**87**

Number of Labs Reporting Data: 7
Fail Rate of Operationally Valid Tests: 14%

D7528: Oxidation by ROBO

Operationally Invalid Tests

- 2 tests unexplained high EOT volatiles (RC)
- 2 tests heater or heater control failure (XC)
- 1 test wrong vacuum control valve setting (XC)
- 2 tests vacuum failure (RC)
- 2 tests air leak (LC, XC)
- 1 test heating temperature off-spec (XC)
- 2 tests stirrer failure (XC)
- 1 test power failure (XC)

D7528: Oxidation by ROBO

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

- No technical memos were issued this period for ROBO.

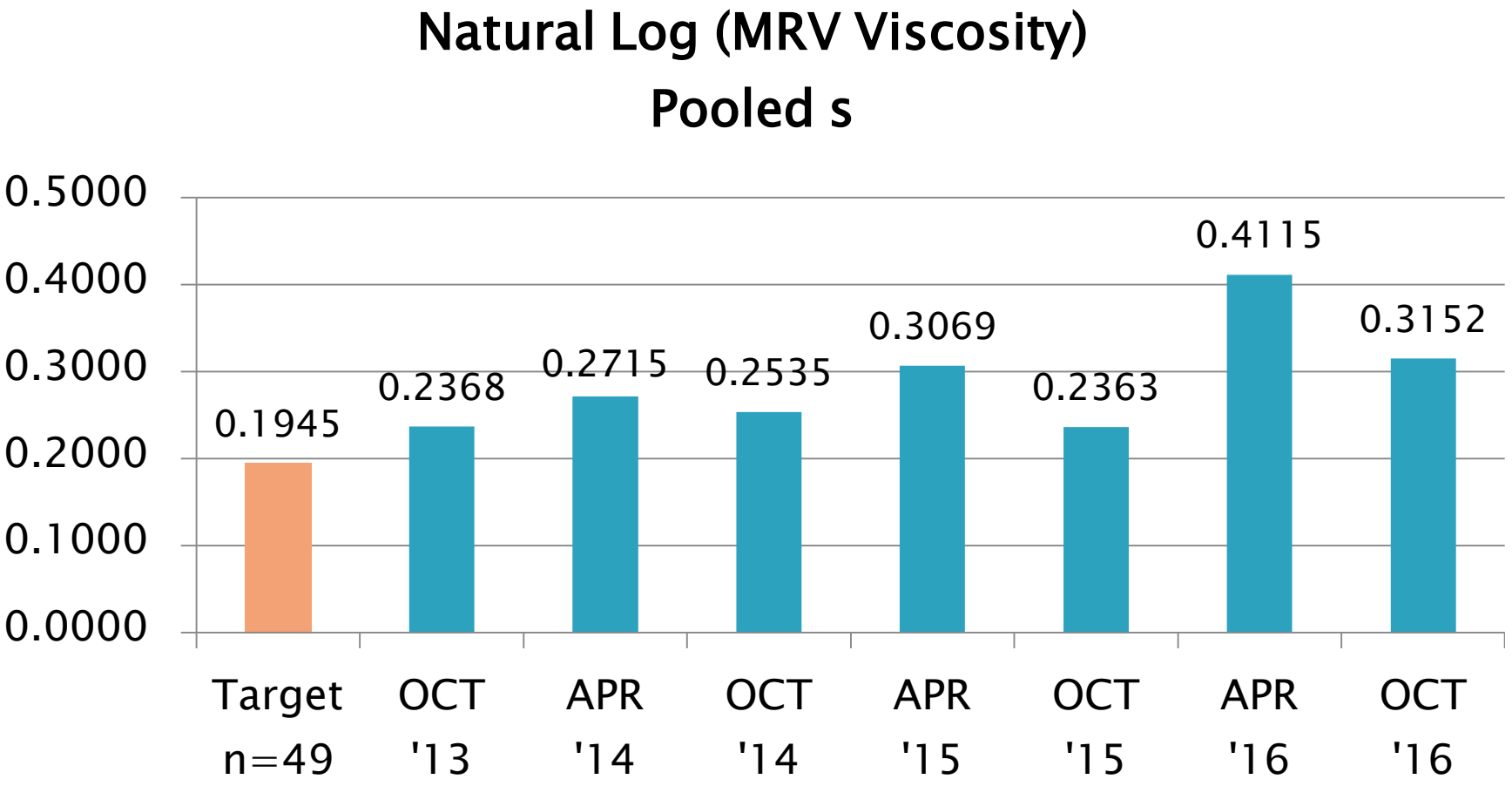
D7528: Oxidation by ROBO

Period Precision and Severity Estimates

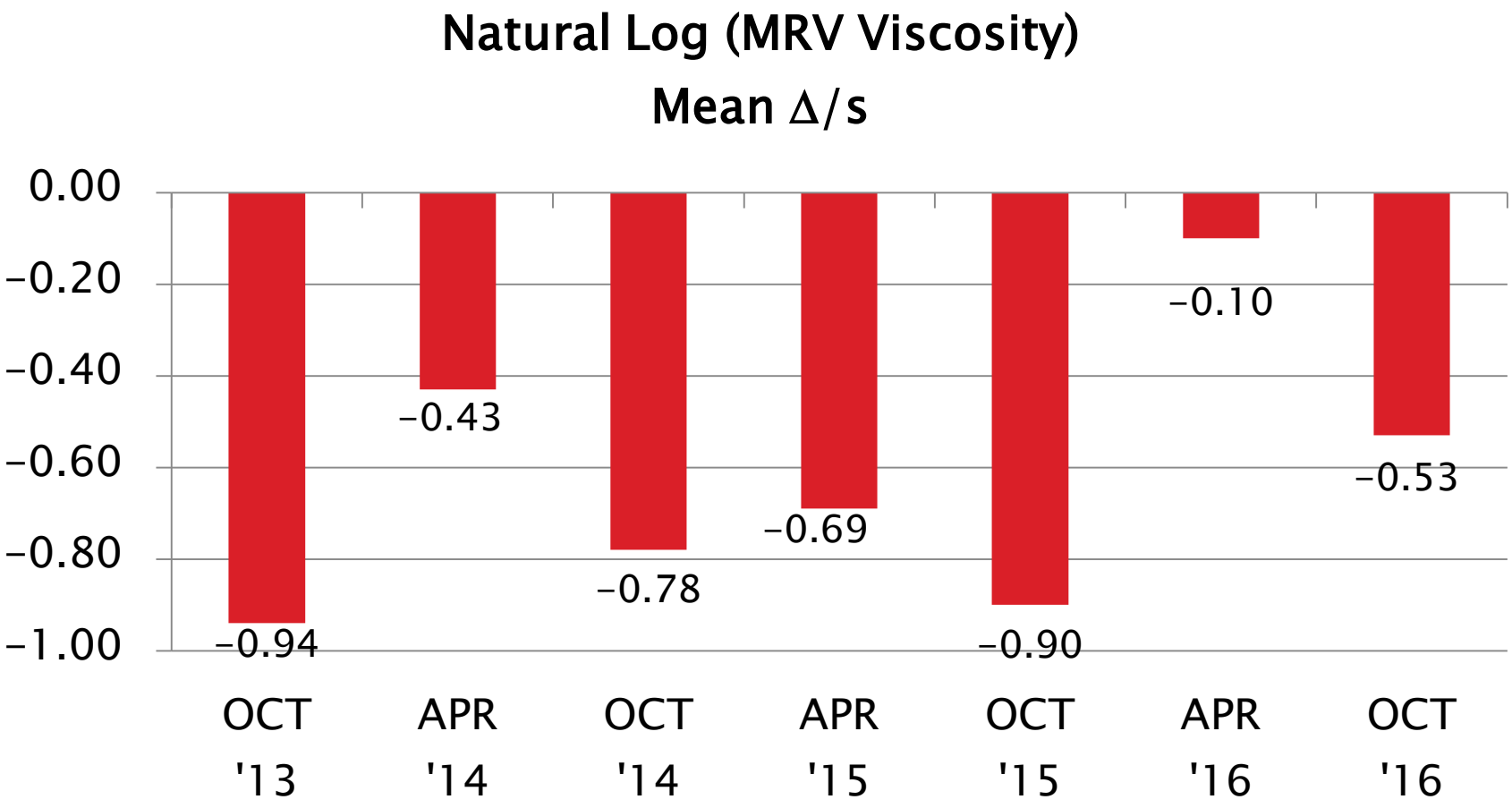
Natural Log (MRV Viscosity)	n	df	Pooled s	Mean Δ/s
Current Targets	49	46	0.1945	-----
4/1/13 through 9/30/13	90	87	0.2368	-0.94
10/1/13 through 3/31/14	85	82	0.2715	-0.43
4/1/14 through 9/30/14	83	80	0.2535	-0.78
10/1/14 through 3/31/15	97	94	0.3069	-0.69
4/1/15 through 9/30/15	85	82	0.2363	-0.90
10/1/15 through 3/31/16* 10/1/15 through 3/31/16*	92 91	89 88	0.4115 0.3661	-0.10 -0.20
4/1/16 through 9/30/16	74	71	0.3152	-0.53

*Period statistics with and without extreme result included

D7528: Oxidation by ROBO



D7528: Oxidation by ROBO



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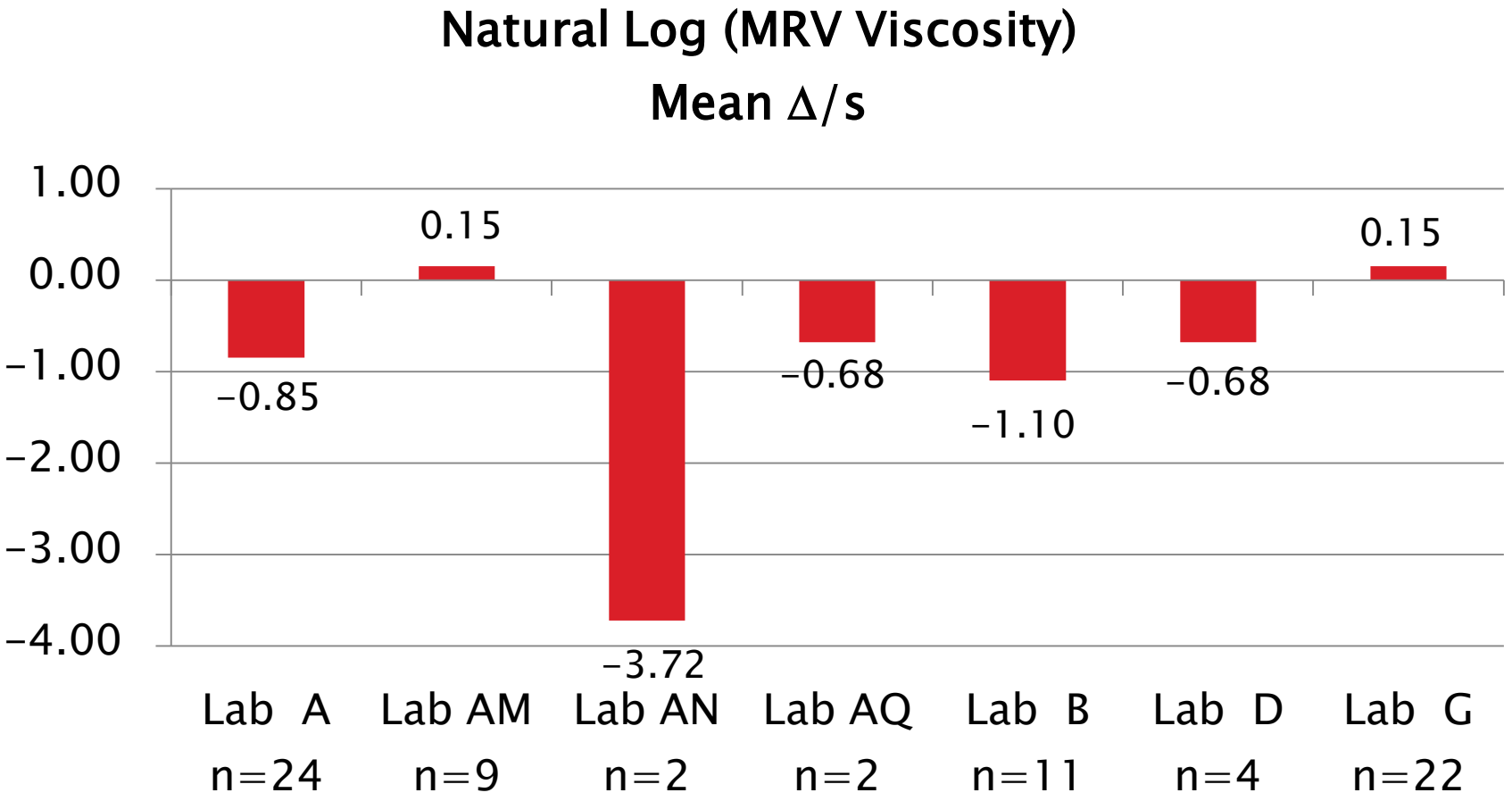
D7528: Oxidation by ROBO

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

	n	Mean Δ/s
Lab A	24	-0.85
Lab AM	9	0.15
Lab AN	2	-3.72
Lab AQ	2	-0.68
Lab B	11	-1.10
Lab D	4	-0.68
Lab G	22	0.15

D7528: Oxidation by ROBO



D7528: Oxidation by ROBO

- Precision (Pooled s) is more precise than last period but less precise than all prior periods since at least October 2013
  - Continues to be less precise than target precision
  - Five tests on various rigs are between 3 and 6 s mild or severe this period (rig G 4 @ 3.4 s, G 4 @ 5.7 s, A 2 @ -3.3 s, AN 2A @ -6.1 s, B 4A @ -4.2 s)
  - Rig B 1 on fifth pair of failing runs (two-test calibration), with four fails occurring in prior periods, and rig still not calibrated to date.
- Performance (Mean Δ/s) is -0.53 s mild

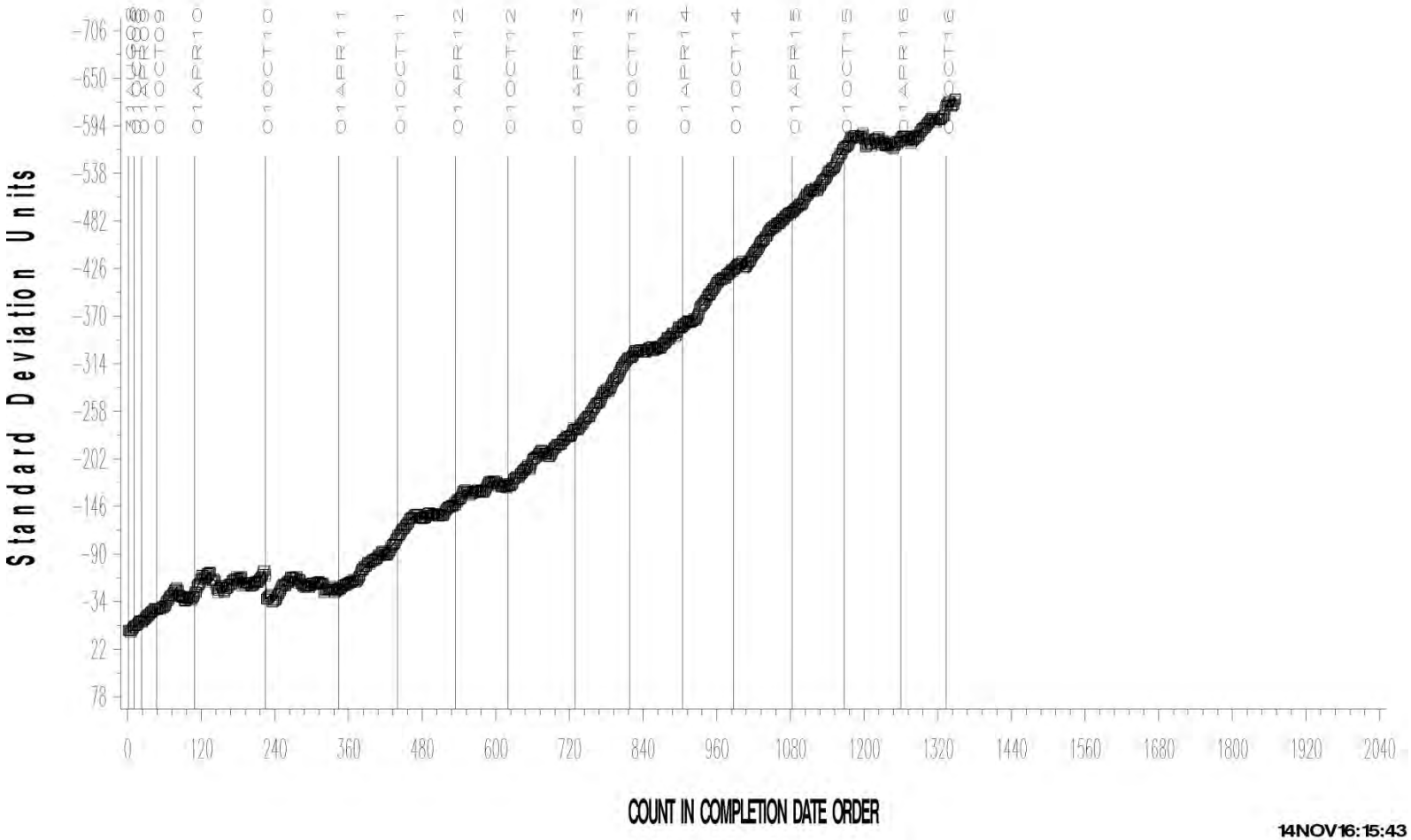
D7528: Oxidation by ROBO

- Oils 434-1 and 435-1 continue to be especially imprecise
- CUSUM Severity Plot shows an overall mild trend since the 01APR11 timeline (following a 2011 ROBO workshop) with significant 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 replacement oil 434-2.

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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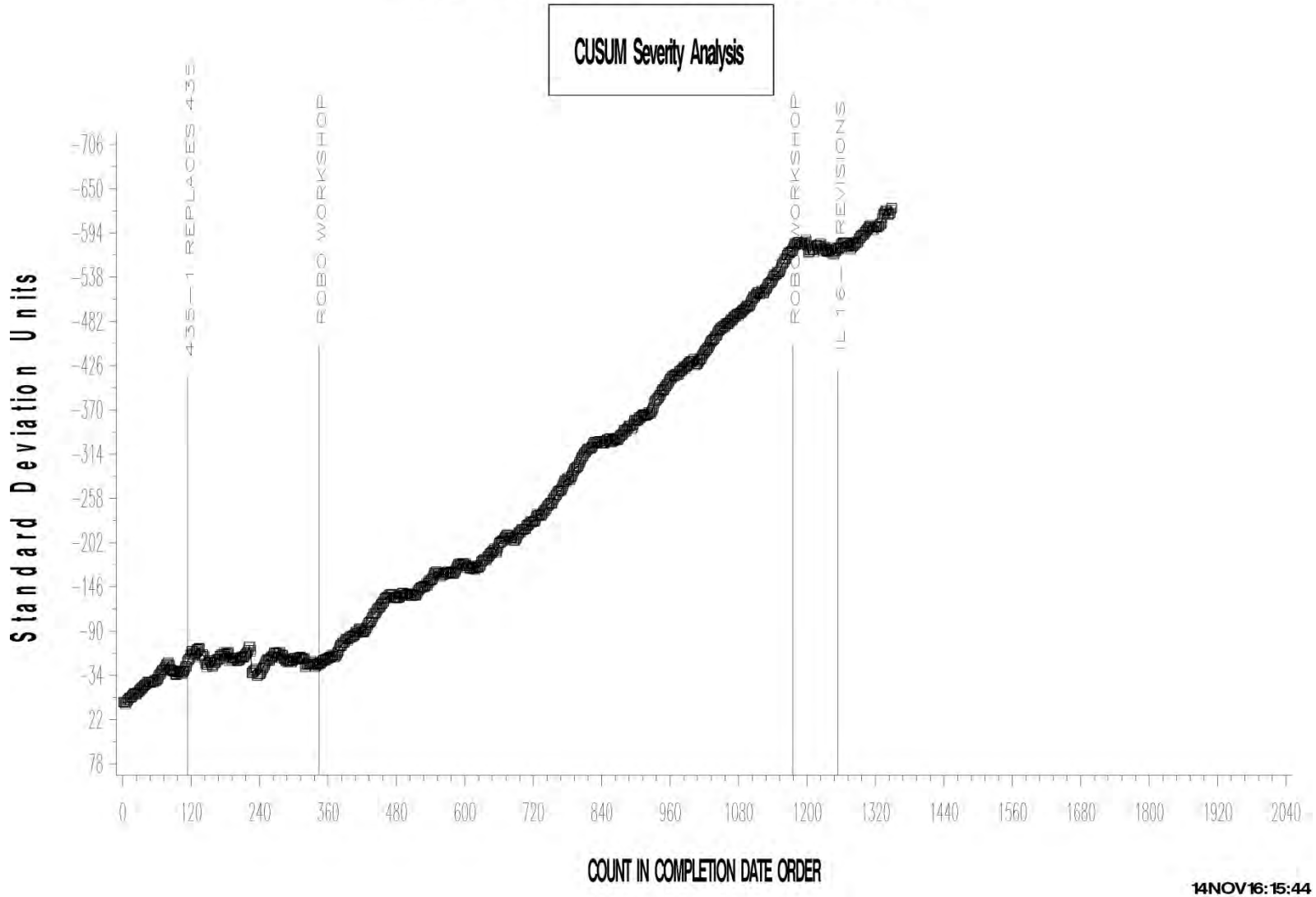
AGED OIL MRV APPARENT VISCOSITY



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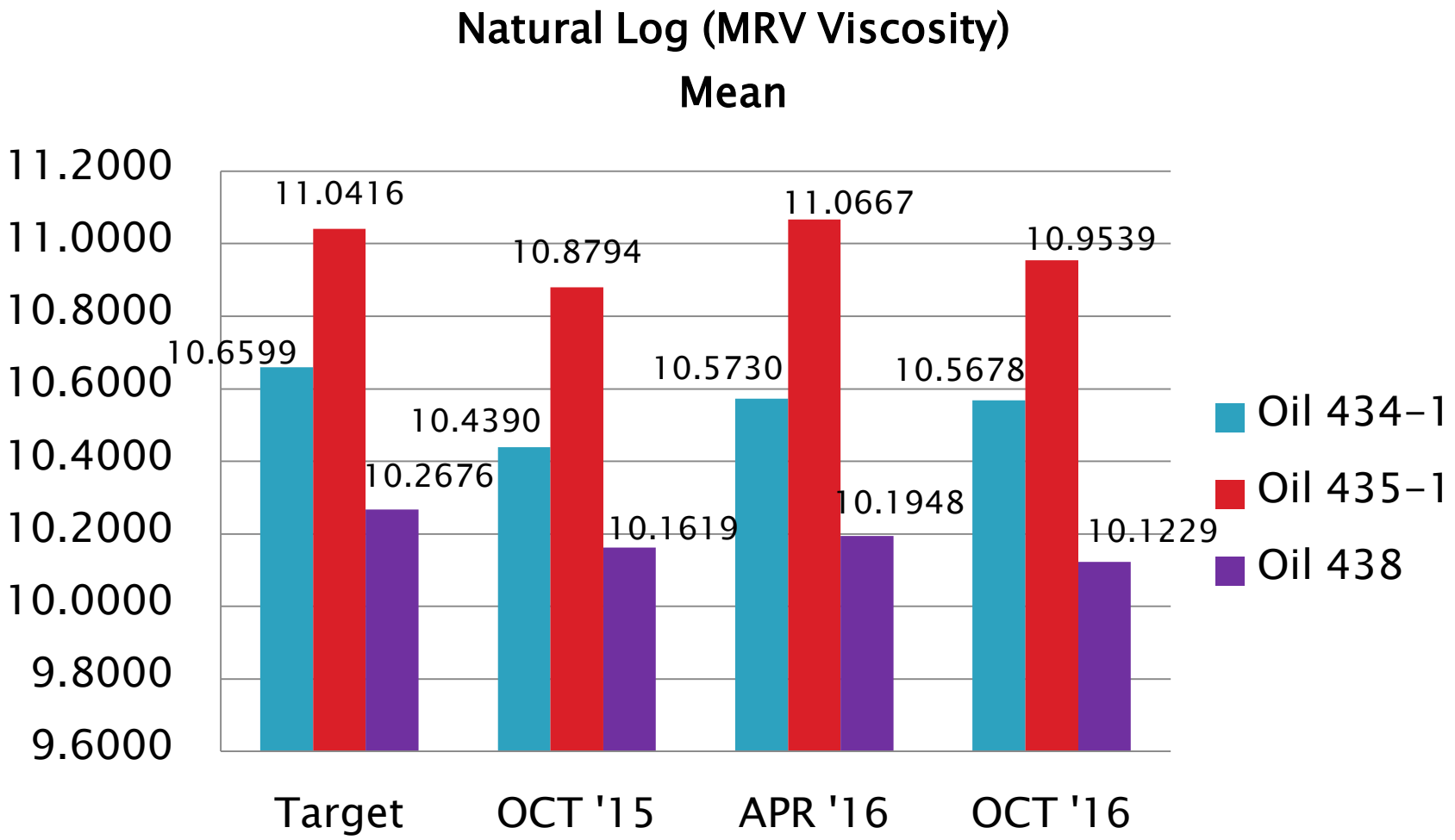
D7528: Oxidation by ROBO

Performance by Oil
Natural Log (MRV Viscosity)

	Targets			4/1/15 - 9/30/15				10/1/15 - 3/31/16				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	26	10.4390	0.1991	-1.32	31	10.5730	0.3303	-0.52	20	10.5678	0.3262	-0.55
435-1	22	11.0416	0.2030	41	10.8794	0.2220	-0.80	40*	11.0667	0.4304	0.12	36	10.9539	0.3391	-0.43
438	14	10.2676	0.2037	18	10.1619	0.3085	-0.52	20	10.1948	0.2612	-0.36	18	10.1229	0.2437	-0.71

*Extreme (9 s) result excluded

D7528: Oxidation by ROBO



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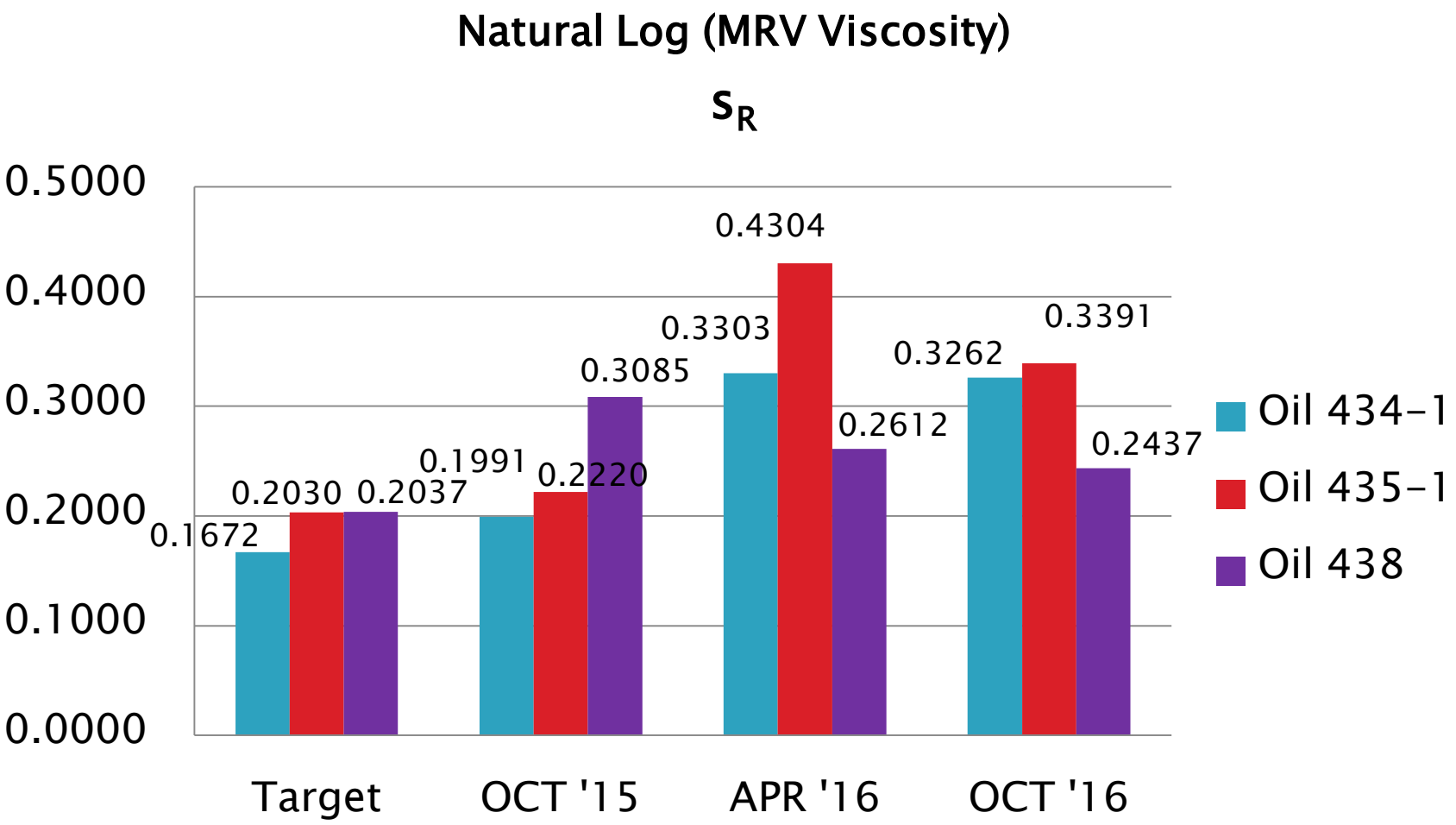
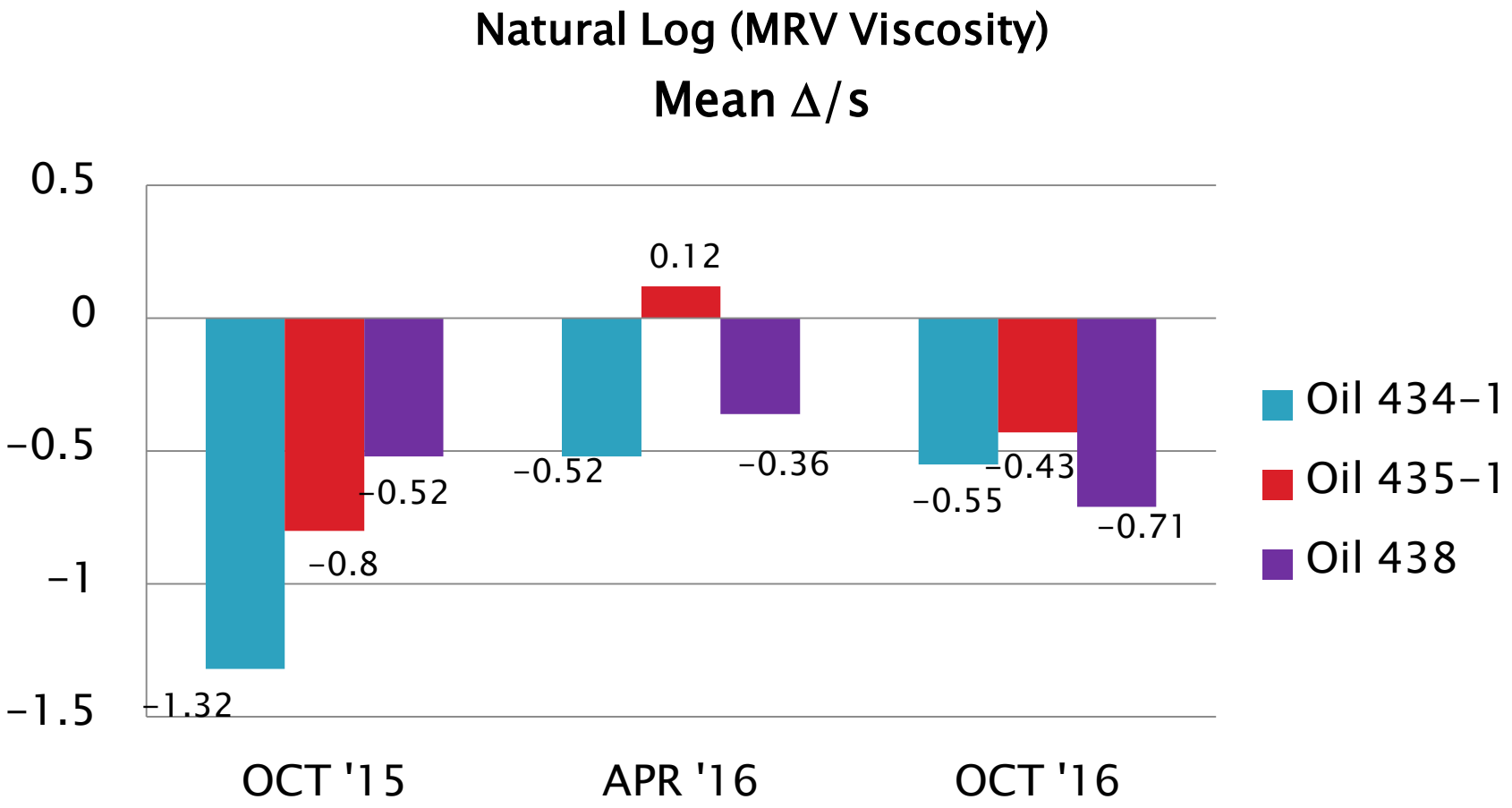
D7528: Oxidation by ROBO



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 13 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 9/30/2016

Reference Oil Inventory

D5800, D6417, GI

Oil	Year Rec'd By TMC	Tests	TMC Inventory, gallons	Gallons Shipped last 12 months
VOLC12	2013	D5800	6.1	1.8
VOLD12	2013	D5800	48.4	1.5
VOLE12	2013	D5800	47.3	1.5
VOLD14	2014	D5800QC	233.8	121.8
52	1995	D6417	59.1	0.0
55	1995	D6417	66.2	0.0
58	1998	D6417, GI	116.2	0.3
62	1996	GI	0.9	0.2
1009*	2002	GI	33.0	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	108.4	0.6
434	2003	MTEOS	2.8	0.6
75	2010	TEOST	3.1	1.1
435-2*	2010	TEOST	44.3	0.6
434-1	2008	ROBO	6 SAMPLES	----
435-1	2008	ROBO	450.5	6.8
438*	2003	ROBO	9.1	1.8

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

Reference Oil Inventory

D6082 & D874

Oil	Year Rec'd By TMC	Tests	TMC Inventory, gallons	Gallons Shipped last 12 months
1007	1998	D6082	11.0	3.5
66	2002	D6082	86.9	1.5
820-2	2001	D874	10.2	0.0
90	2005	D874	24.4	2.1
91	2006	D874	4.0	0.0

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	127.8	7.9
HMB	2002	H&M	131.3	7.9
HMC	2003	H&M	118.1	7.9
HMD	2002	H&M	125.5	7.9
HME	2002	H&M	111.8	7.9
HMF	2002	H&M	134.3	7.9

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

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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