Test Monitoring Center

http://astmtmc.cmu.edu

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

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

April 2016

B0.07 Bench Testing Executive Summary

- D6417 (Volatility by GC)
- Precision (Pooled s) is more precise than last period
  - More precise than target precision
- Performance (Mean Δ/s) is on target (0.04 s severe)
- CUSUM plot shows overall on-target performance this period.

B0.07 Bench Testing
Executive Summary

- D5800 (Volatility by Noack)
- Precision (Pooled s), at 0.50 mass %, is more precise than prior period and matches the target precision.
- Performance (Mean Δ/s) is 1.08 s severe, comparable to last period and more severe than any period since at least April 2010
- Testing has moved substantially more severe over the last two report periods, but precision has improved over that same time.
- Fail rate of operationally valid tests (AC & OC) is 19% (fail rate of the three prior periods was 20%, 27% and 36%).
- Historical long-term severe trend continues with only a modest decrease in severity following the introduction of the new reference oils (3Q 2013), and a substantial increase in severity for the last two report periods.

B0.07 Bench Testing
Executive Summary

- D5800 (Volatility by Noack)
  - All three reference oils are again performing severe, with oil VOLC12 performing 1.5 s severe, and oil VOLE12 performing 0.92 s severe.

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 on target (0.03 s)
- Reference oil 62 inventory is down to 1.0 gallons remaining (but only 0.2 gallons shipped prior 12 months).

B0.07 Bench Testing Executive Summary

- D6335 (TEOST-33C)
  - Precision (Pooled s) is less precise than prior period
    - Less precise than target precision
    - Less precise than all periods since at least April 2013
  - Performance (Mean Δ/s) is -0.43 s mild
    - Instrument G2 reported results 1.2 s, 4.8 s, -3.7 s and -1.3 s this period, with a mean severity of only 0.25 s, but contributing to the overall poor precision this period.
    - Instrument B5 had two consecutive fails, one 2 s and one -2 s, balancing out on severity, but also contributing to the poor precision estimate this period.
- All tests this period report using Rod Batches L or M

B0.07 Bench Testing Executive Summary

- D7097 (MHT-4 TEOST)

- Precision (Pooled s) is more precise than prior period
  - Less precise than target precision

- Performance (Mean Δ/s) is 0.29 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 or 15AA

B0.07 Bench Testing Executive Summary

- D7097 (MHT-4 TEOST)

- CUSUM severity plot shows slight severe trend this period
  - However, lab performance differences persist
  - Severe oil 432 overall performance is closer to target but is a result of performance differences between catalyst batches offsetting:
    - CATBATCH 14AA is 0.75 s severe (n=34)
    - CATBATCH 15AA is -0.86 s mild (n=10)
    - Catalyst batches have been observed to bias performance differently for different oils
      - does not explain ongoing lab severity differences.

B0.07 Bench Testing Executive Summary

- D6082 (High Temperature Foam)
  - Foam Tendency Precision (Pooled s) is more precise than prior period
    - More precise than target precision
  - Performance (Mean Δ/s) is -0.45 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 more precise than 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)
  - Period overall precision and severity estimates shown with 9 s severe result included and excluded.
  - Exceptionally high OC fail rate this period (32%), with individual rigs failing 3, 4 and 5 times, and 4 tests 5 s or more severe (5.0 s, 5.6 s, 5.6 s and 9.2 s)
  - Precision (Pooled s) is less precise than prior period
    - Continues to be less precise than target precision
    - Even with extreme (9 s) result excluded, the worst period precision since at least April 2013
  - Performance (Mean Δ/s) is -0.10 s mild (-0.20 s mild with 9 s result excluded)

B0.07 Bench Testing Executive Summary

- D7528 (ROBO)
  - Oils 434-1 and 435-1 are especially imprecise (even with extreme 9 s result excluded on 435-1)
  - 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.
  - One Information Letter Issued for ROBO This Period:
    - ROBO IL 16-1; March 11, 2016; Numerous Revisions to Test Method D7528

Calibrated Labs and Stands*

Test	Labs	Stands
D6417	5	6
D5800	9	24
D5133 (GI)	5	9
D6335 (TEOST)	6	9
D7097 (MTEOS)	8	37
D6082	4	4
D874	3	--
D7528 (ROBO)	4	12

*As of 9/30/2016

D02.B0.07
TMC Monitored Tests

- October 1, 2015 –
  March 31, 2016

Test Monitoring Center
http://astmtmc.cmu.edu
A Program of ASTM International

D6417: Estimation of Engine Oil Volatility by Capillary GC

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

Number of Labs Reporting Data: 5
Fail Rate of Operationally Valid Tests: 0%

D6417: Estimation of Engine Oil Volatility by Capillary GC

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

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

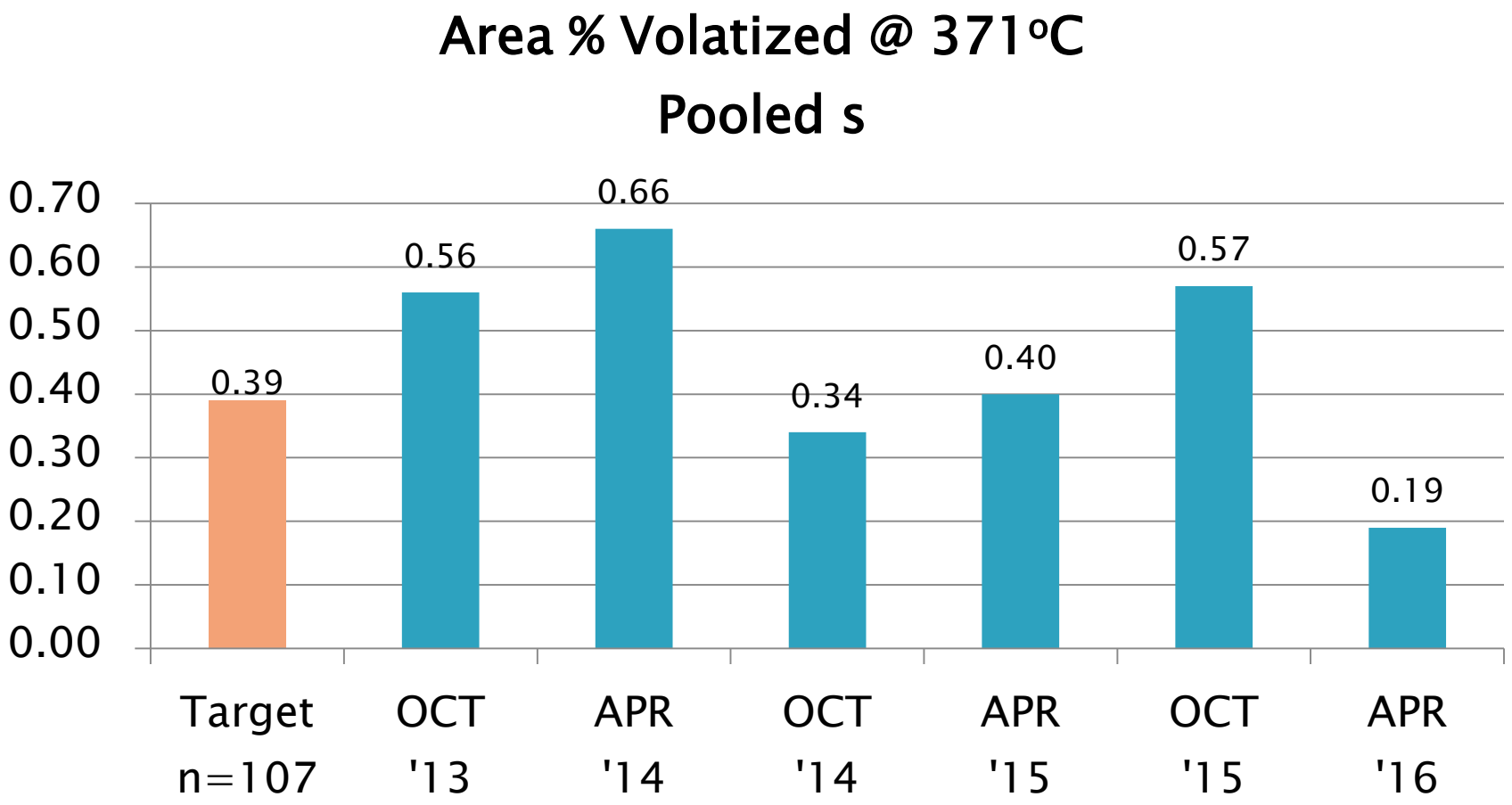
D6417: Estimation of Engine Oil Volatility by Capillary GC

Period Precision and Severity Estimates

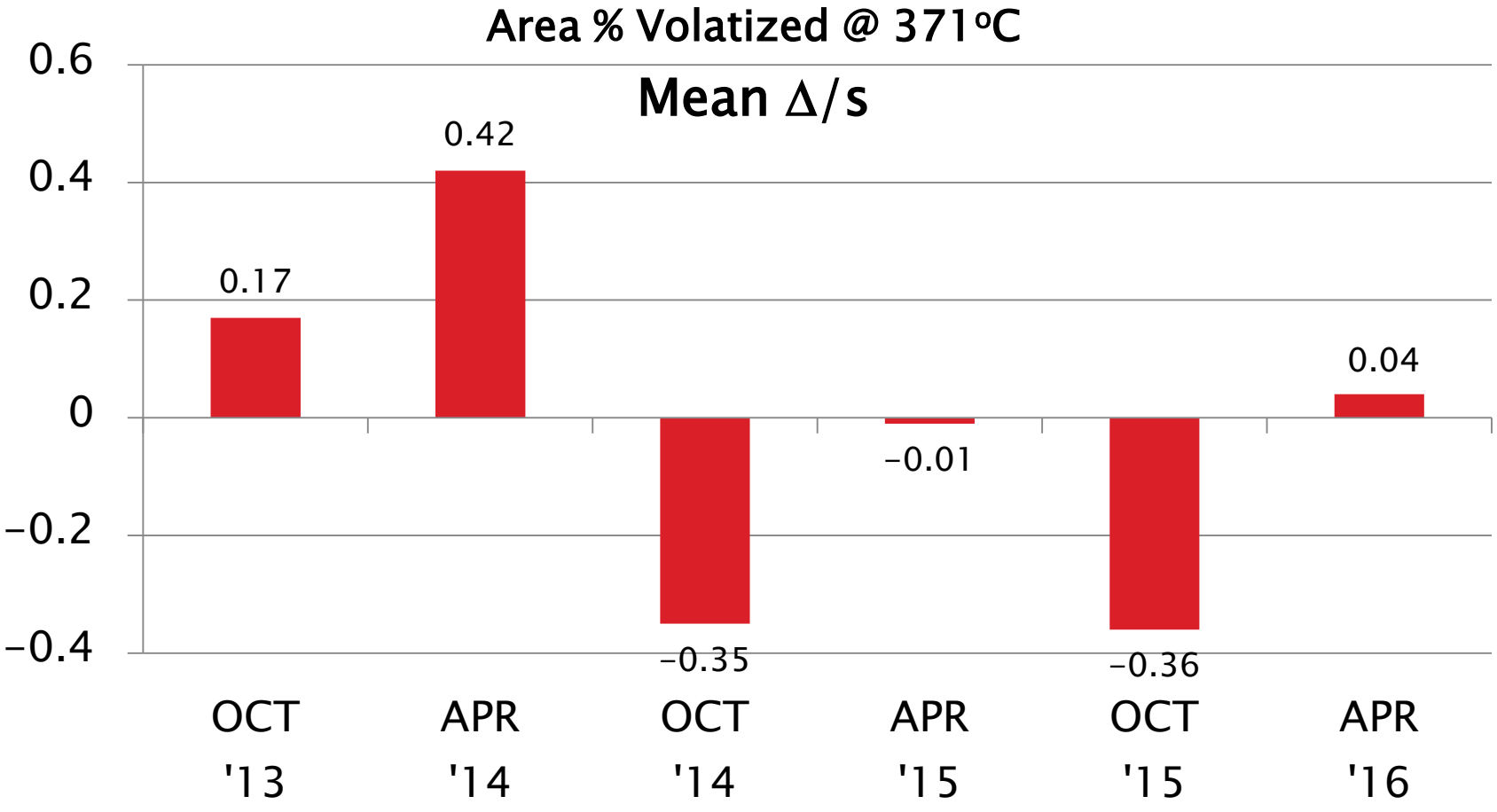
Area % Volatized @ 371°C	n	df	Pooled s	Mean Δ/s
Initial Selected Oils from RR	54	51	0.39	-----
4/1/13 through 9/30/13	17	14	0.56	0.17
10/1/13 through 3/31/14	15	12	0.66	0.42
4/1/14 through 9/30/14	15	12	0.34	-0.35
10/1/14 through 3/31/15	14	11	0.40	-0.01
4/1/15 through 9/30/15* 4/1/15 through 9/30/15*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

*Extreme OC result included and excluded

D6417 Precision Estimates



D6417 Severity Estimates

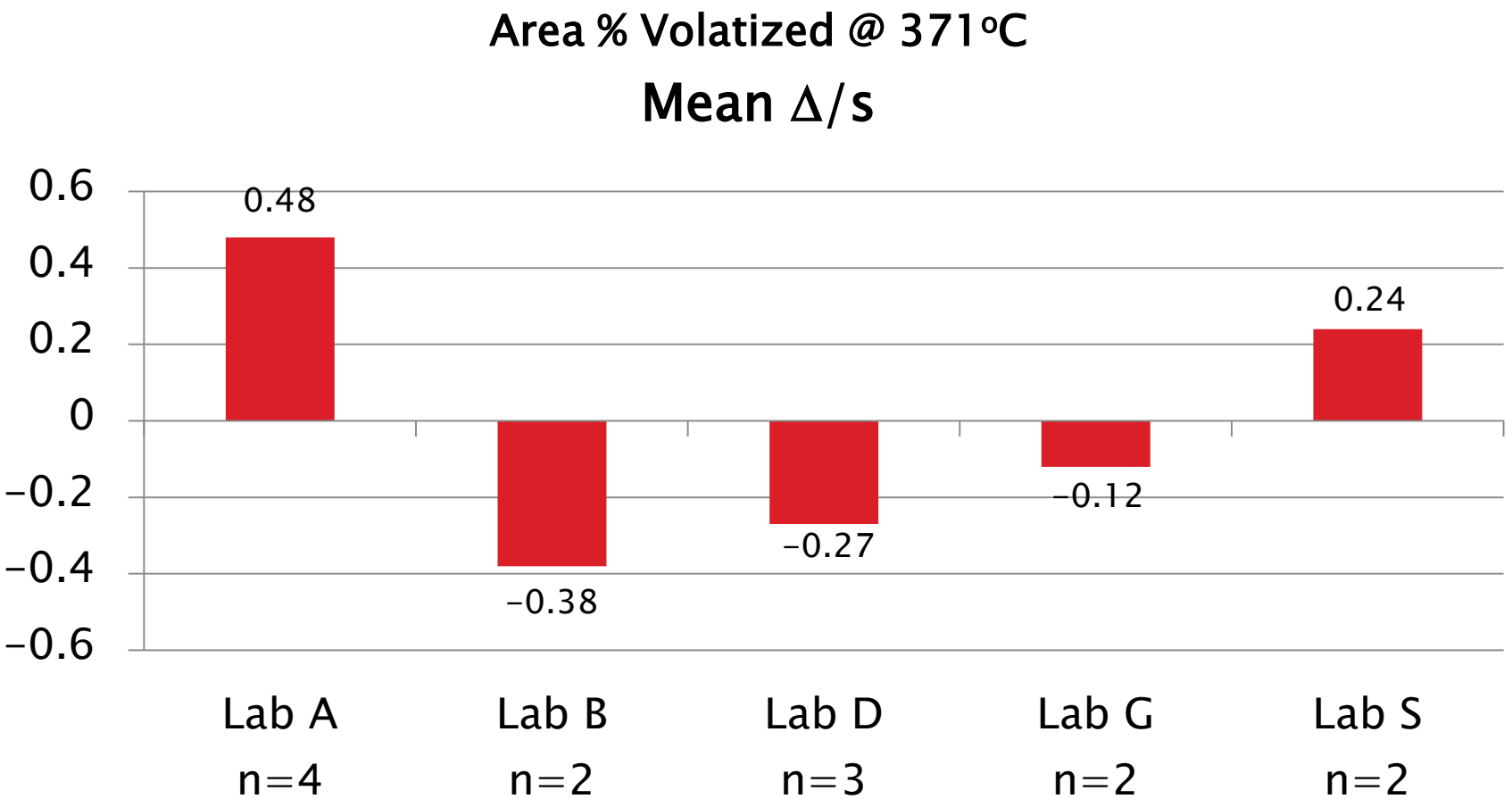


D6417: Estimation of Engine Oil Volatility by Capillary GC

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

	n	Mean Δ/s
Lab A	4	0.48
Lab B	2	-0.38
Lab D	3	-0.27
Lab G	2	-0.12
Lab S	2	0.24

D6417 Lab Severity Estimates



Test Monitoring Center
http://astmtmc.cmu.edu
A Program of ASTM International

D6417: Estimation of Engine Oil Volatility by Capillary GC

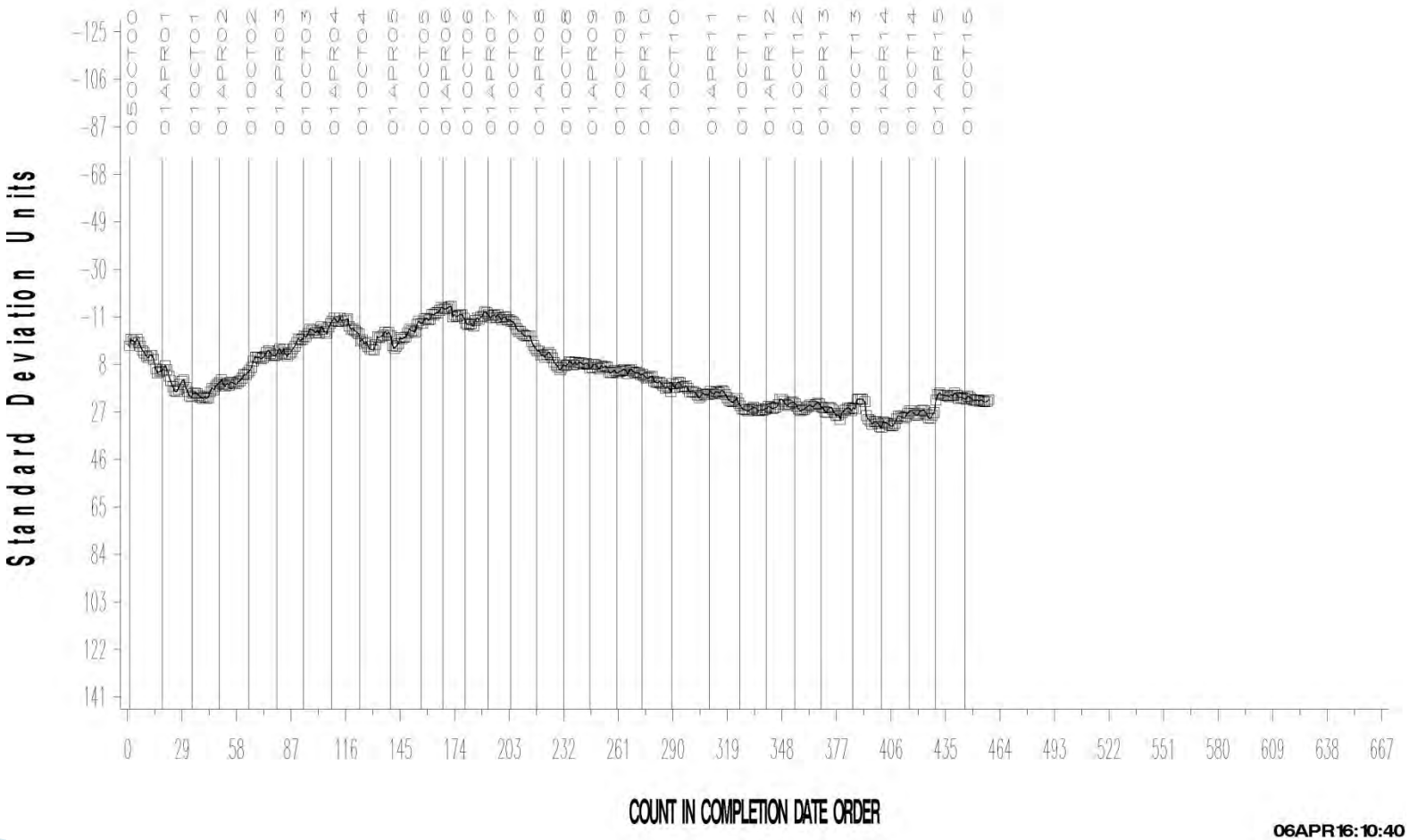
- Precision (Pooled s) is more precise than last period
  - More precise than target precision
- Performance (Mean Δ/s) is on target (0.04 s severe)
- CUSUM plot shows overall on-target performance this period.

D6417 VOLATILITY BY GC INDUSTRY OPERATIONALLY VALID DATA

A Program of ASTM International

SAMPLE AREA % VOLATIZED

CUSUM Severity Analysis



06APR16:10:40

Test Monitoring Center

http://astmtmc.cmu.edu

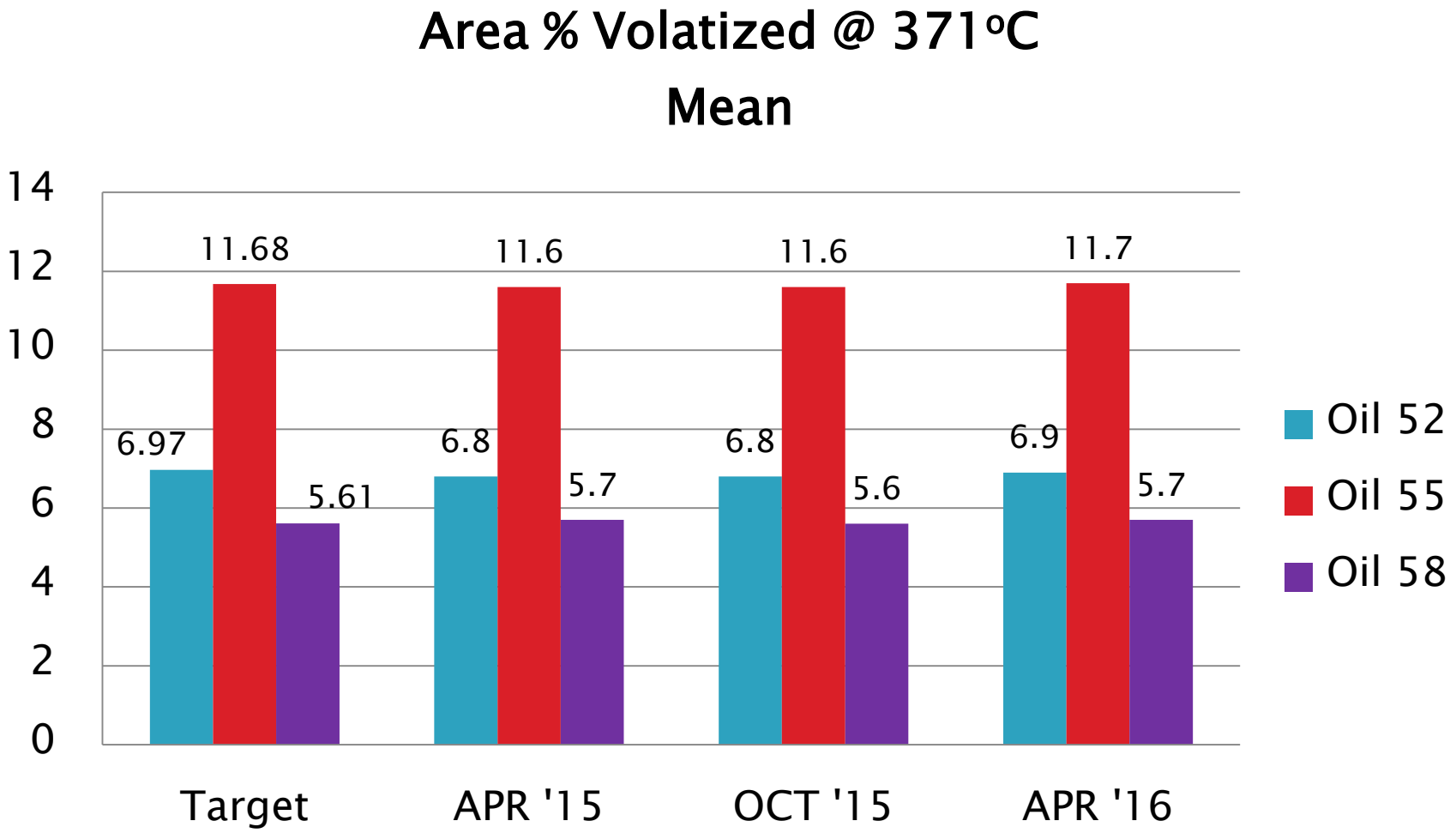
A Program of ASTM International

D6417: Estimation of Engine Oil Volatility by Capillary GC

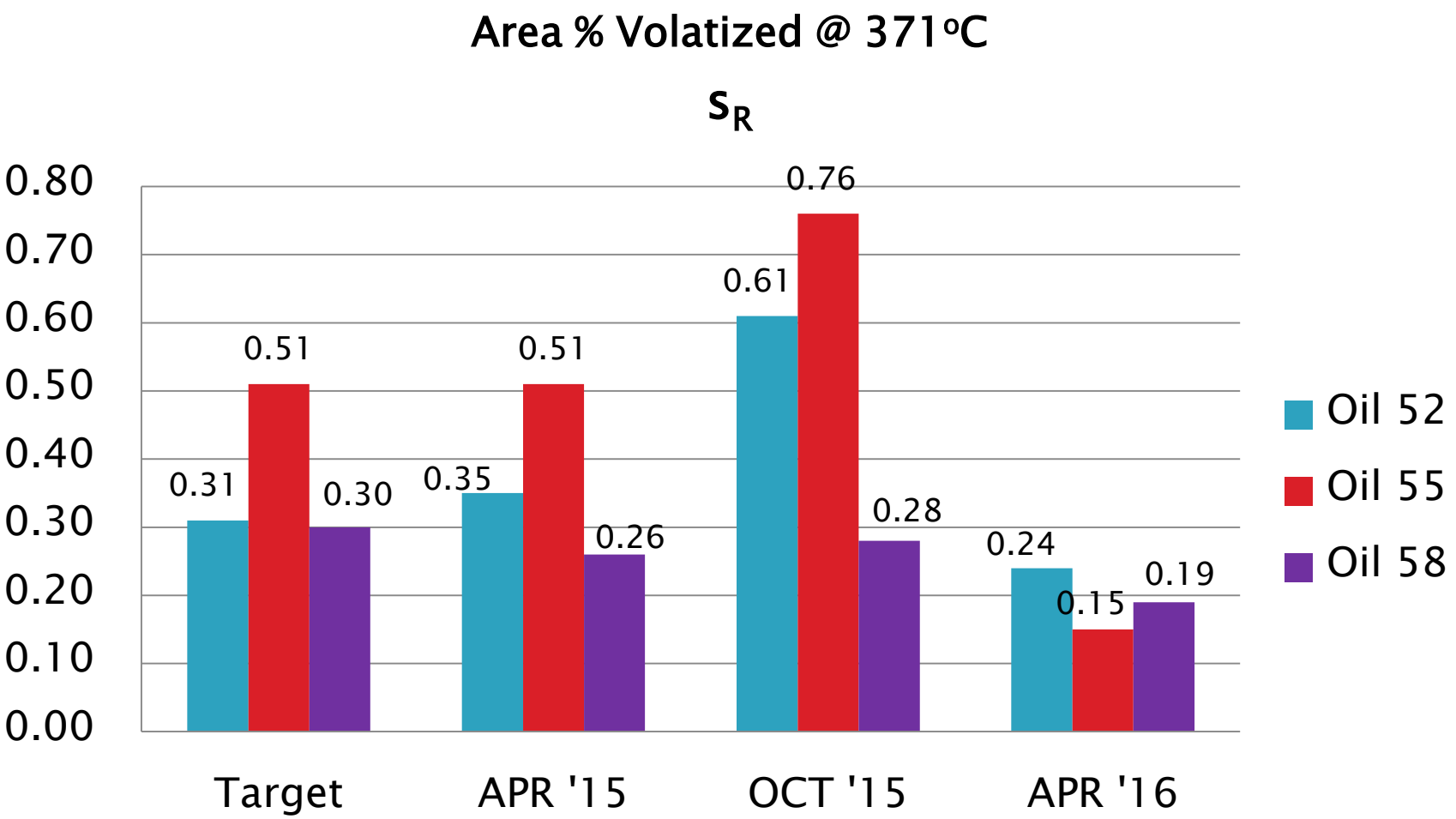
Area % Volatized @ 371°C
Performance by Oil

	Targets			10/1/14 - 3/31/15				4/1/15 - 9/30/15				10/1/15 - 3/31/16			
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	2	6.8	0.35	-0.39	7	6.8	0.61	-0.69	4	6.9	0.24	-0.23
55	18	11.68	0.51	6	11.6	0.51	-0.09	4	11.6	0.76	-0.11	5	11.7	0.15	0.12
58	18	5.61	0.30	6	5.7	0.26	0.19	5	5.6	0.28	-0.10	4	5.7	0.19	0.22

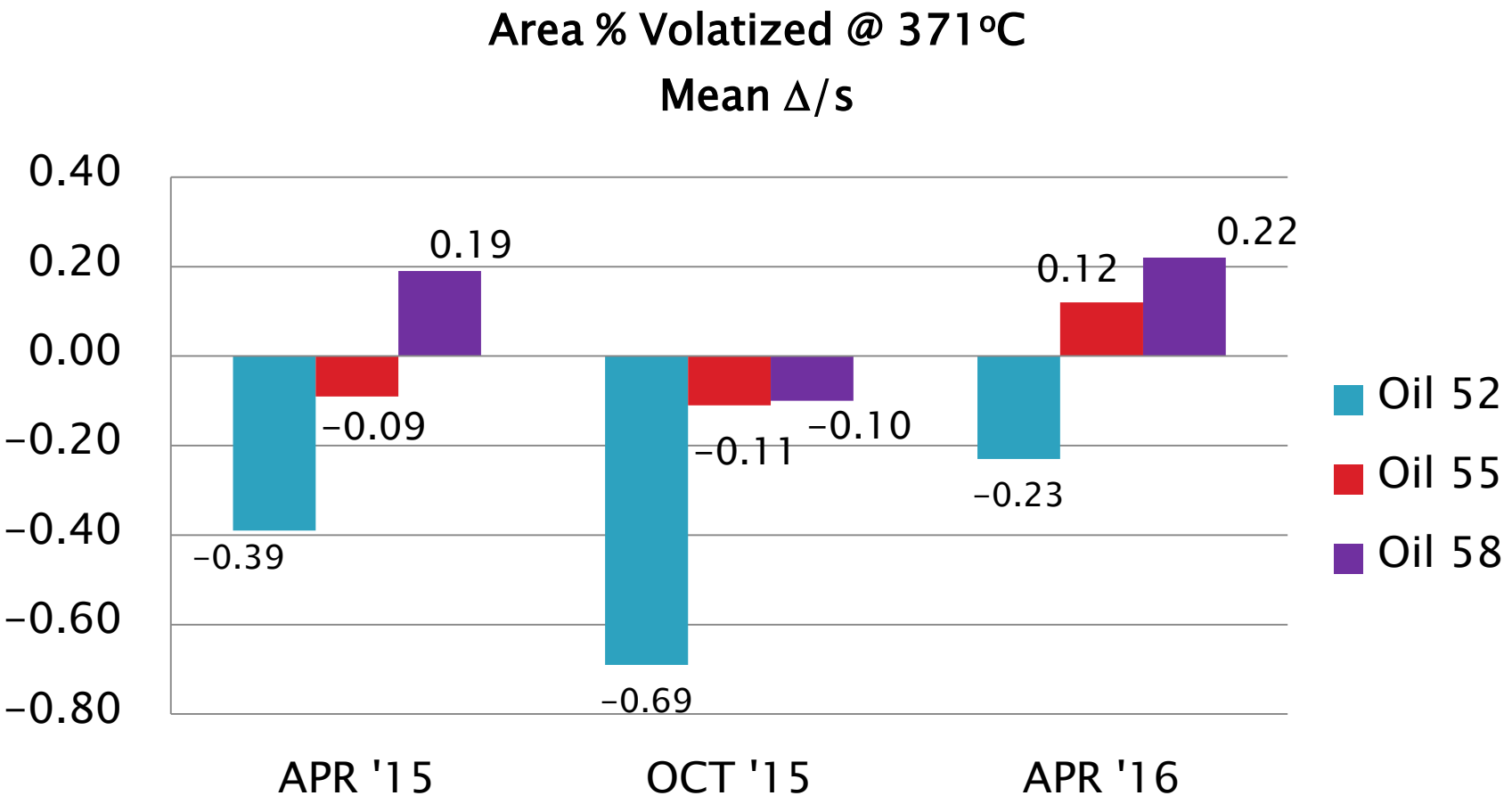
D6417 Performance by Oil



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	46
Failed Calibration Test	OC	11
Operationally Invalidated by Lab	LC, XC	0
Operationally Invalidated After Initially Reported as Valid	RC	0
Total		**57**

Number of Labs Reporting Data: 9
Fail Rate of Operationally Valid Tests: 19%

D5800: Evaporation Loss of Lubricating Oil by Noack Method

Statistically Unacceptable Tests (OC)	No. Of Tests
Evaporation Loss Mild	0
Evaporation Loss Severe	11

- Failing results are across multiple labs, instruments and oils.
  - Apparatus J5 (model NCK25G) contributed three severe fails this period, the most from one instrument; one on VOLC12 and, later, two consecutive on VOLE12.

- Number of operationally valid results reported by oil:
  - VOLC12: 13 AC, 5 OC (severe)
  - VOLD12: 13 AC, 3 OC (severe)
  - VOLE12: 20 AC, 3 OC (severe)

D5800: Evaporation Loss of Lubricating Oil by Noack Method

- There were no technical updates issued this report period.

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	-----
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* 4/1/15 through 9/30/15*	55 54	52 51	0.67 0.61	1.04 0.95
10/1/15 through 3/31/16	57	54	0.50	1.08

*Extreme OC result included and excluded

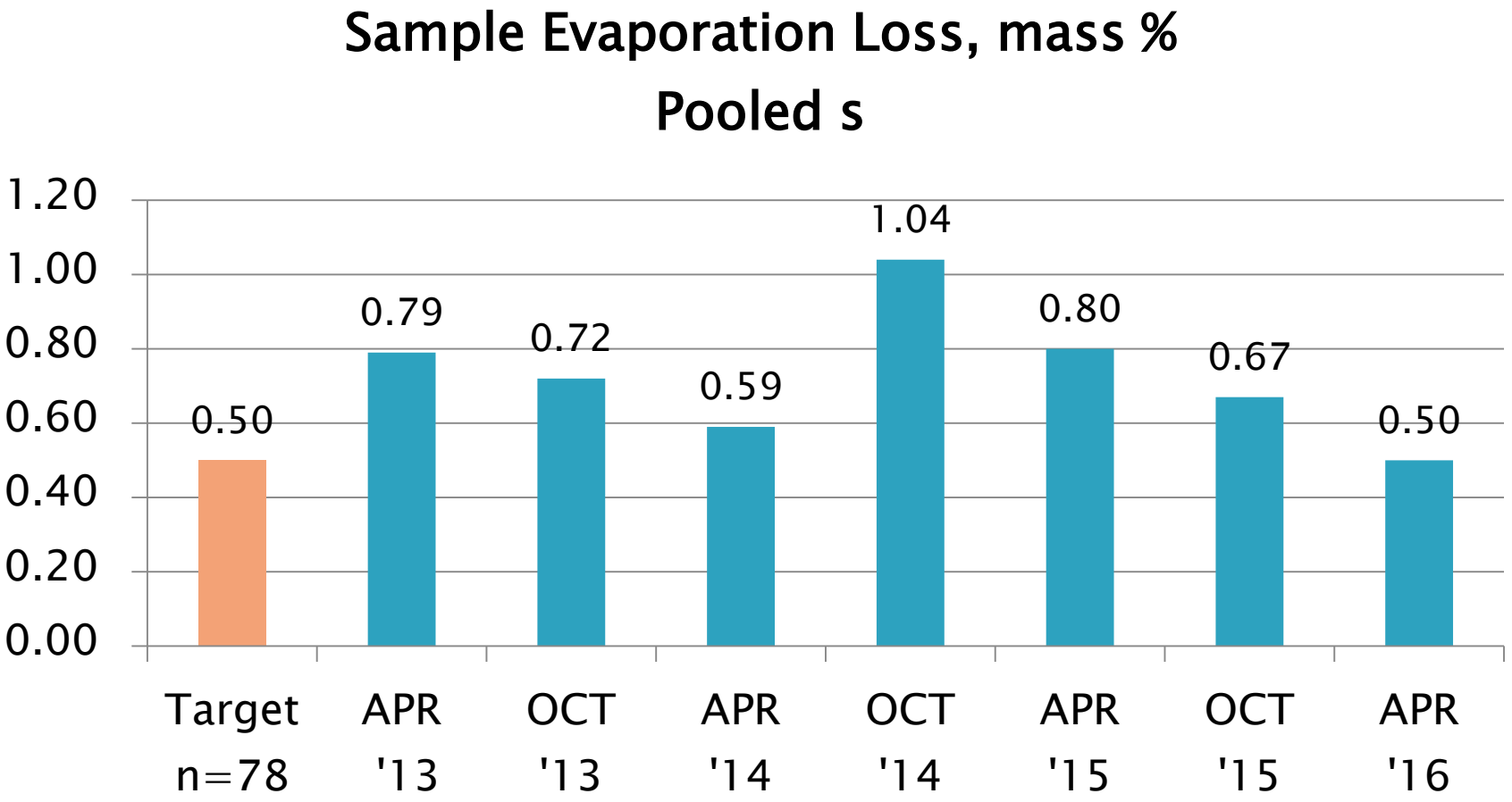
D5800: Evaporation Loss of Lubricating Oil by Noack Method

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

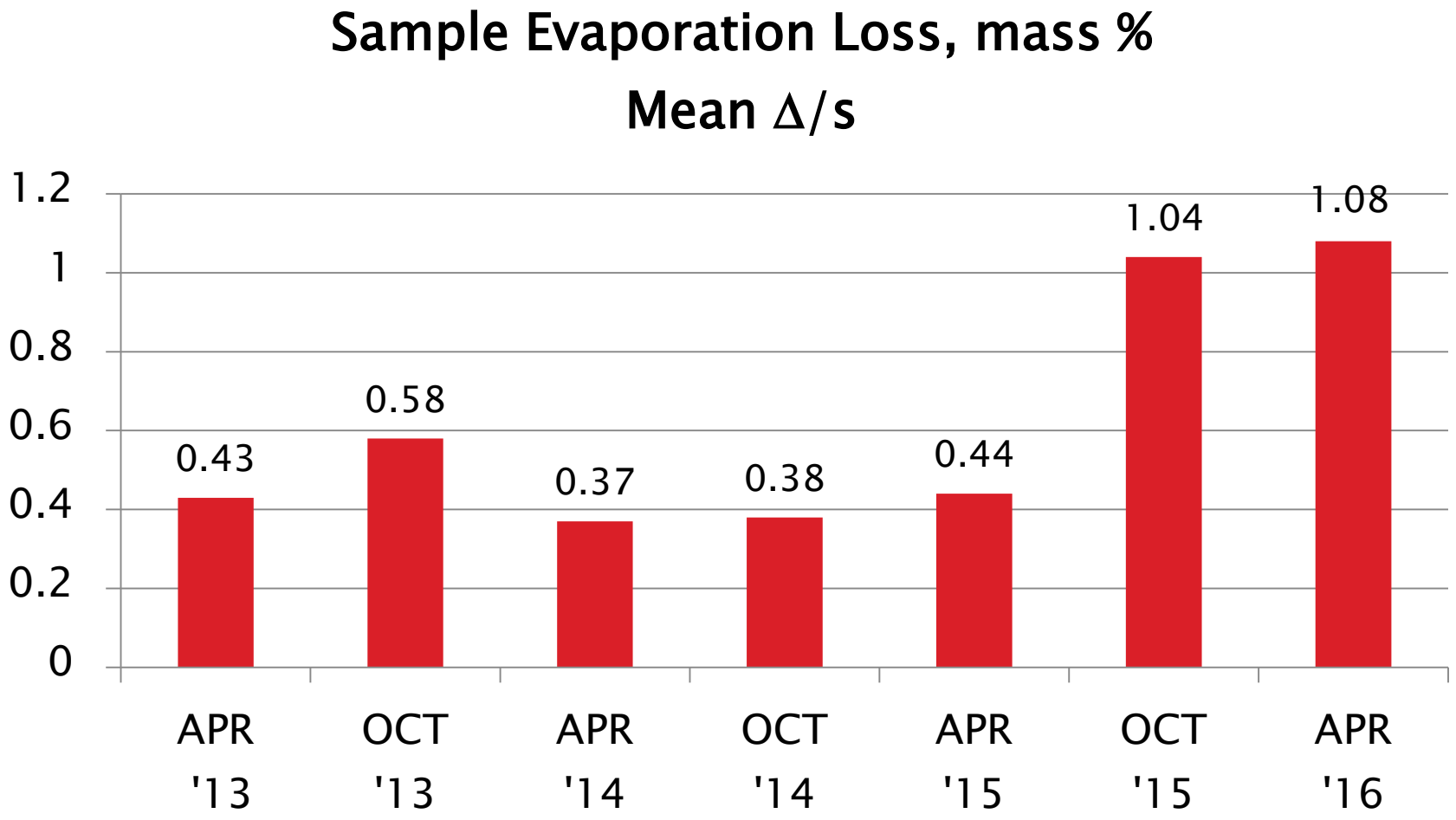
	n	df	Pooled s	Mean Δ/s
Procedure B	50	47	0.50	1.08
Procedure C	7	4	0.47	1.12

Model	n	df	Pooled s	Mean Δ/s
NCK2	11	8	0.32	1.46
NCK25G	39	36	0.54	0.97
SVT1	7	4	0.47	1.12

D5800 Precision Estimates



D5800 Severity Estimates

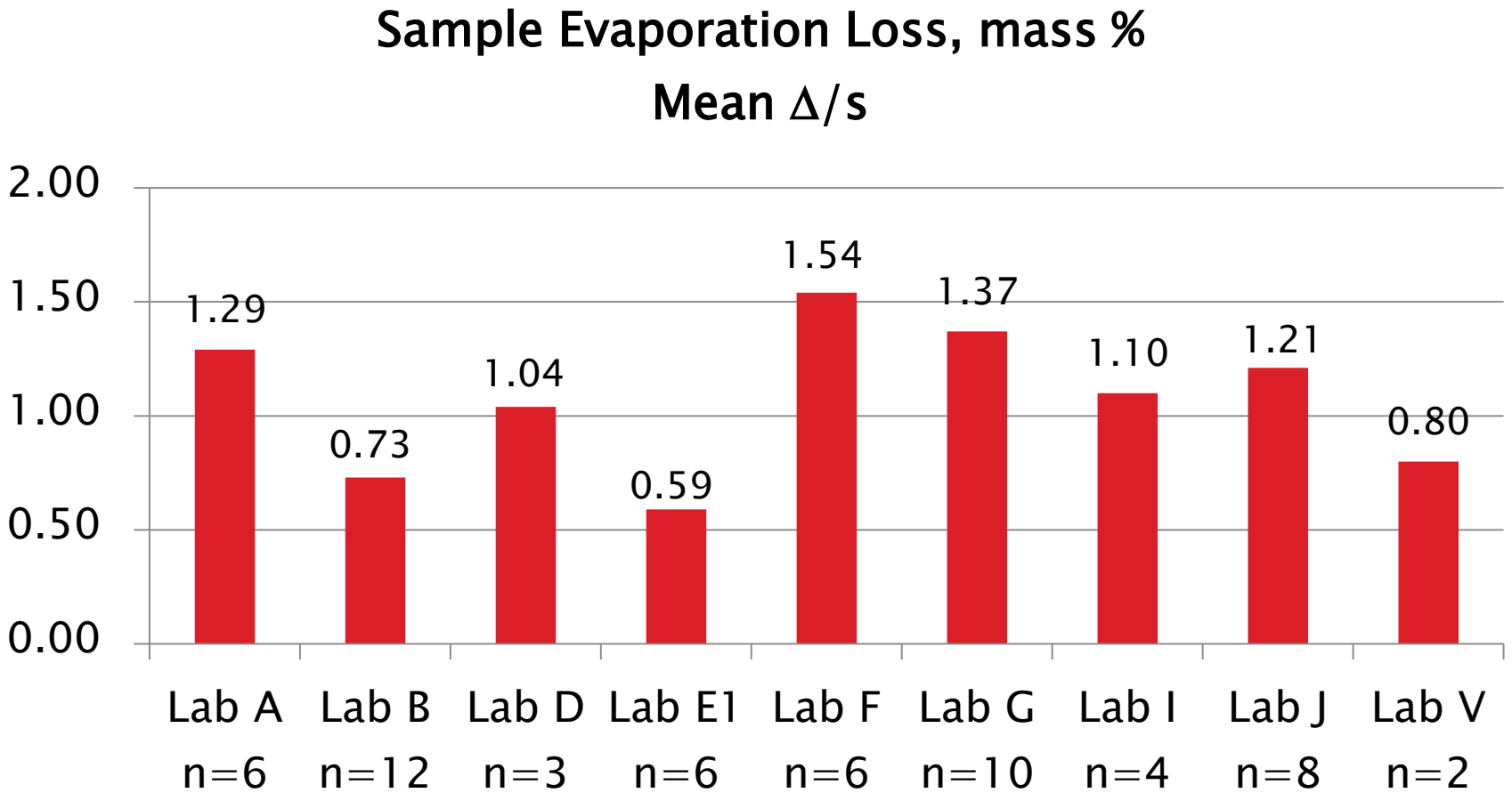


D5800: Evaporation Loss of Lubricating Oil by Noack Method

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

	n	Mean Δ/s
Lab A	6	1.29
Lab B	12	0.73
Lab D	3	1.04
Lab E1	6	0.59
Lab F	6	1.54
Lab G	10	1.37
Lab I	4	1.10
Lab J	8	1.21
Lab V	2	0.80

D5800 Lab Severity Estimates



D5800: Evaporation Loss of Lubricating Oil by Noack Method

- Precision (Pooled s), at 0.50 mass %, is more precise than prior period and matches the target precision.
- Performance (Mean Δ/s) is 1.08 s severe, comparable to last period and more severe than any period since at least April 2010
- Testing has moved substantially more severe over the last two report periods, but precision has improved over that same time.
- Fail rate of operationally valid tests (AC & OC) is 19% (fail rate of the three prior periods was 20%, 27% and 36%).
- Historical long-term severe trend continues with only a modest decrease in severity following the introduction of the new reference oils (3Q 2013), and a substantial increase in severity for the last two report periods.

D5800: Evaporation Loss of Lubricating Oil by Noack Method

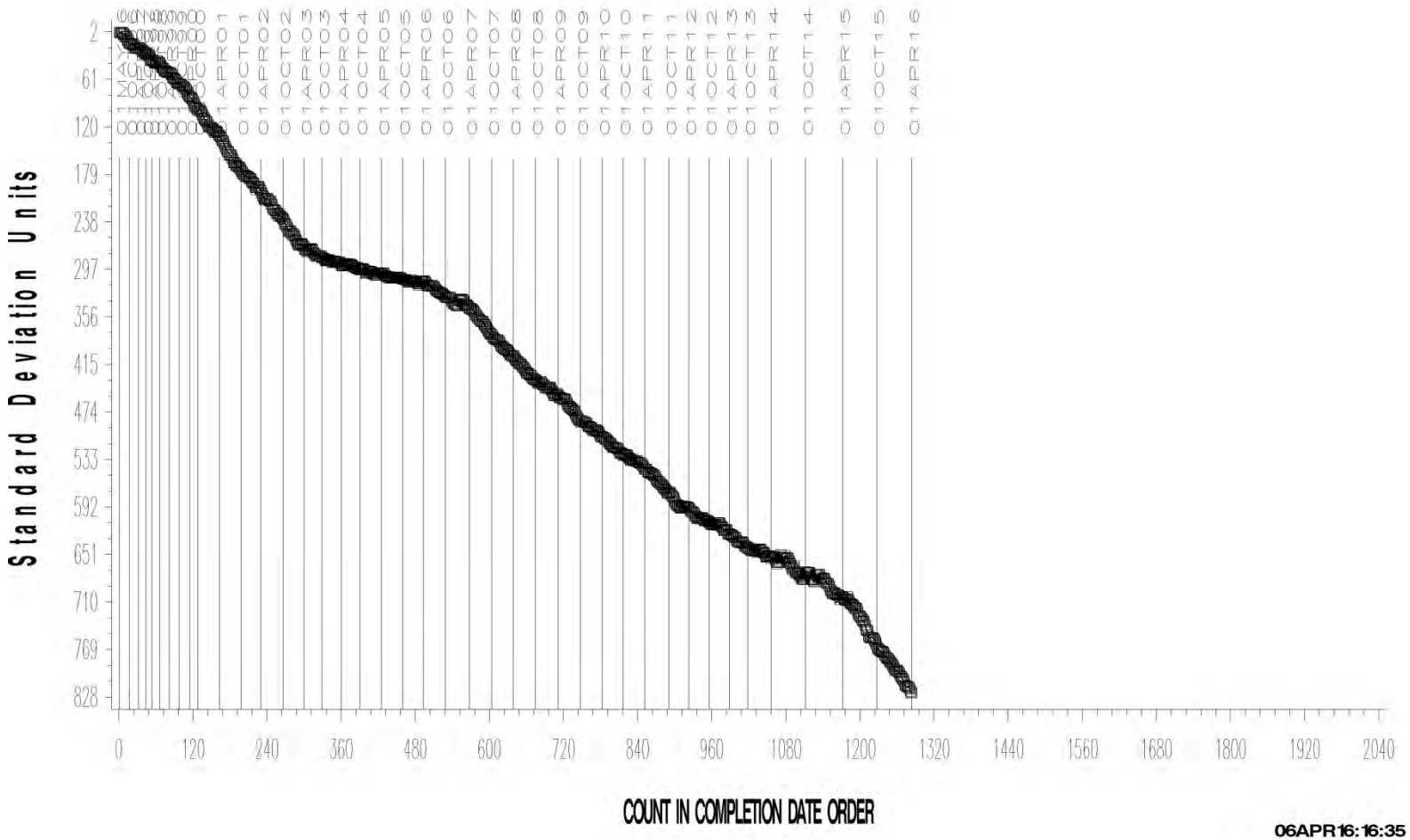
- Breakdown of tests reported this period by severity of results:
  - 2 < and < 3 s severe of targets:
    - 11 tests (two pass on acceptance bands due to rounding)
    - models NCK2 and NCK25G.
  - 3 < and < 4 s severe of targets:
    - 2 tests
    - models NCK2 and SVT1
- All three reference oils are again performing severe, with oil VOLC12 performing 1.5 s severe, and oil VOLE12 performing 0.92 s severe.

D5800 VOLATILITY BY NOACK INDUSTRY OPERATIONALLY VALID DATA

A Program of ASTM International

EVAPORATION LOSS, MASS%

CUSUM Severity Analysis



06APR16:16:35

Test Monitoring Center

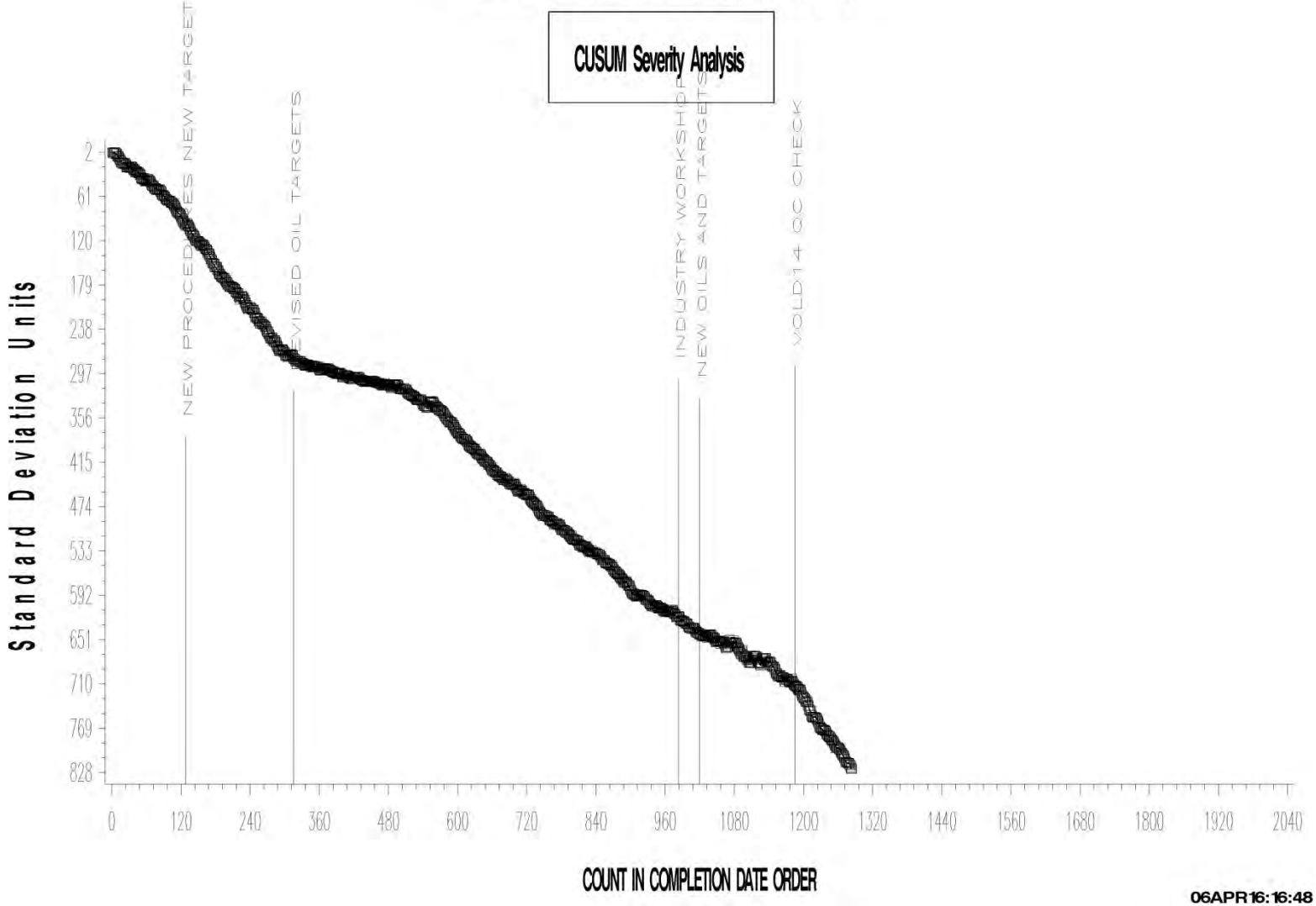
http://astmtmc.cmu.edu

A Program of ASTM International

D5800 VOLATILITY BY NOACK INDUSTRY OPERATIONALLY VALID DATA

A Program of ASTM International

EVAPORATION LOSS, MASS%



06APR16:16:48

Test Monitoring Center

http://astmtmc.cmu.edu

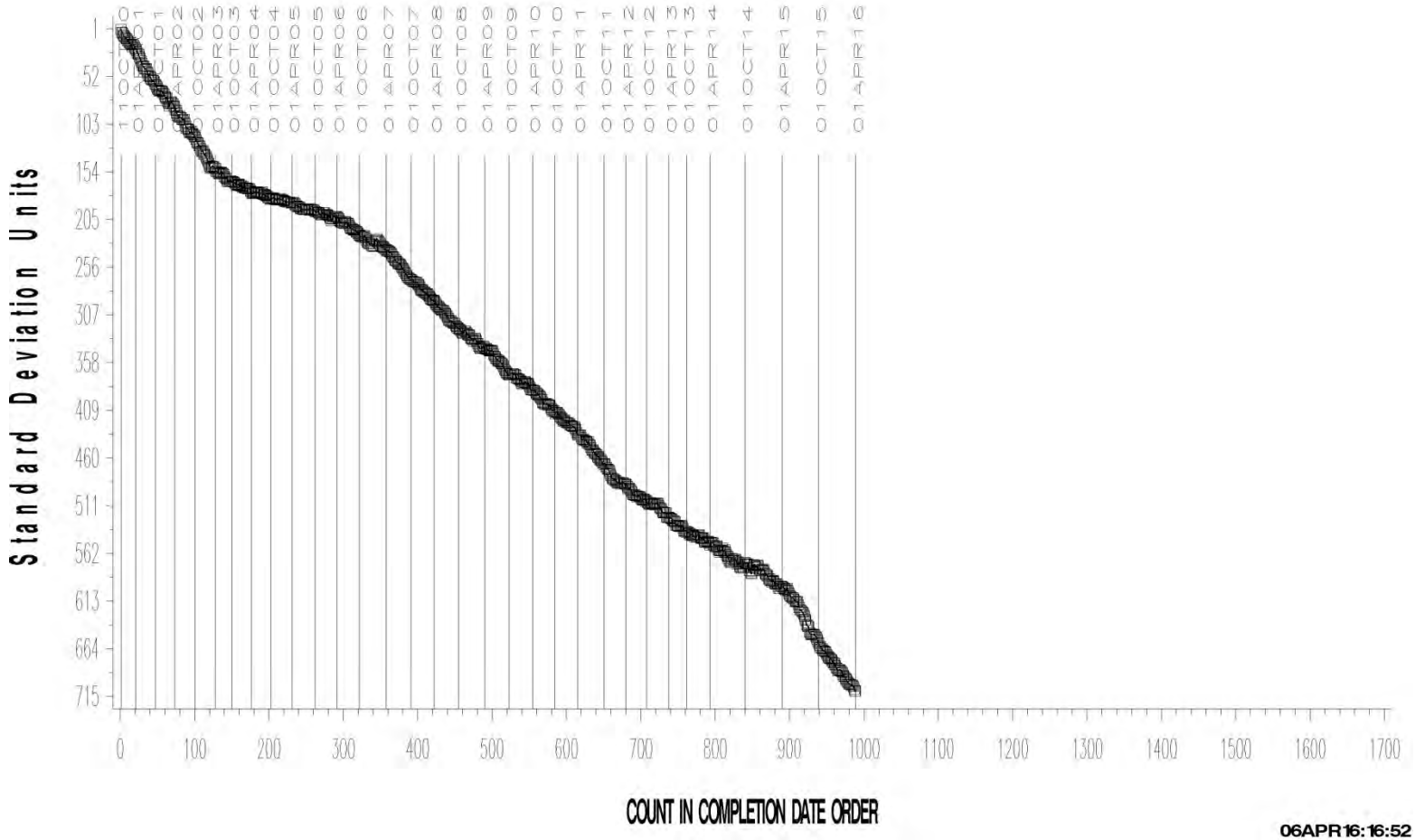
A Program of ASTM International

D5800 VOLATILITY BY NOACK INDUSTRY OPERATIONALLY VALID DATA

PRCDR='B'

EVAPORATION LOSS, MASS%

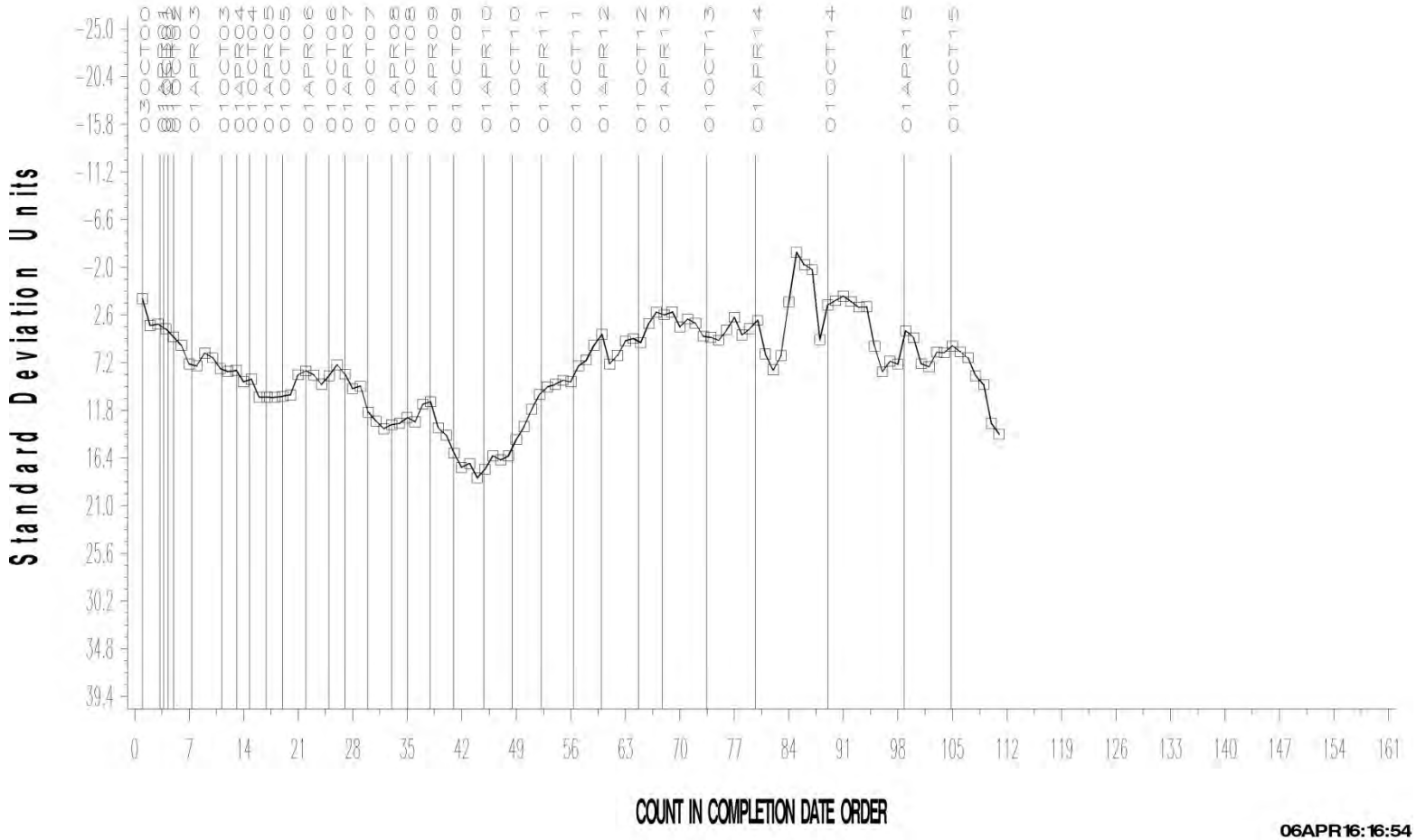
CUSUM Severity Analysis



06APR16:16:52

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

CUSUM Severity Analysis



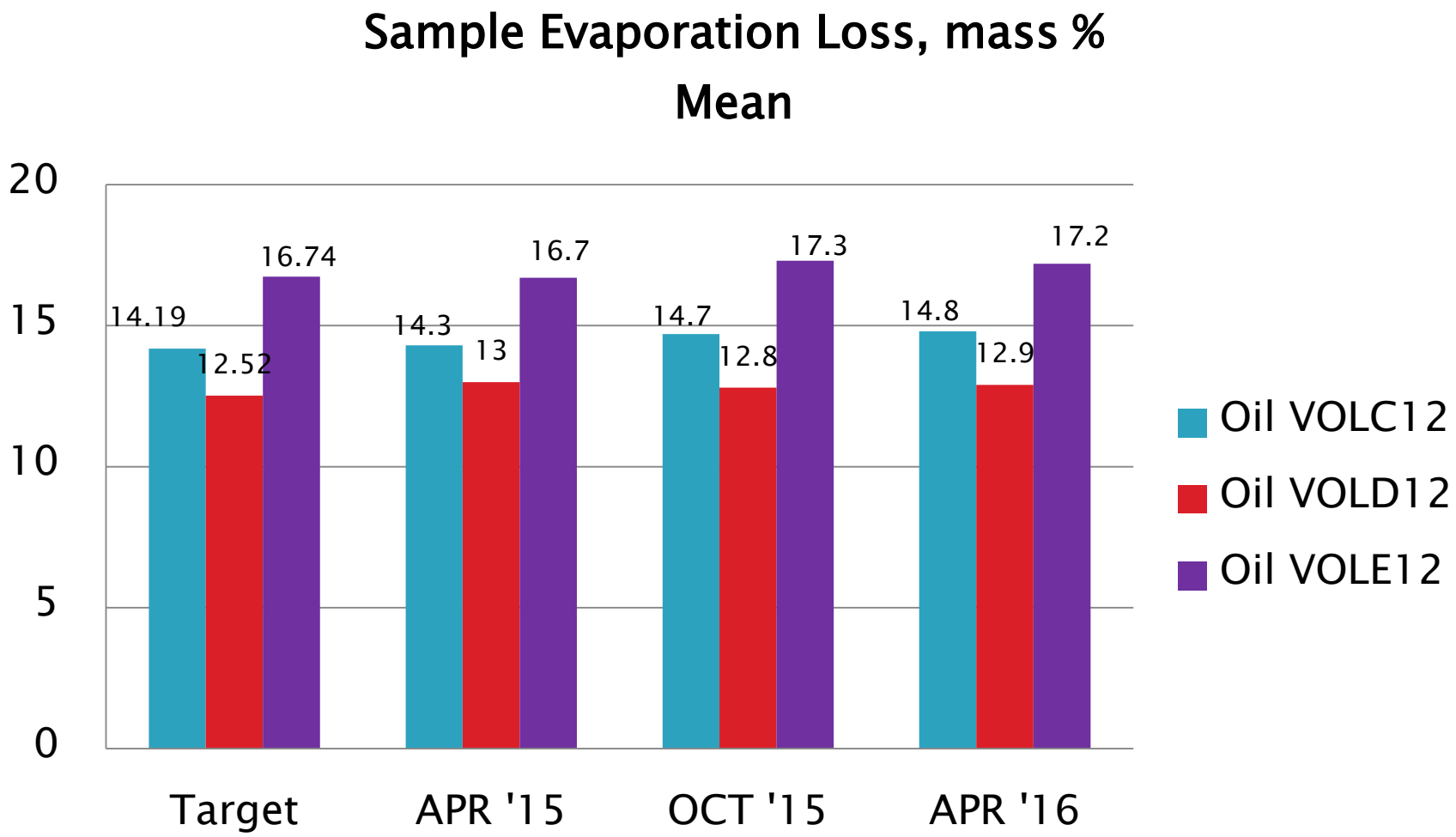
06APR16:16:54

D5800: Evaporation Loss of Lubricating Oil by Noack Method

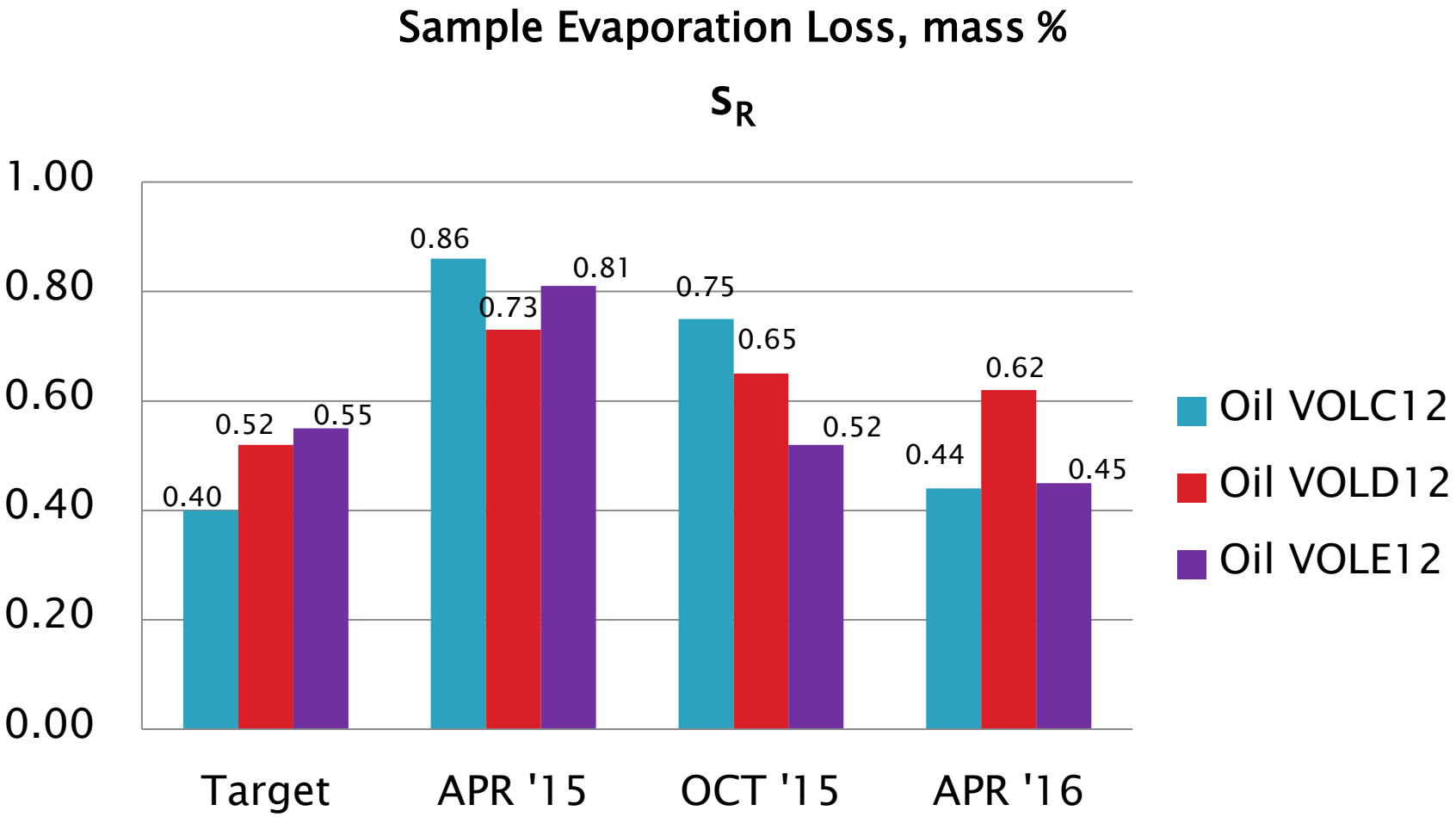
Sample Evaporation Loss, mass %
Performance by Oil

	Targets			10/1/14 – 3/31/15				4/1/135– 9/30/15				10/1/15 – 3/31/16			
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	21	14.3	0.86	0.33	25	14.7	0.75	1.32	18	14.8	0.44	1.57
VOLD12	27	12.52	0.52	21	13.0	0.73	0.93	16	12.8	0.65	0.57	16	12.9	0.62	0.77
VOLE12	27	16.74	0.55	18	16.7	0.81	0.00	14	17.3	0.52	1.10	23	17.2	0.45	0.92

D5800 Performance by Oil

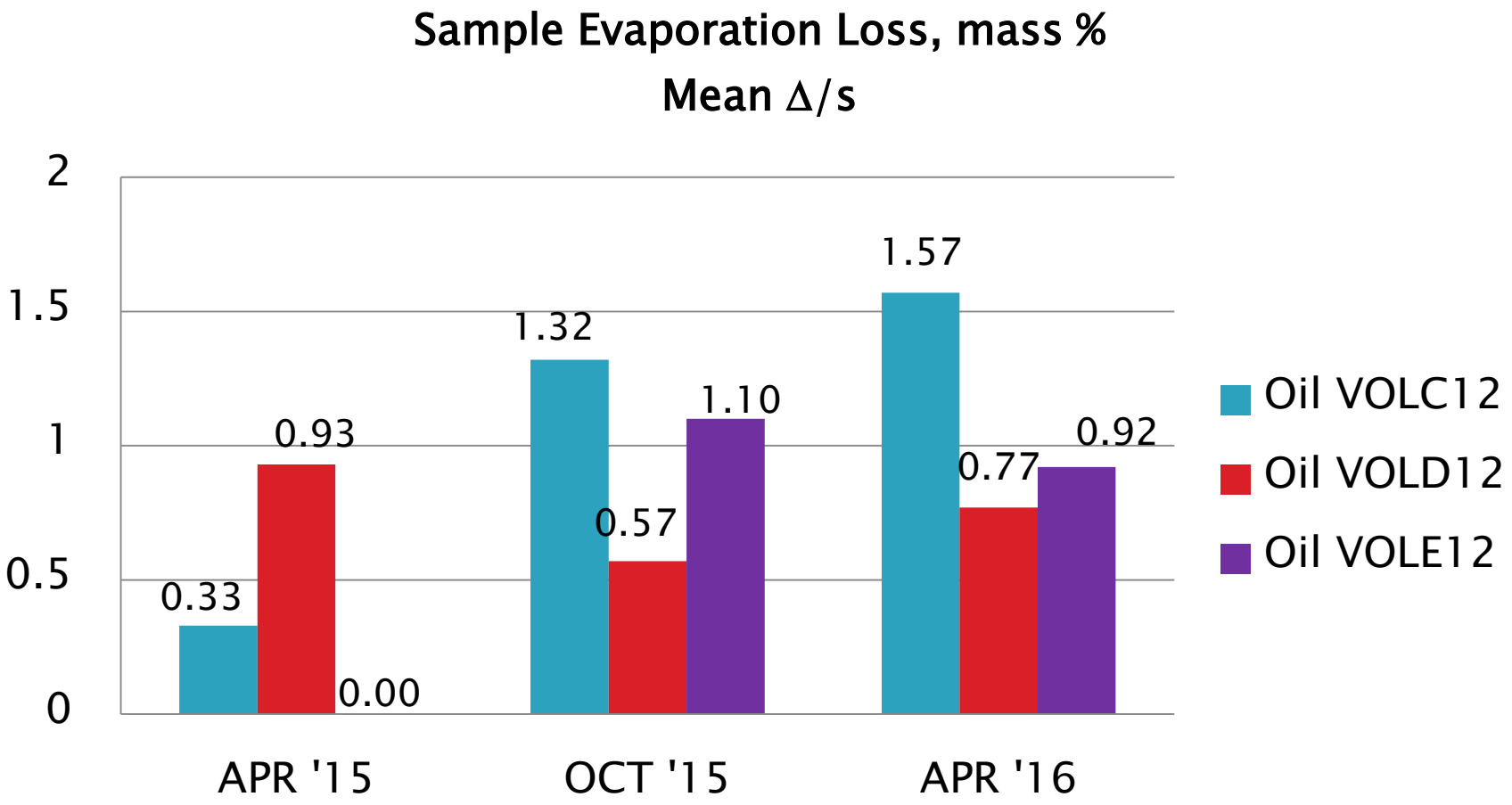


D5800 Performance by Oil



Test Monitoring Center
http://astmtmc.cmu.edu
A Program of ASTM International

D5800 Performance by Oil



Return to Executive Summary

D5133: Gelation Index

Test Status	Validity Code	No. Tests
Acceptable Calibration Test	AC	30
Failed Calibration Test	OC	1
Operationally Invalidated by Lab	LC, XC	2
Operationally Invalidated After Initially Reported as Valid	RC	0
Instrument Shakedown	NN	8
Total		**41**

Number of Labs Reporting Data: 8
Fail Rate of Operationally Valid Tests: 3%

D5133: Gelation Index

Statistically Unacceptable Tests (OC)	No. Of Tests
Gelation Index Mild	1
Gelation Index Severe	0

- Two operationally invalid tests reported this period:
  - Temperature control failure (XC)
  - Software data collection failure (XC)

- New instruments S4 and S5 reported eight shakedown runs (validity NN); lab has not yet reported any calibration runs on these rigs.

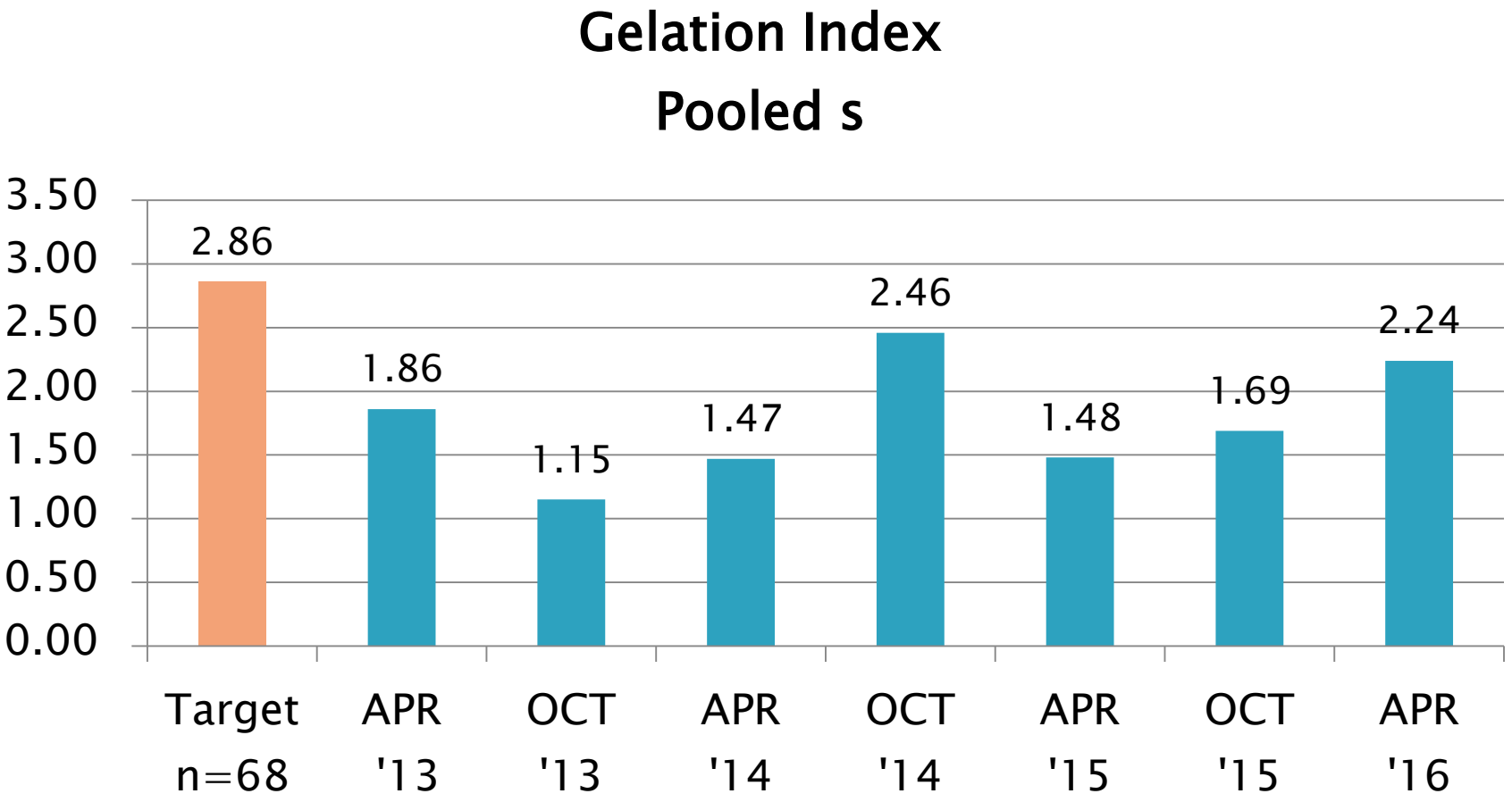
- No TMC technical updates issued this period

D5133: Gelation Index

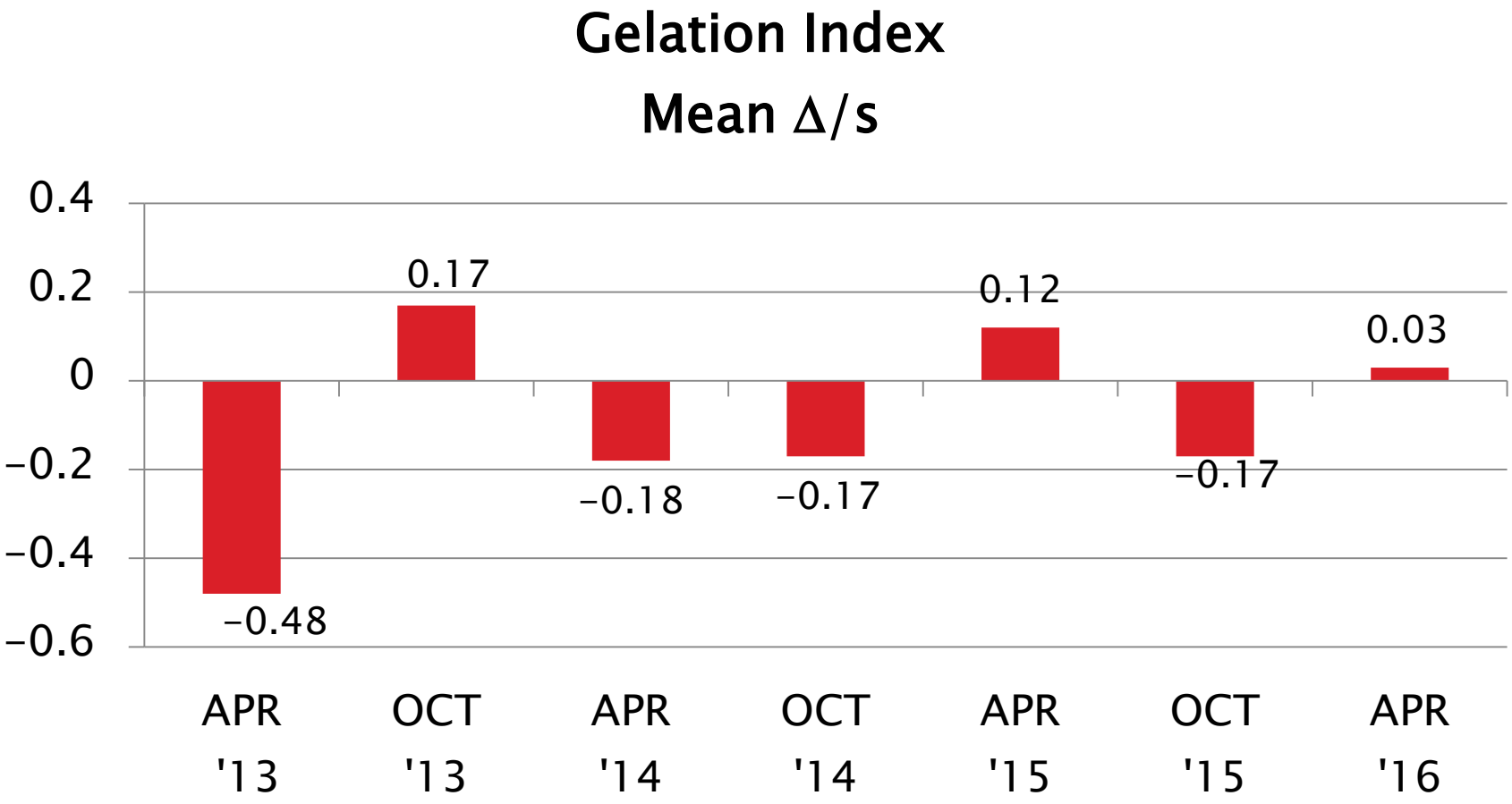
Period Precision and Severity Estimates

Gelation Index	n	df	Pooled s	Mean Δ/s
Current Targets 7/15/2003	68	65	2.86	-----
10/1/12 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
10/1/15 through 3/31/16	31	28	2.24	0.03

D5133 Precision Estimates



D5133 Severity Estimates



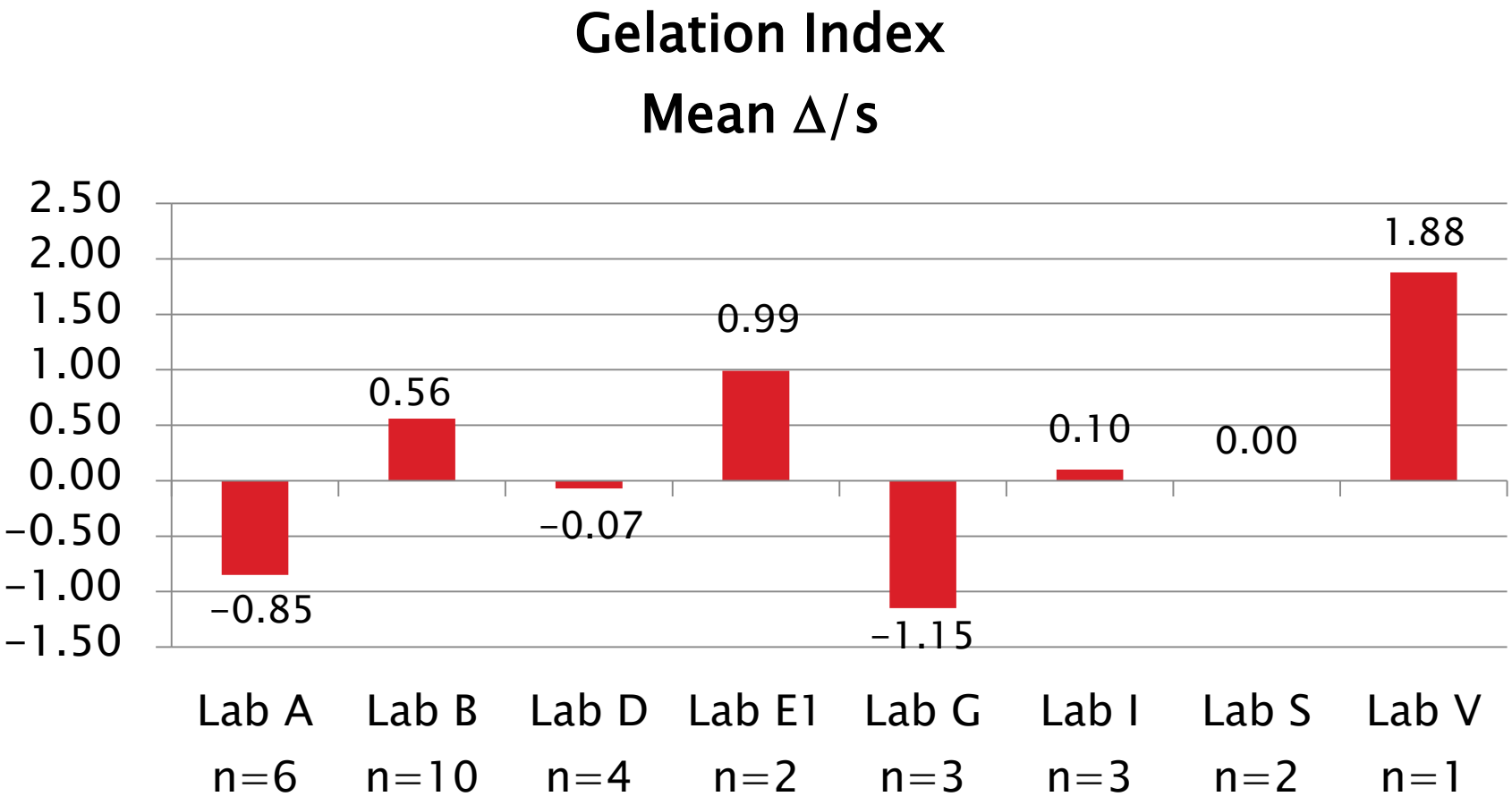
D5133: Gelation Index

Current Period Severity Estimates by Lab

Gelation Index

	n	Mean Δ/s
Lab A	6	-0.85
Lab B	10	0.56
Lab D	4	-0.07
Lab E1	2	0.99
Lab G	3	-1.15
Lab I	3	0.10
Lab S	2	0.00
Lab V	1	1.88

D5133 Lab Severity Estimates



D5133: Gelation Index

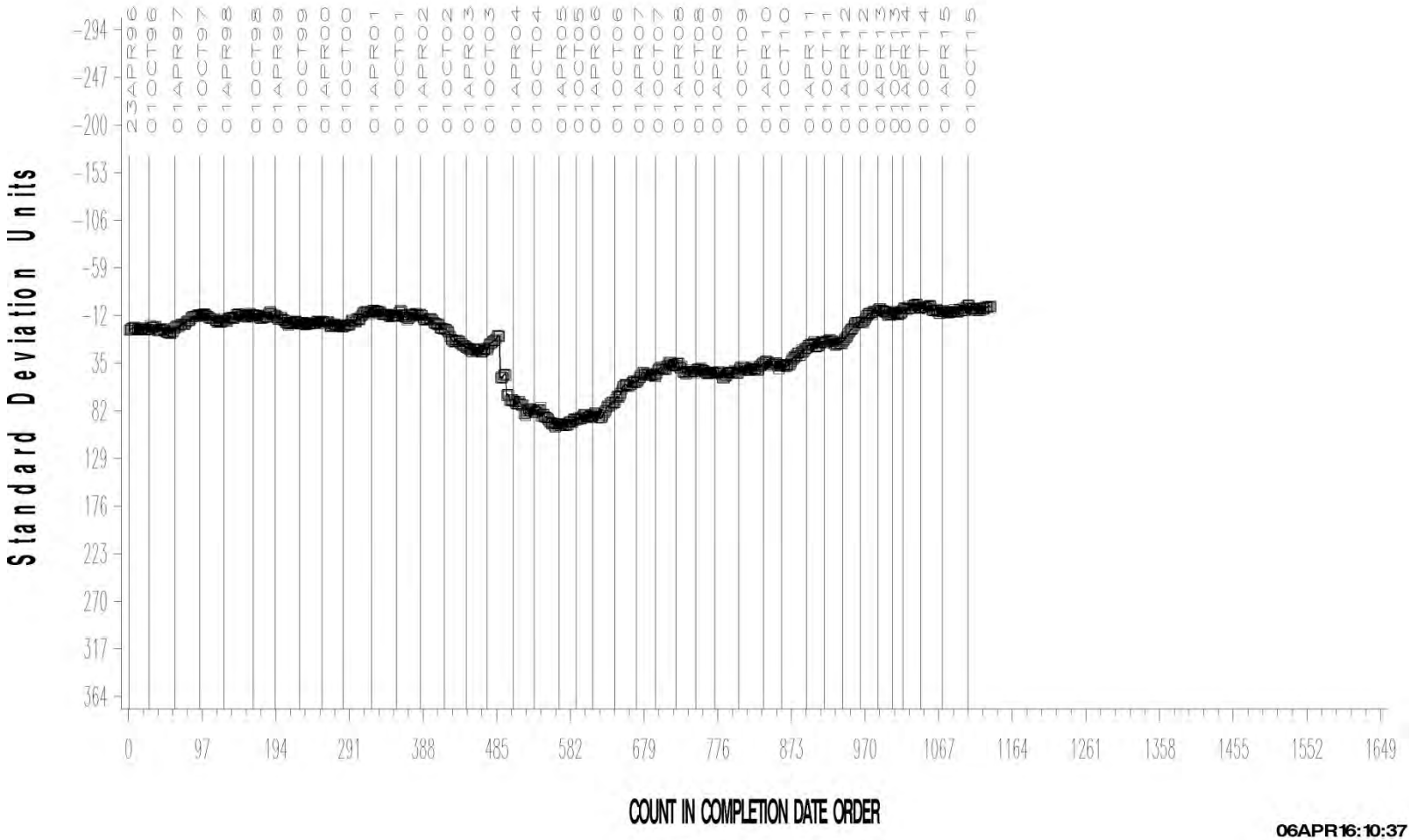
- Precision (Pooled s) is less precise than prior period
  - More precise than target precision
- Performance (Mean Δ/s) is on target (0.03 s)
- Reference oil 62 inventory is down to 1.0 gallons remaining (but only 0.2 gallons shipped prior 12 months).

D5133 GELATION INDEX INDUSTRY OPERATIONALLY VALID DATA

A Program of ASTM International

GELATION INDEX

CUSUM Severity Analysis



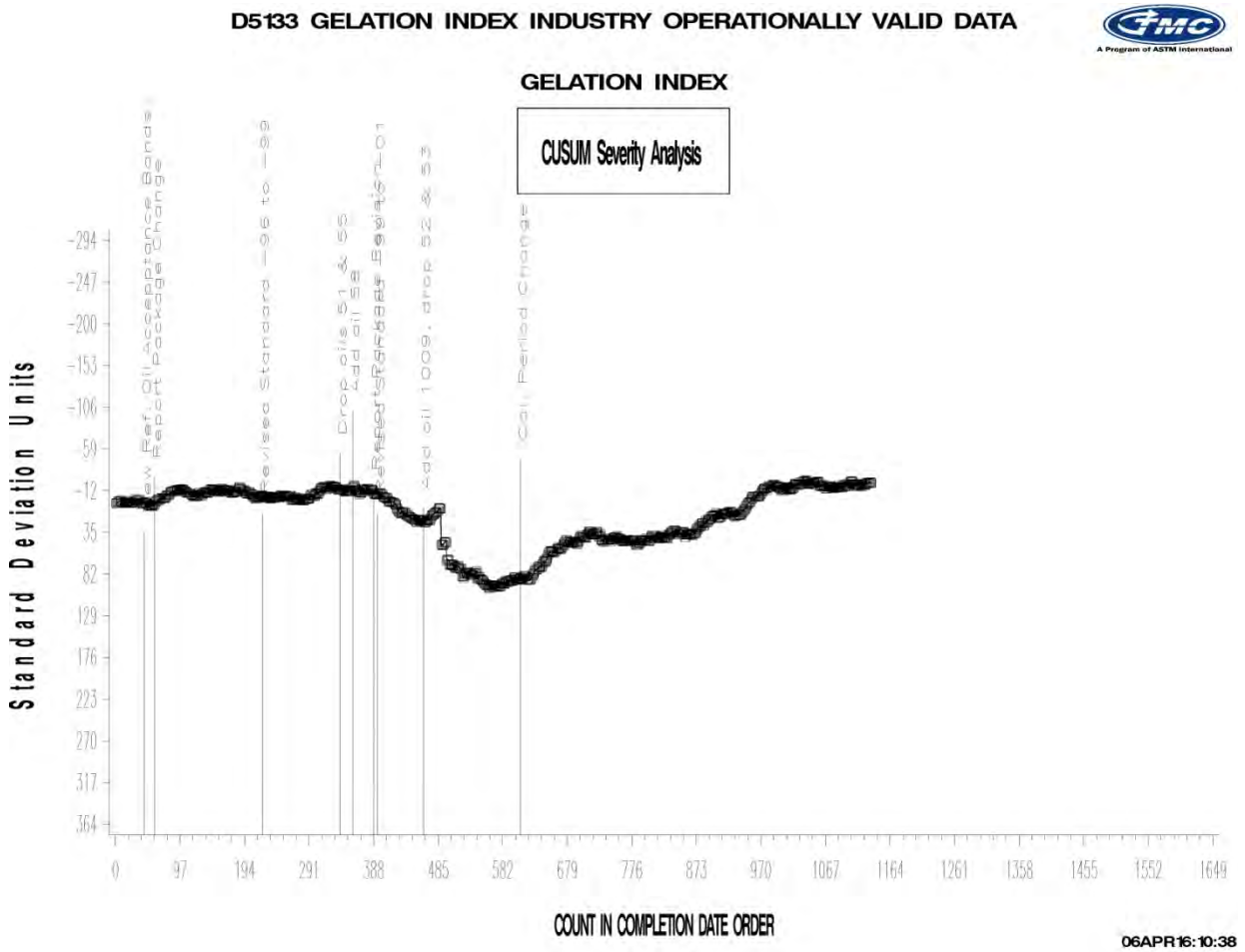
06APR16:10:37

Test Monitoring Center

http://astmtmc.cmu.edu

A Program of ASTM International

D5133: Gelation Index

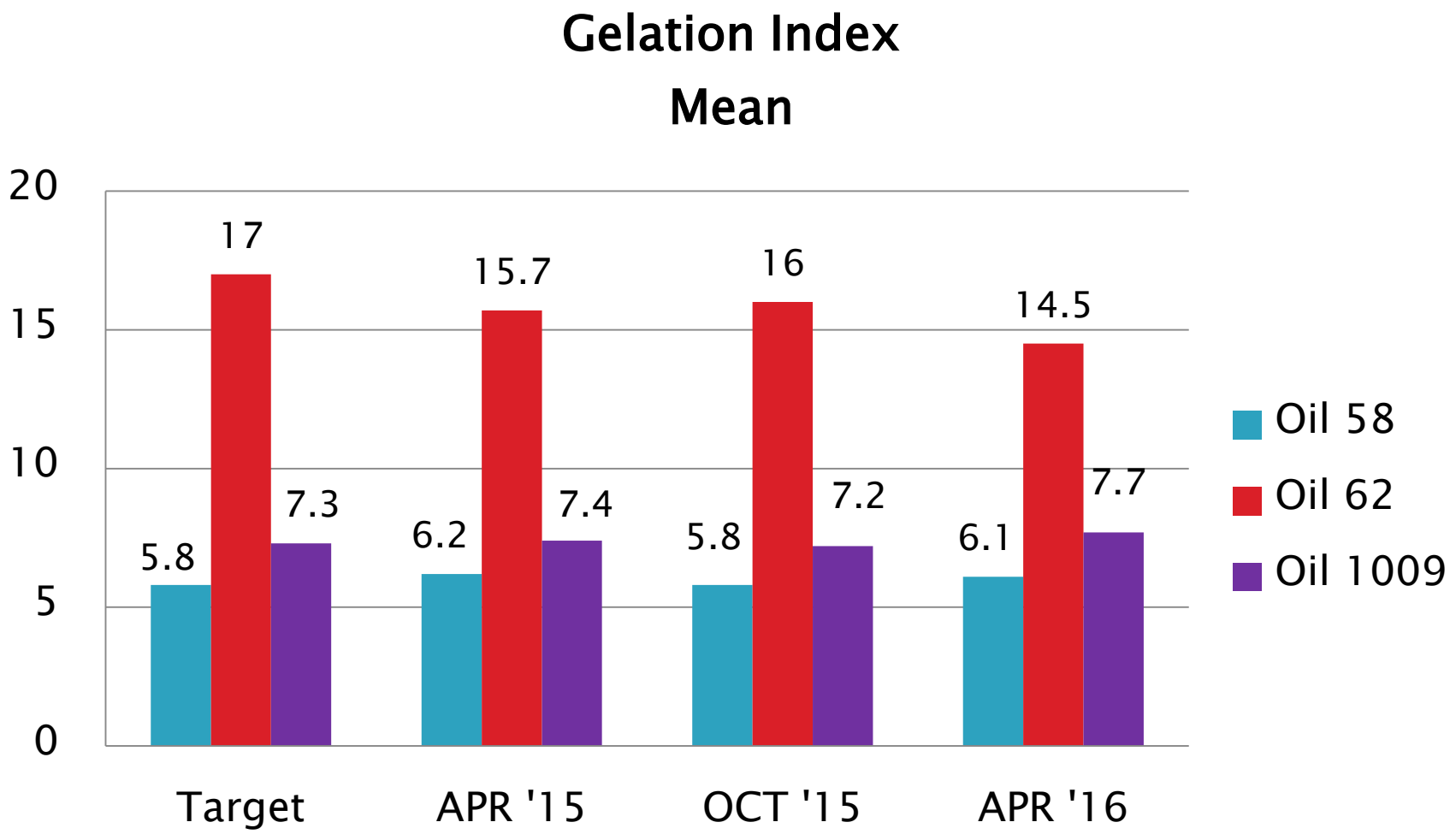


D5133 Performance by Oil

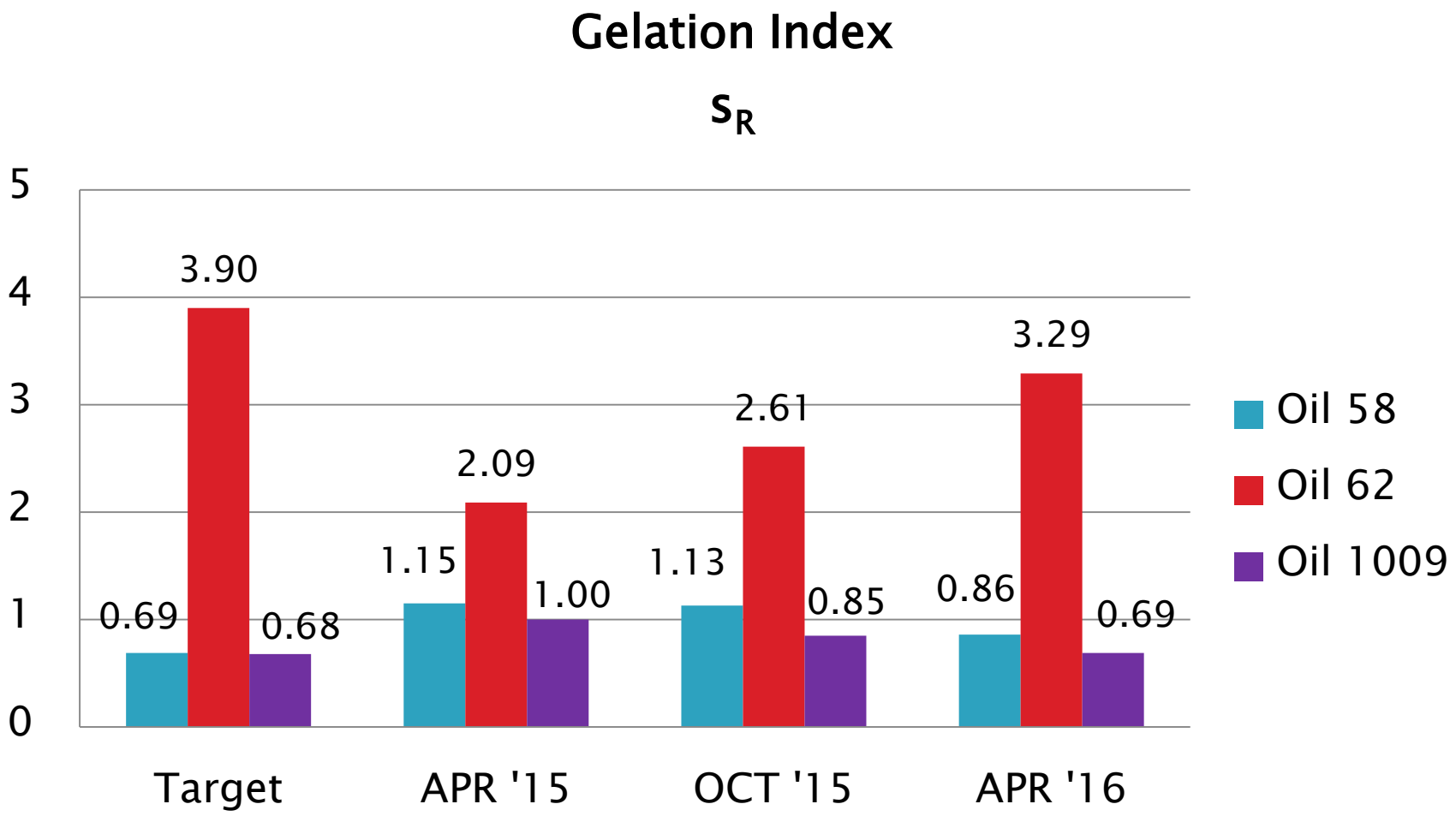
Gelation Index
Performance by Oil

	Targets			10/1/14 – 3/31/15				4/1/145– 9/30/15				10/1/15 – 3/31/16			
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	9	6.2	1.15	0.58	11	5.8	1.13	-0.03	11	6.1	0.86	0.46
62	35	17.0	3.90	9	15.7	2.09	-0.34	11	16.0	2.61	-0.26	13	14.5	3.29	-0.64
1009	16	7.30	0.68	10	7.4	1.00	0.12	12	7.2	0.85	-0.22	7	7.7	0.69	0.61

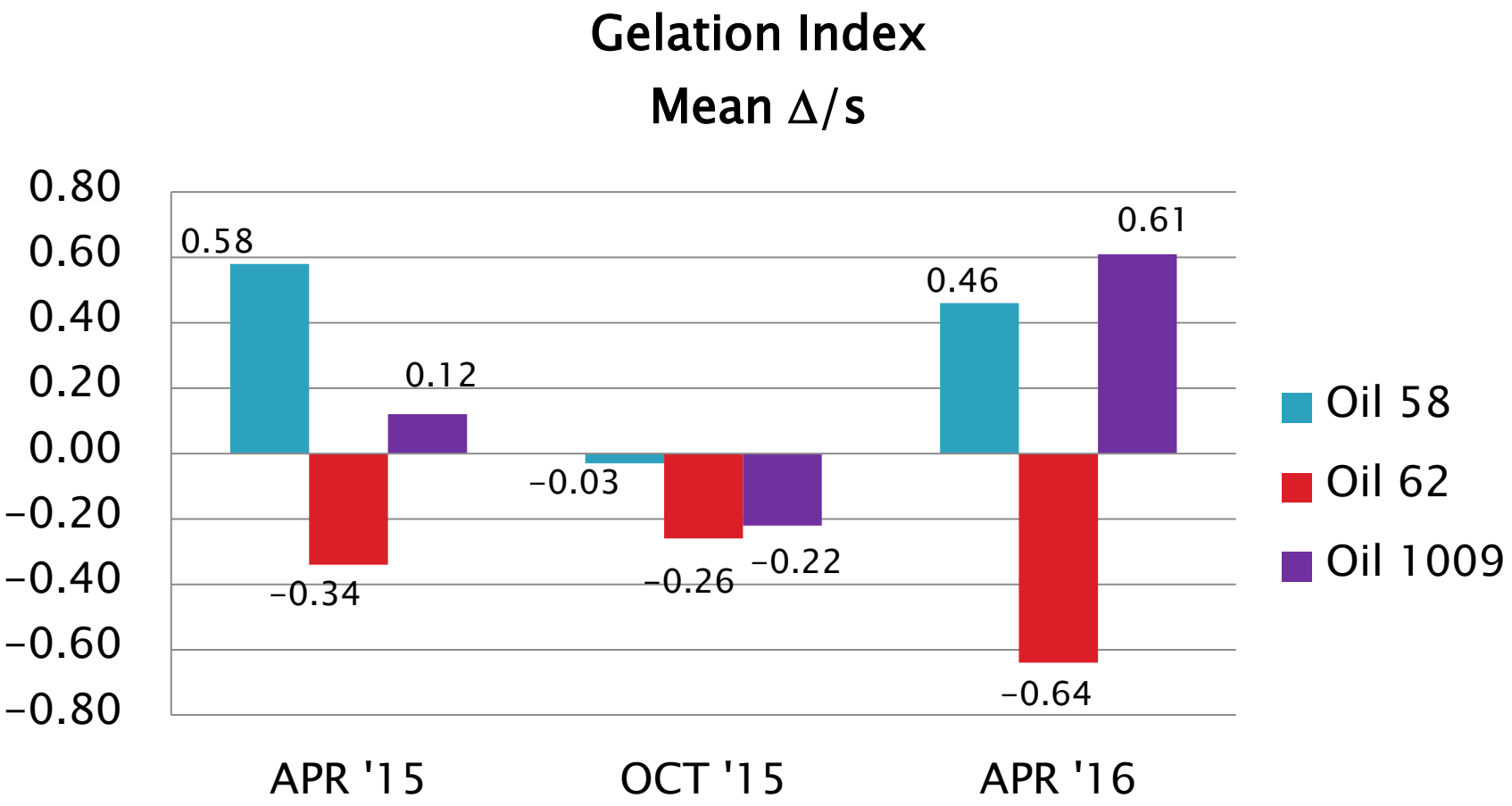
D5133 Performance by Oil



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	0
Operationally Invalidated After Initially Reported as Valid	RC	0
Instrument Shakedown	NN	7
Total		**28**

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	3
Total Deposits Severe	1

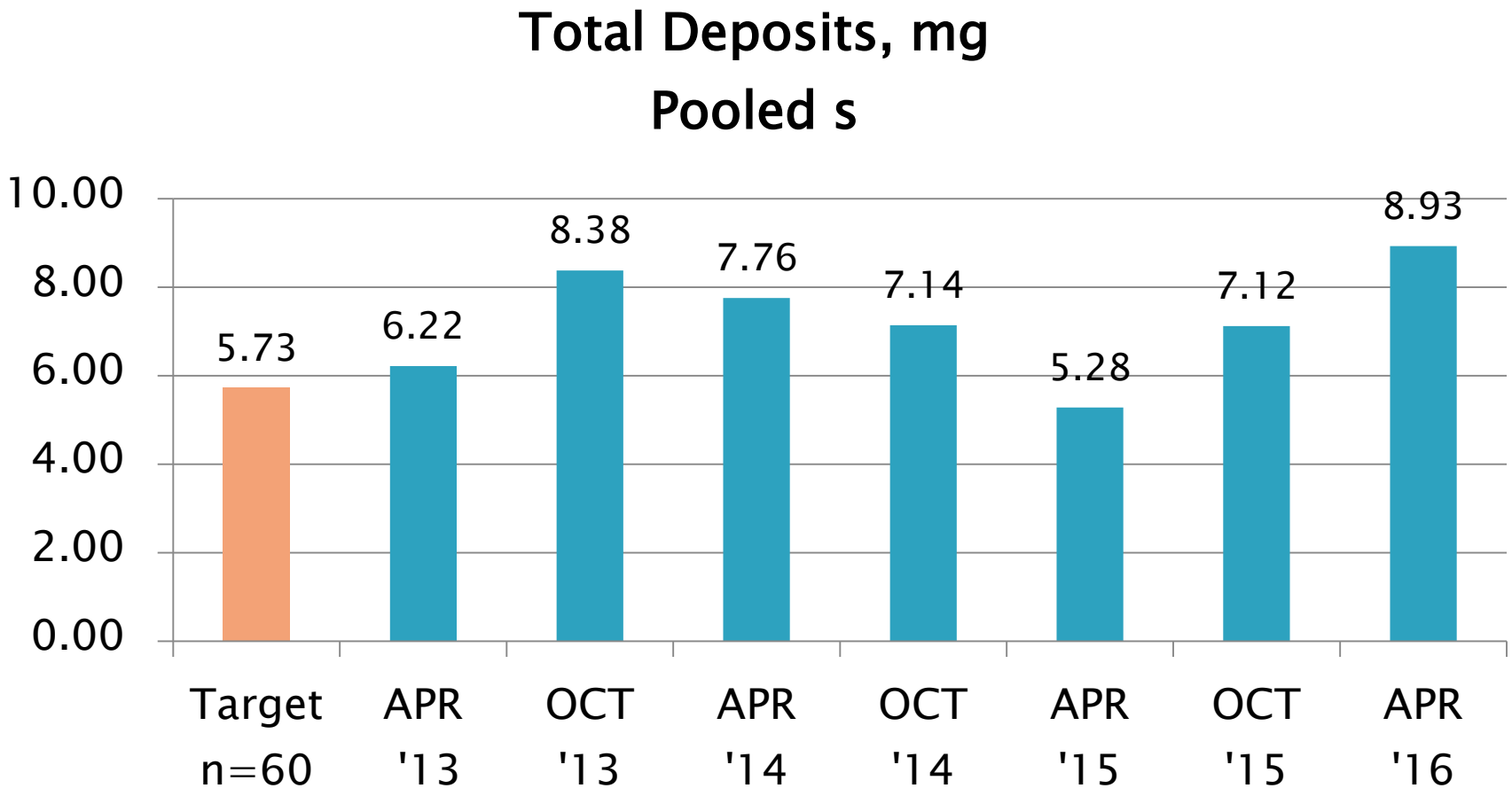
- No operationally invalid tests reported this period
- Shakedown runs on instruments A1, B5 and G2
- No TMC technical updates issued this period

D6335: Deposits by TEOST-33C

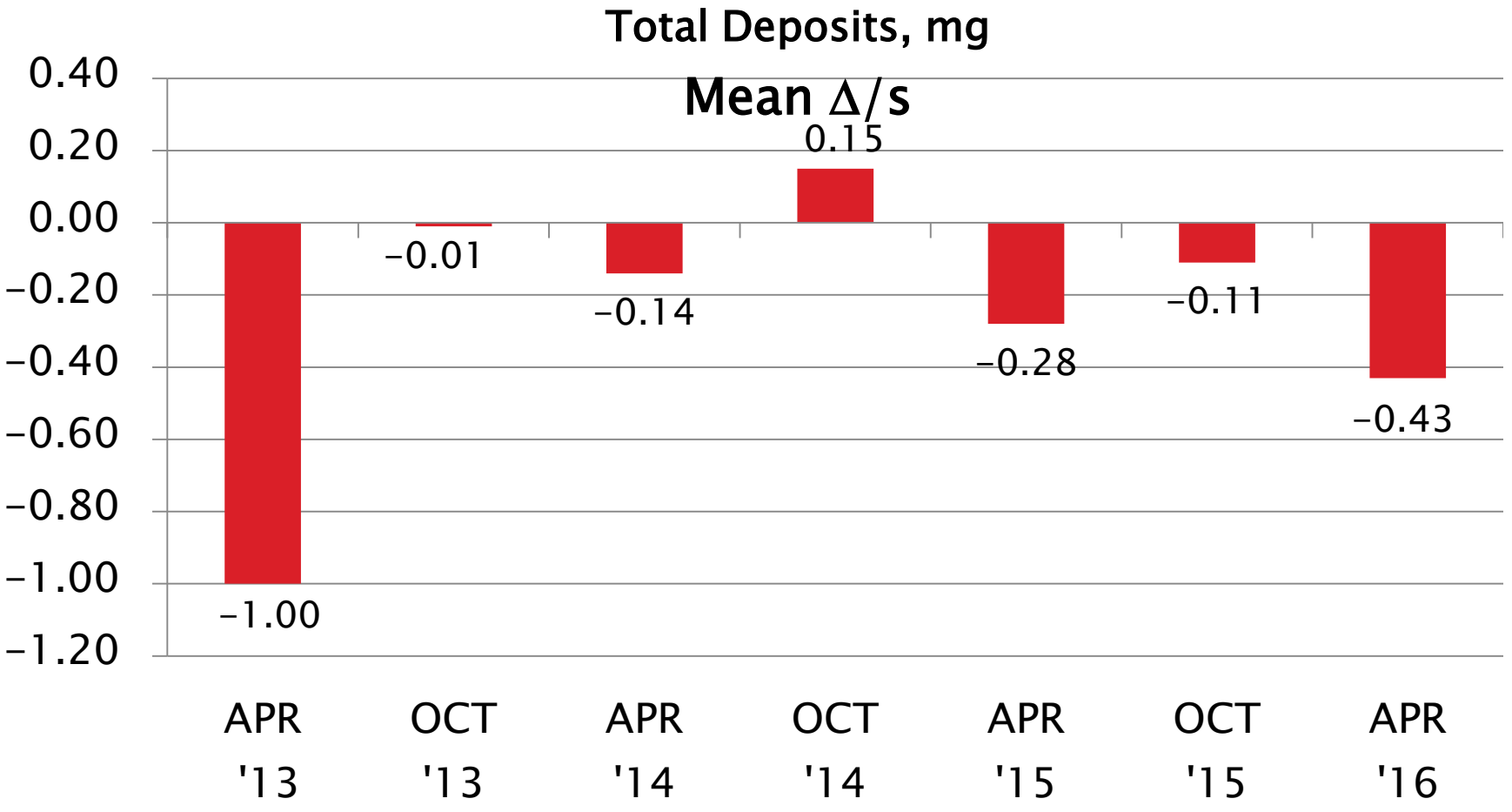
Period Precision and Severity Estimates

Total Deposits, mg	n	df	Pooled s	Mean Δ/s
Updated Targets 20130415	60	58	5.73	-----
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
10/1/15 through 3/31/16	21	19	8.93	-0.43

D6335 Precision Estimates



D6335 Severity Estimates

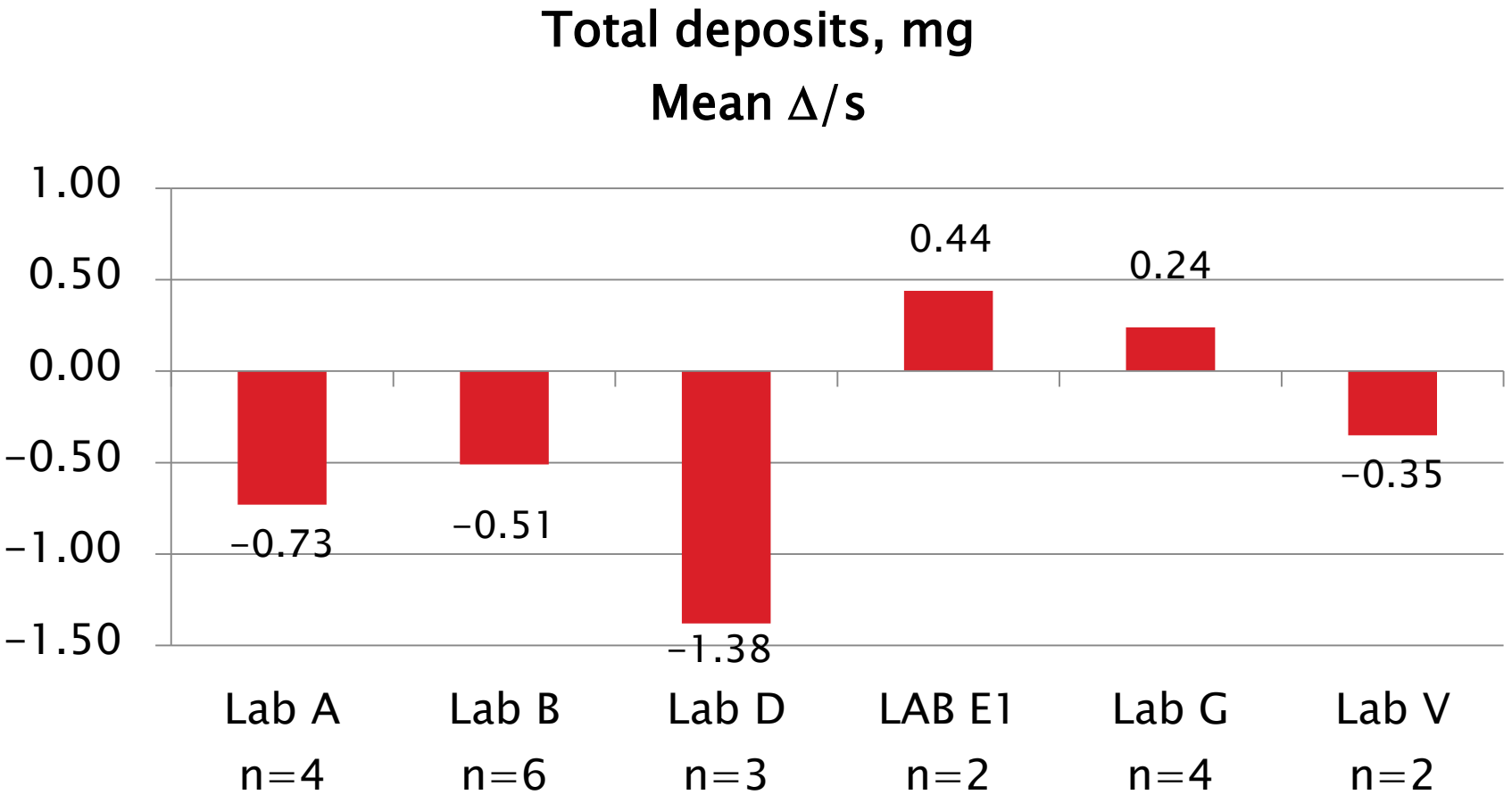


D6335: Deposits by TEOST-33C

Current Period Severity Estimates by Lab
Total Deposits, mg

	n	Mean Δ/s
Lab A	4	-0.73
Lab B	6	-0.51
Lab D	3	-1.38
Lab E1	2	0.44
Lab G	4	0.24
Lab V	2	-0.35

D6335 Lab Severity Estimates



D6335: Deposits by TEOST-33C

- Precision (Pooled s) is less precise than prior period
  - Less precise than target precision
  - Less precise than all periods since at least April 2013

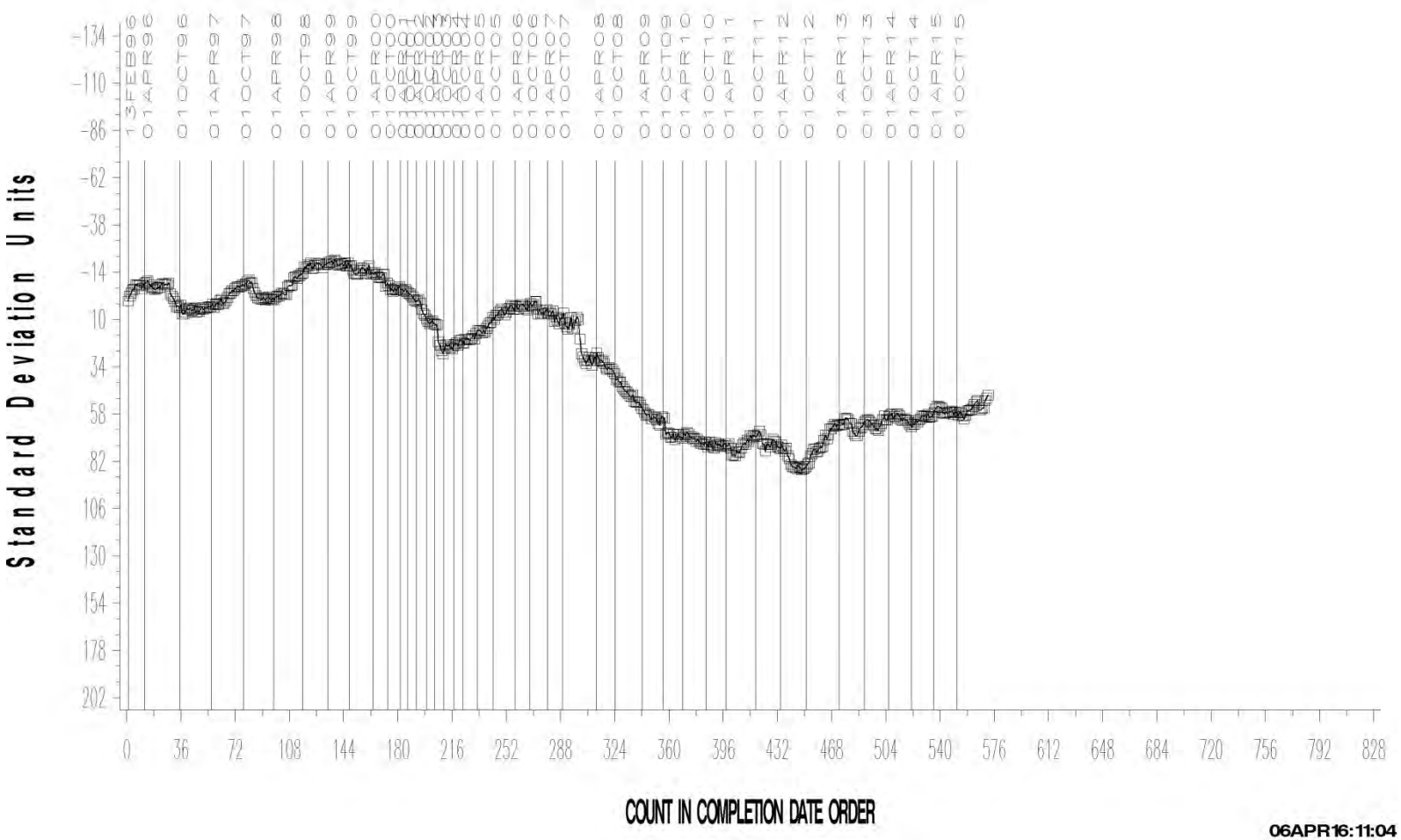
- Performance (Mean Δ/s) is -0.43 s mild
  - Instrument G2 reported results 1.2 s, 4.8 s, -3.7 s and -1.3 s this period, with a mean severity of only 0.25 s, but contributing to the overall poor precision this period.
  - Instrument B5 had two consecutive fails, one 2 s and one -2 s, balancing out on severity, but also contributing to the poor precision estimate this period.

- All tests this period report using Rod Batches L or M

TEOST—33C INDUSTRY OPERATIONALLY VALID DATA

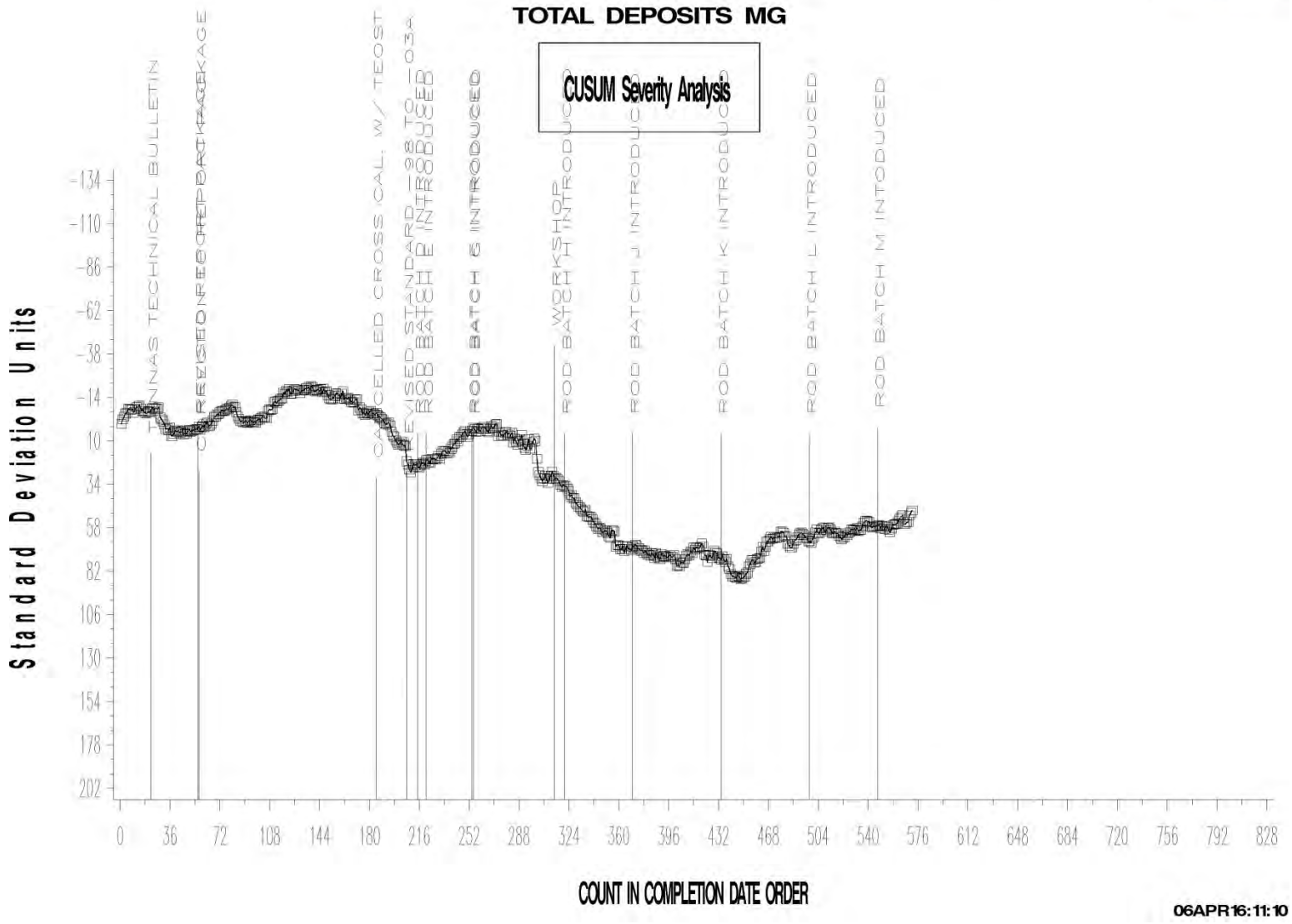
TOTAL DEPOSITS MG

CUSUM Severity Analysis



06APR16:11:04

TEOST–33C INDUSTRY OPERATIONALLY VALID DATA



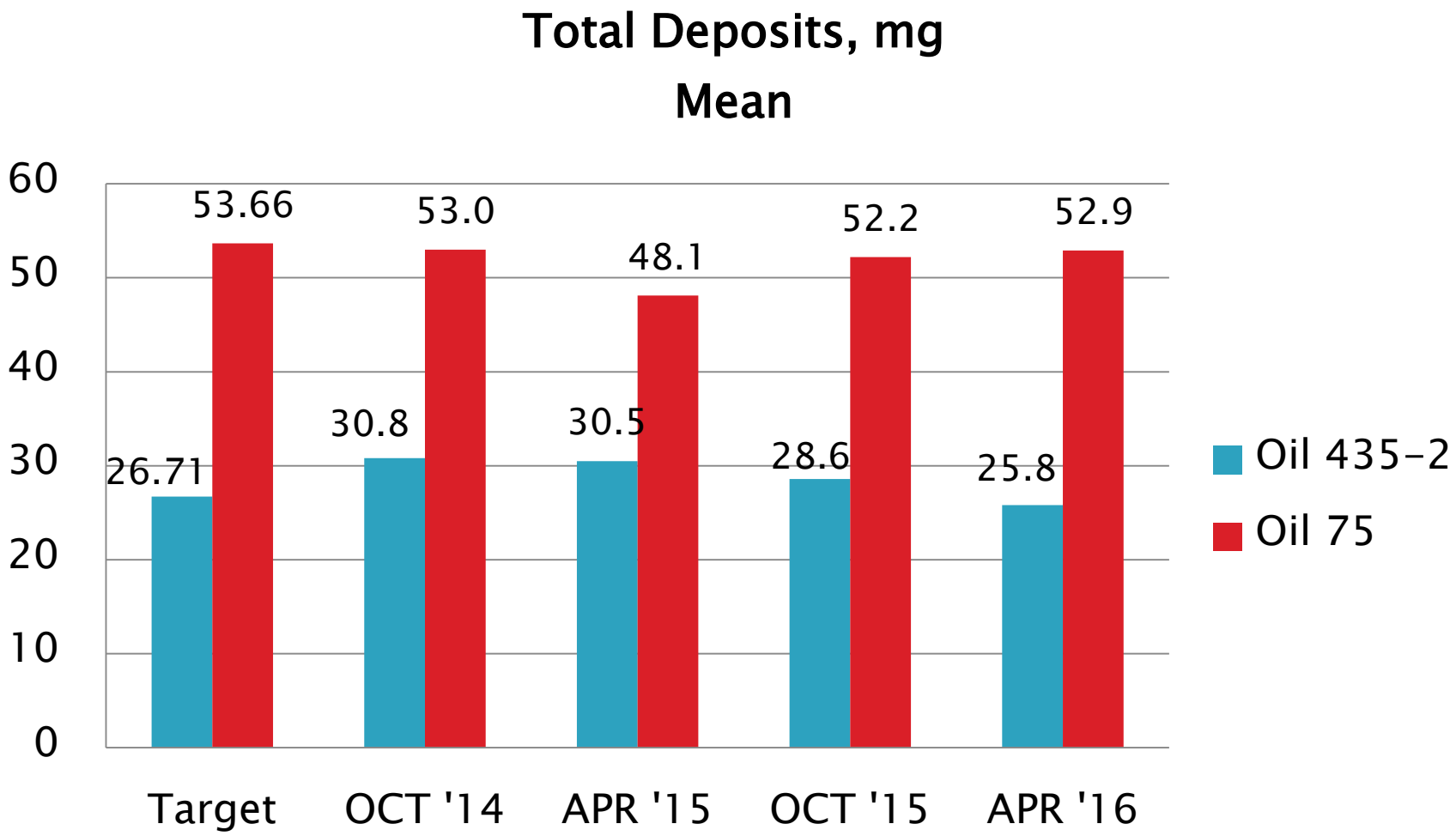
06APR16:11:10

D6335 Performance by Oil

Total Deposits, mg
Performance by Oil

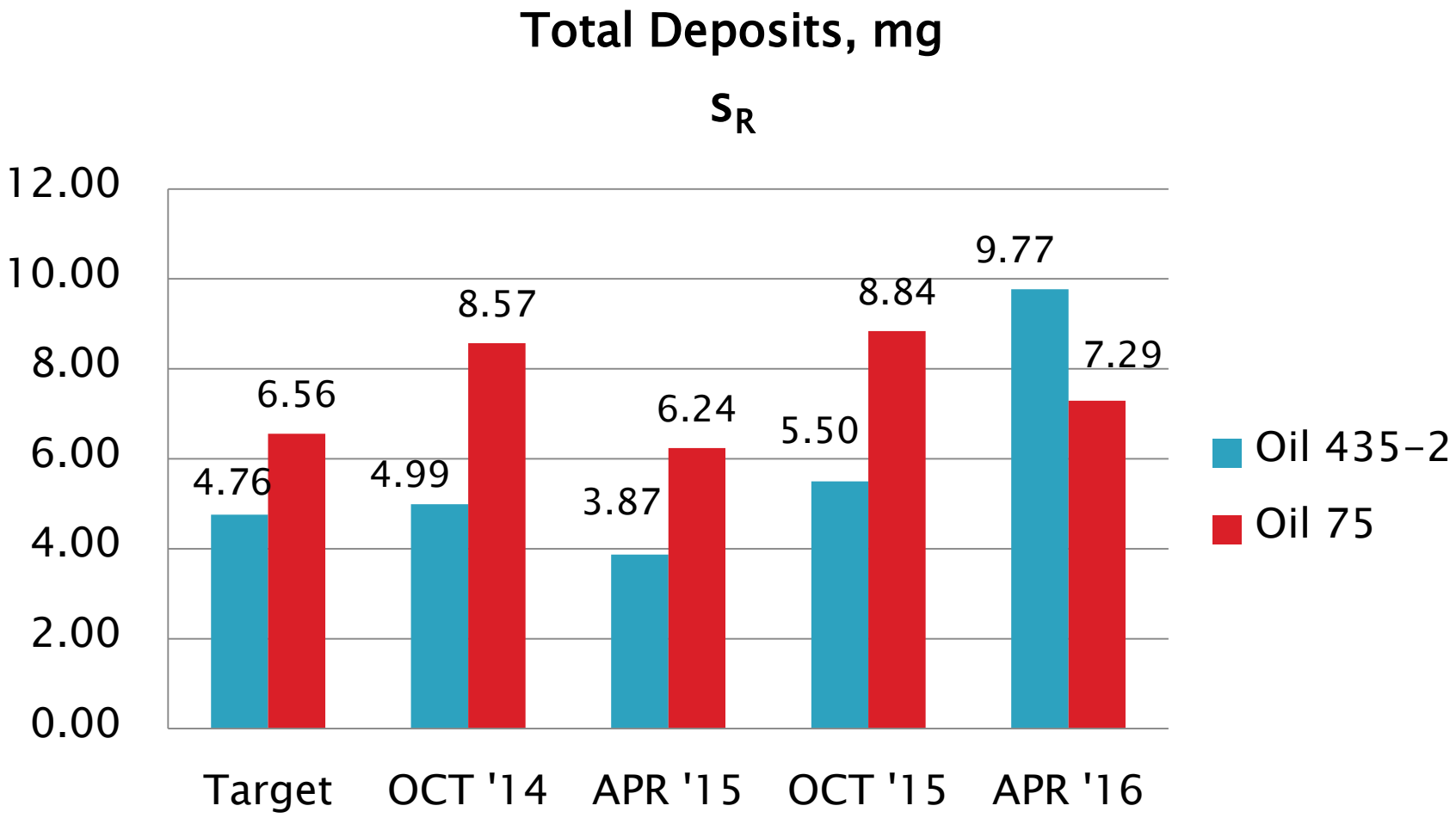
	Targets 20130415			10/1/14 – 3/31/15				4/1/15 – 9/30/15				10/1/15 – 3/31/16			
Oil Code	n	Mean	s_R	n	Mean	s_R	Mean Δ/s	n	Mean	s_R	Mean Δ/s	n	Mean	s_R	Mean Δ/s
435-2	30	26.71	4.76	7	30.5	3.87	0.37	9	28.6	5.50	-0.01	13	25.8	9.8	-0.62
75	30	53.66	6.56	8	48.1	6.24	-0.85	7	52.2	8.84	-0.22	8	52.9	7.3	-0.11

D6335 Performance by Oil

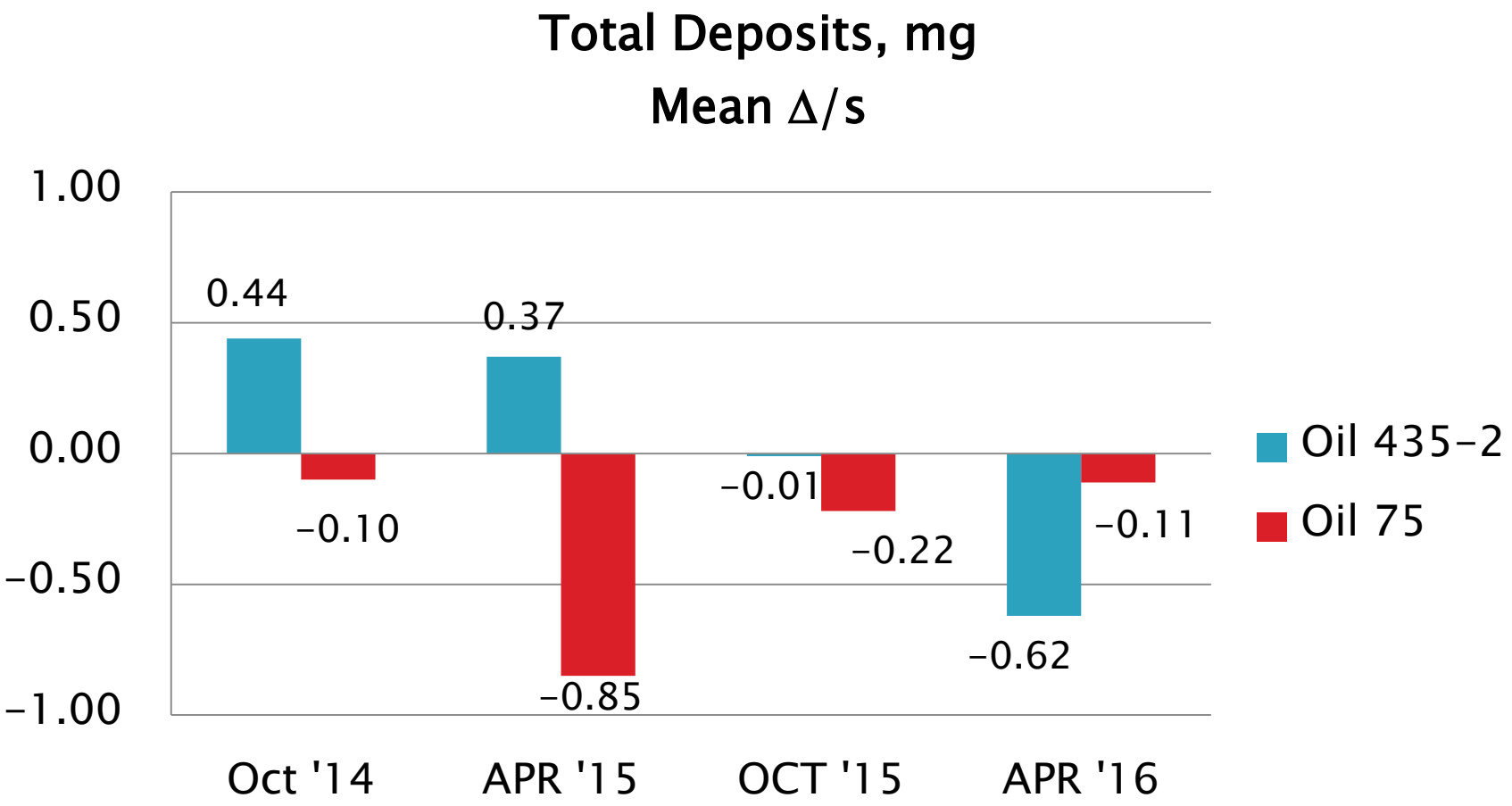


Test Monitoring Center
http://astmtmc.cmu.edu
A Program of ASTM International

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	75
Failed Calibration Test	OC	9
Operationally Invalidated by Lab	LC, XC	4
Operationally Invalidated After Initially Reported as Valid	RC	0
Donated Catalyst Screener Runs	AG	4
Non-blind Shakedown Run	NN	5
Excluded from Statistics (New Rig)	MC	2
Total		**99**

Number of Labs Reporting Data: 9

Fail Rate of Operationally Valid Tests: 11%

D7097: Deposits by MHT TEOST

Statistically Unacceptable Tests (OC)	No. Of Tests
Total Deposits Mild	3
Total Deposits Severe	6

- Four operationally invalid calibration tests this period:
  - Spilled reference sample at start of test, one test (XC)
  - Rod weight not recorded before test start, one test (LC)
  - Sample completely volatized in under 4 hours, two tests (XC)
    - Unexplained phenomena
    - Same lab, two different instruments (E1 1 & E1 2)
    - Both on TMC oil 434; TMC confirmed oil ID's by FTIR
    - Instrument E1 1 subsequently passed calibration, E1 2 failed severe on subsequent run (new rig)

D7097: Deposits by MHT TEOST

- Two test excluded from statistics (MC), new rigs, reported as operationally valid but failed to calibrate.
- Five shakedown runs (NN), four to troubleshoot new instrument B13, which subsequently calibrated successfully.
- Four donated runs to screen catalyst batch 15AA (AG), eleven more donated runs were reported in prior report period.
- No TMC technical updates issued this period

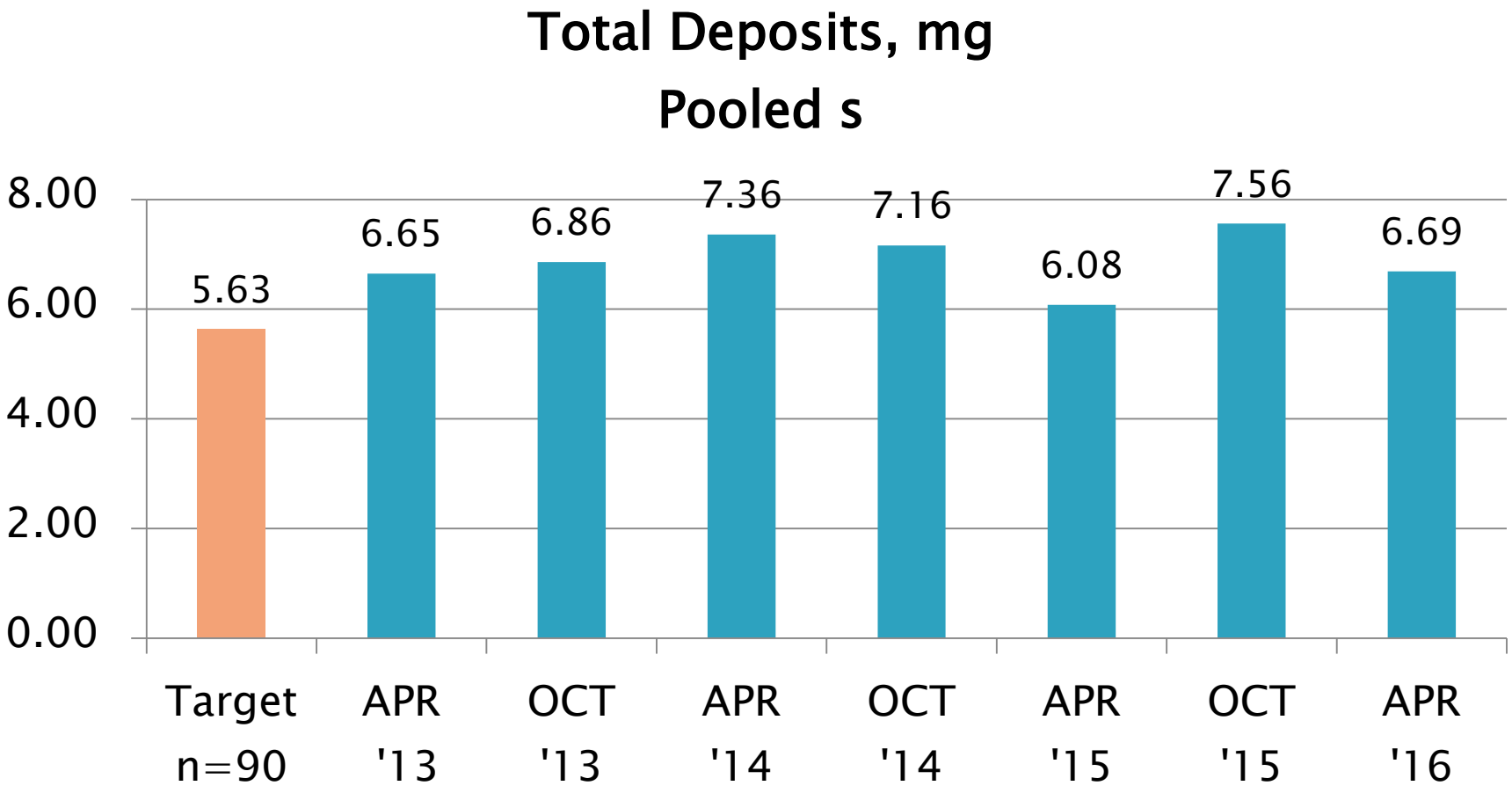
D7097: Deposits by MHT TEOST

Period Precision and Severity Estimates

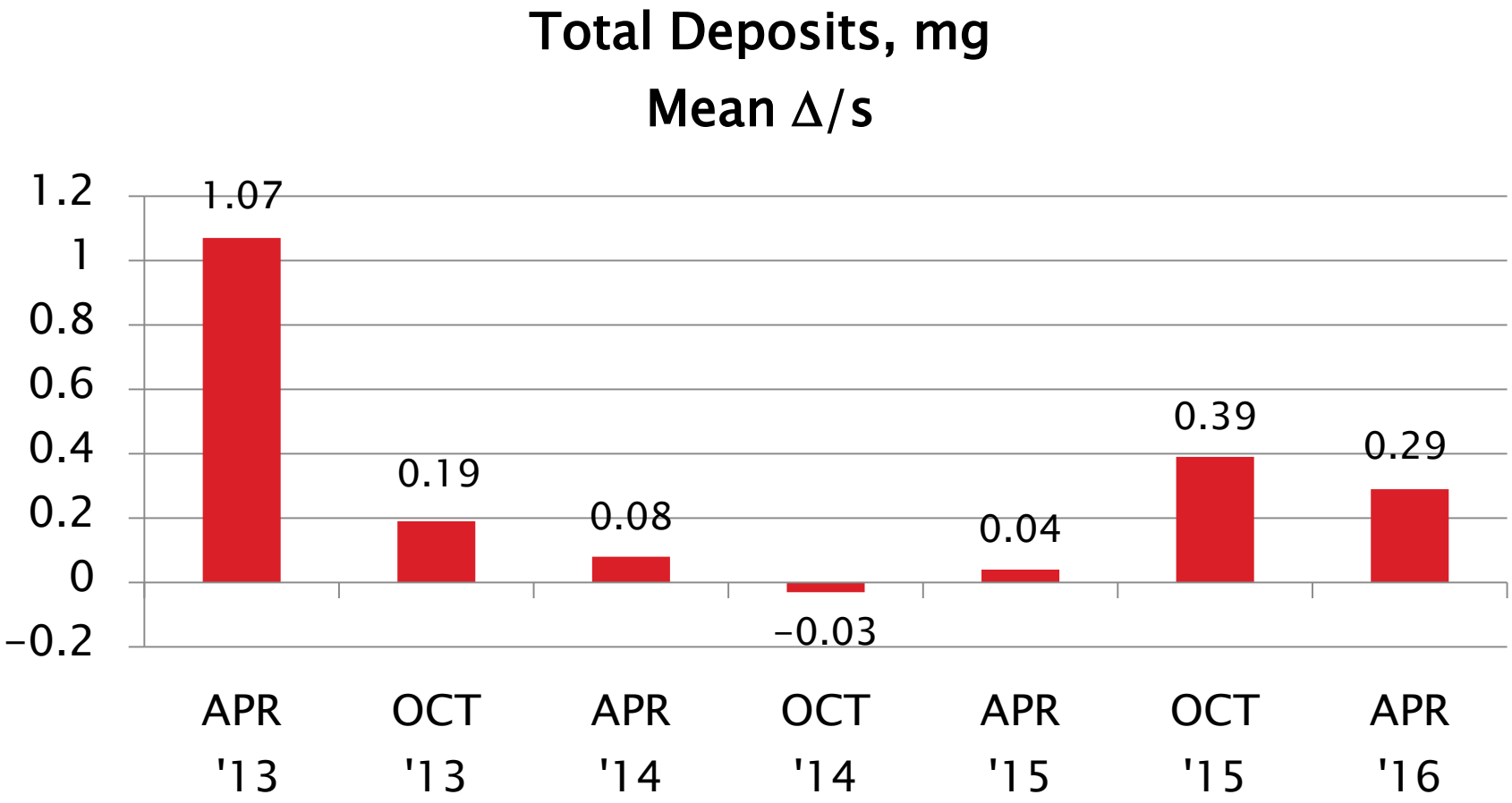
Total Deposits, mg	n	df	Pooled s	Mean Δ/s
Current Targets 7/31/2006	90	87	5.63	-----
10/1/12 through 3/31/13	68	66	6.65	1.07
4/1/13 through 9/30/13	85	83	6.86	0.19
10/1/13 through 3/31/14	71	69	7.36	0.08
4/1/14 through 9/30/14	76	74	7.16	-0.03
10/1/14 through 3/31/15*	94	92	6.60	0.19
10/1/14 through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

*Four severe OC tests from instrument G1 included and excluded

D7097 Precision Estimates



D7097 Severity Estimates



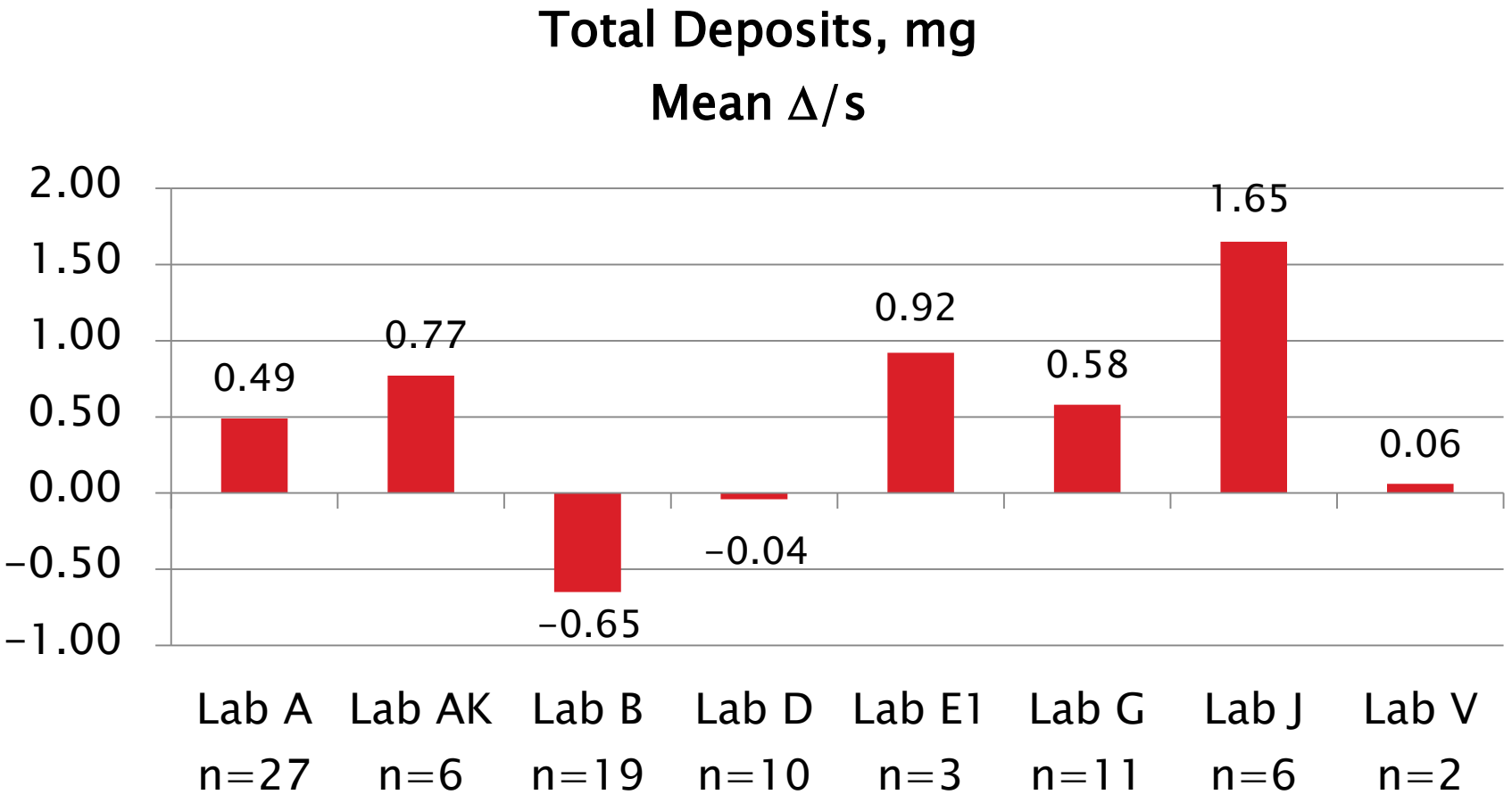
D7097: Deposits by MHT TEOST

Current Period Severity Estimates by Lab
Total Deposits, mg

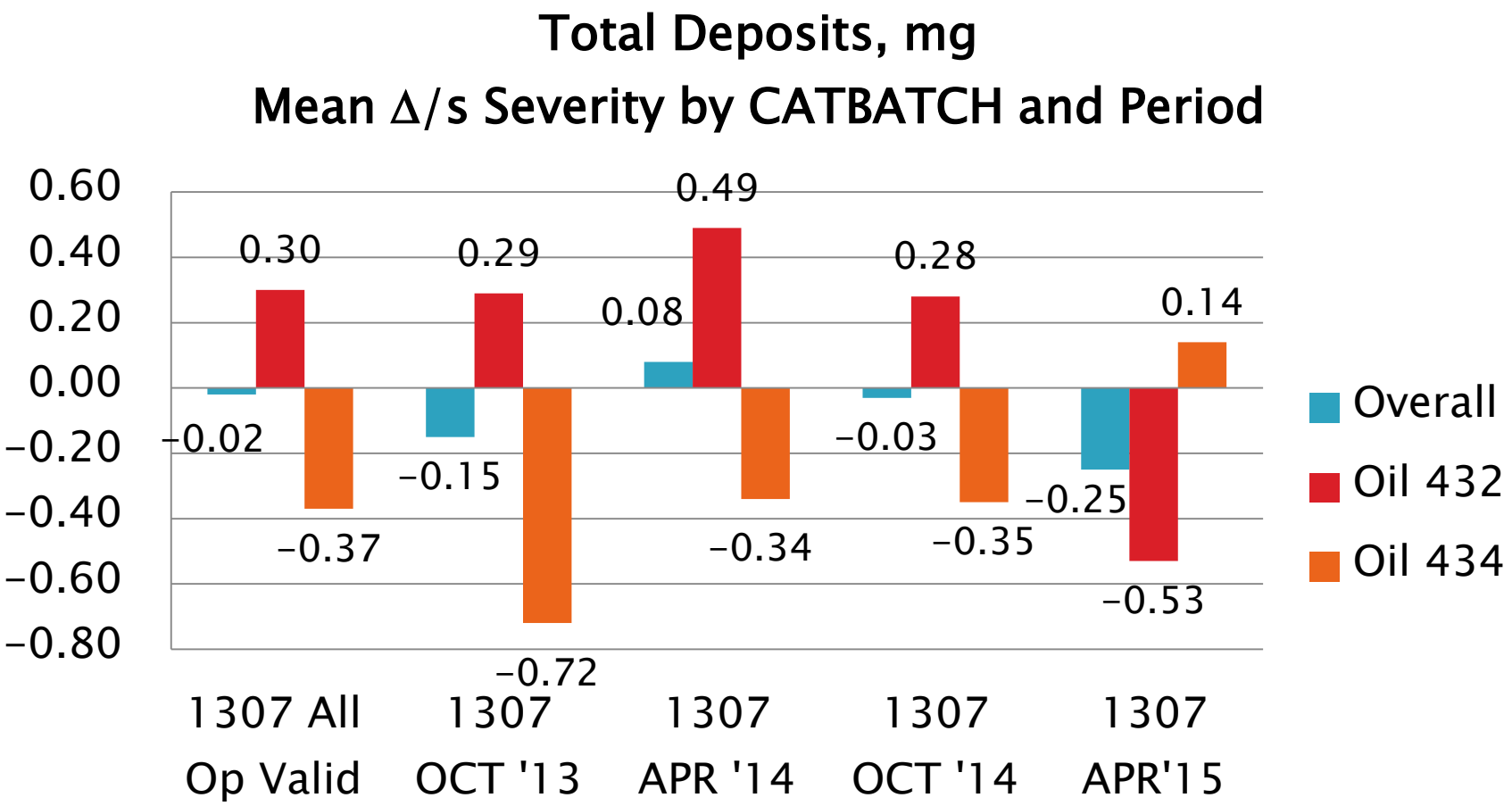
	n	Mean Δ/s
Lab A	27	0.49
Lab AK	6	0.77
Lab B	19	-0.65
Lab D	10	-0.04
LAB E1	3	0.92
Lab G	11	0.58
Lab J	6	1.65
Lab V	2	0.06

Lab AU reported one result, but excluded from statistics (MC)

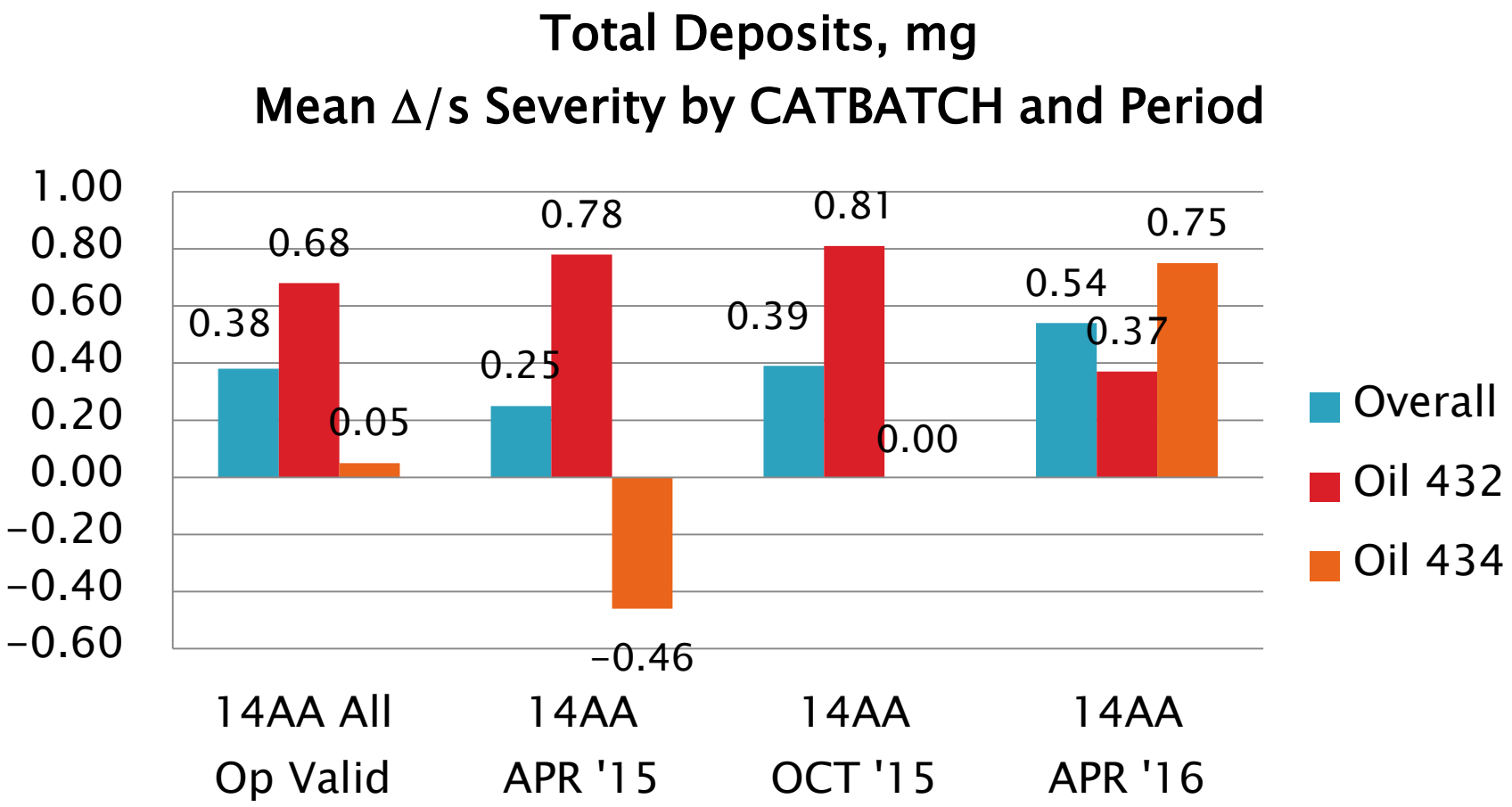
D7097 Lab Severity Estimates



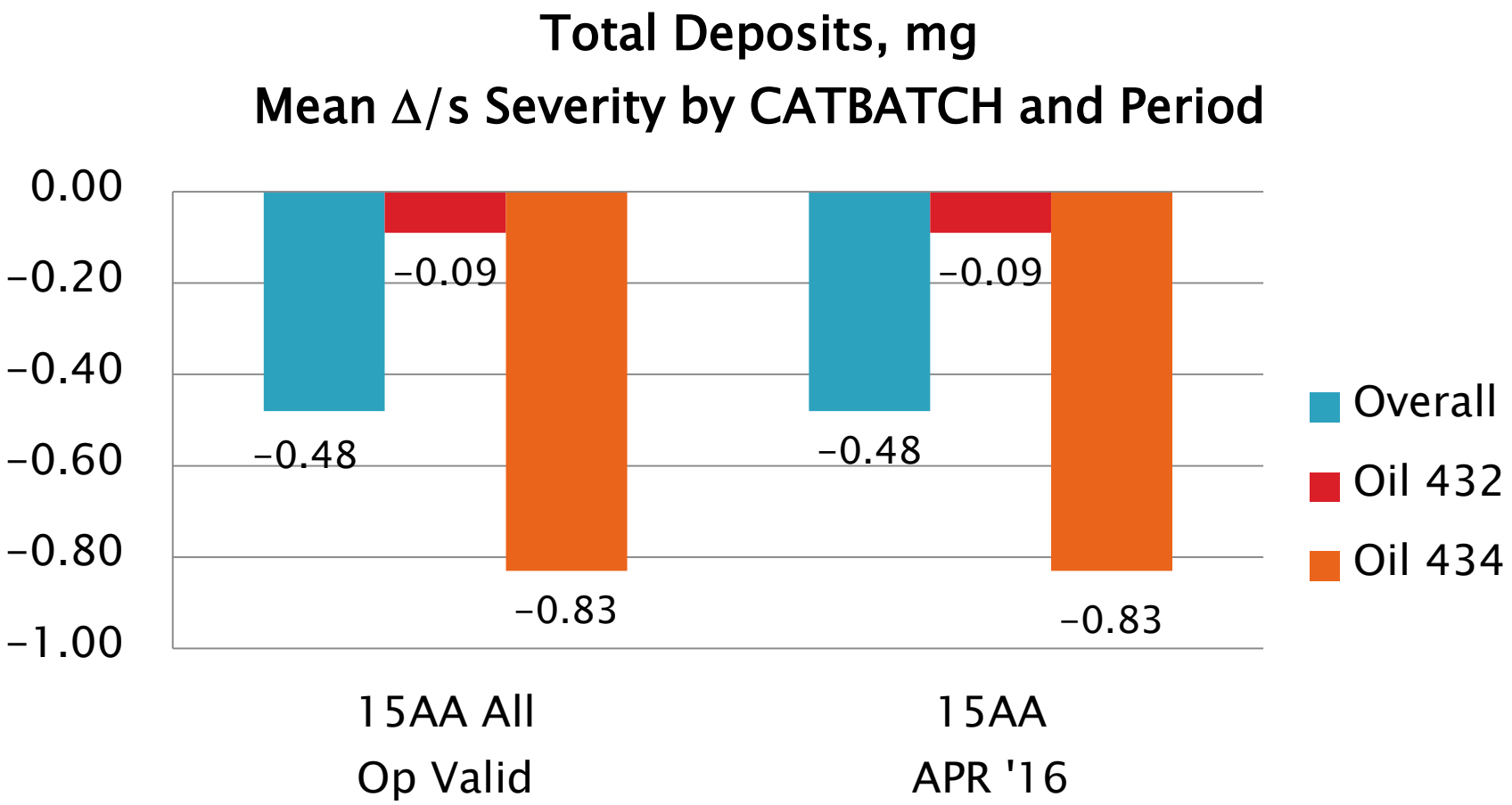
D7097: Deposits by MHT TEOST



D7097: Deposits by MHT TEOST



D7097: Deposits by MHT TEOST



D7097: Deposits by MHT TEOST

- Precision (Pooled s) is more precise than prior period
  - Less precise than target precision
- Performance (Mean Δ/s) is 0.29 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 or 15AA

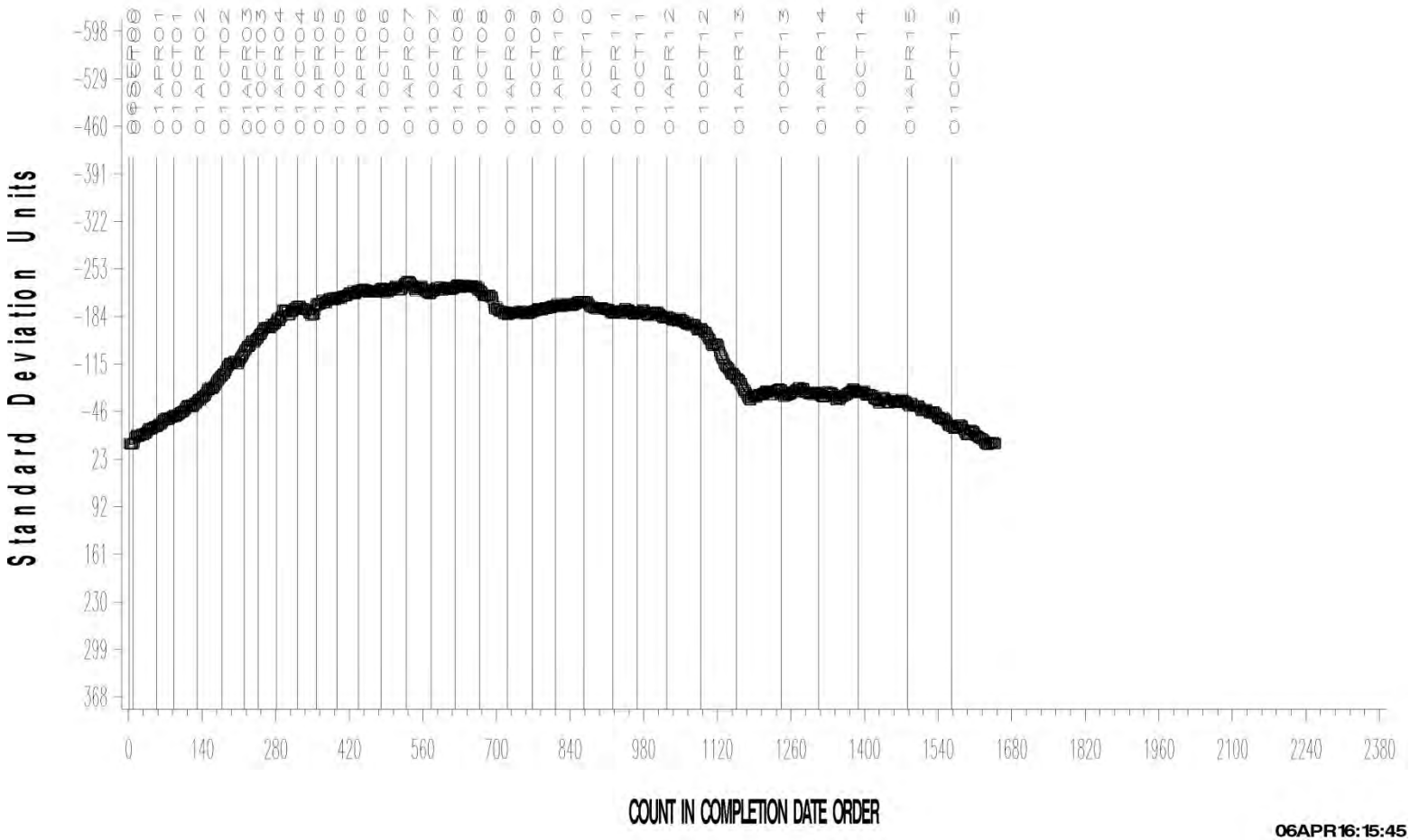
D7097: Deposits by MHT TEOST

- CUSUM severity plot shows slight severe trend this period
  - However, lab performance differences persist
  - Severe oil 432 overall performance is closer to target but is a result of performance differences between catalyst batches offsetting:
    - CATBATCH 14AA is 0.75 s severe (n=34)
    - CATBATCH 15AA is -0.86 s mild (n=10)
    - Catalyst batches have been observed to bias performance differently for different oils
      - does not explain ongoing lab severity differences

MHT—4 TEOST INDUSTRY OPERATIONALLY VALID DATA

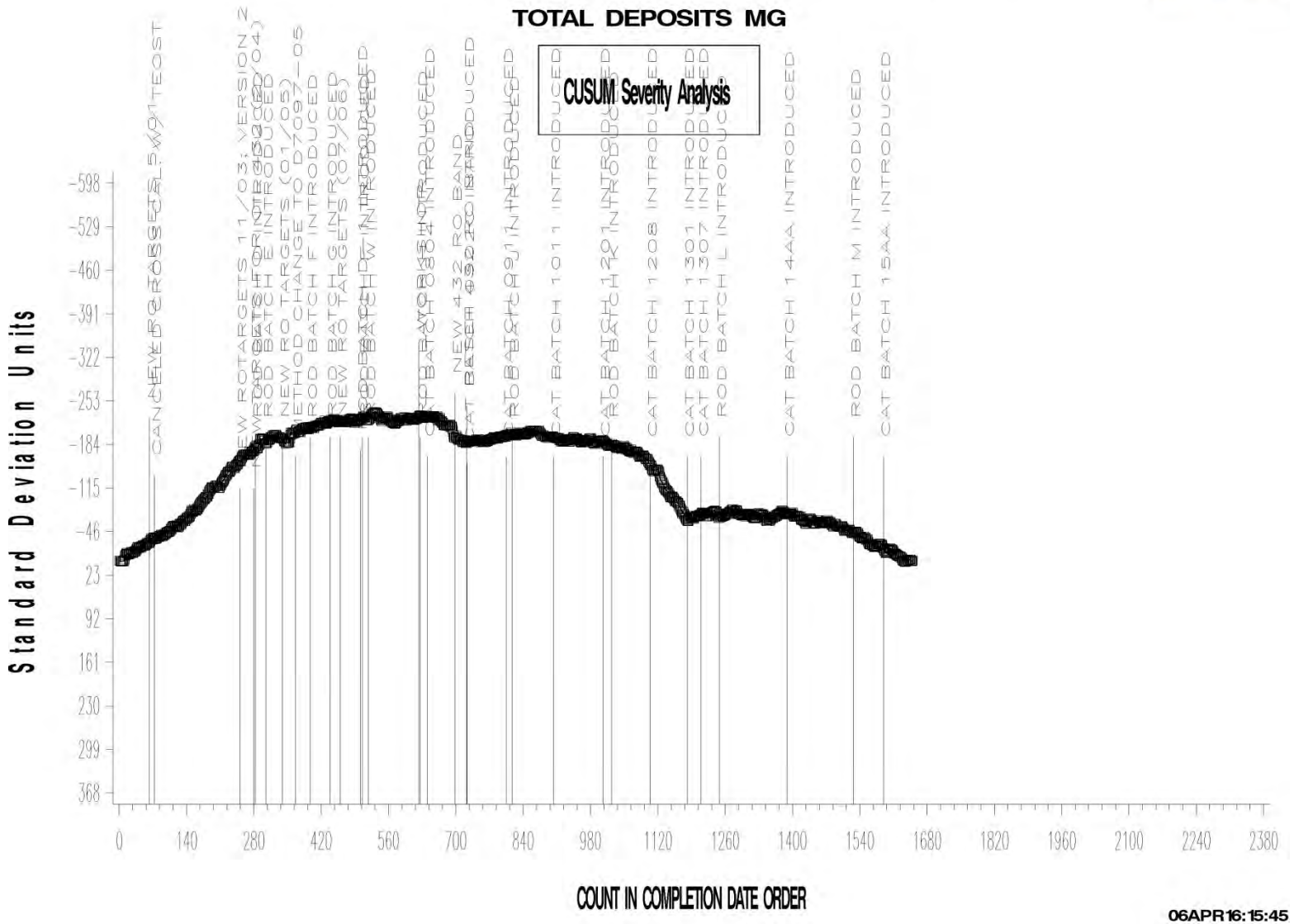
TOTAL DEPOSITS MG

CUSUM Severity Analysis



06APR16:15:45

MHT—4 TEOST INDUSTRY OPERATIONALLY VALID DATA

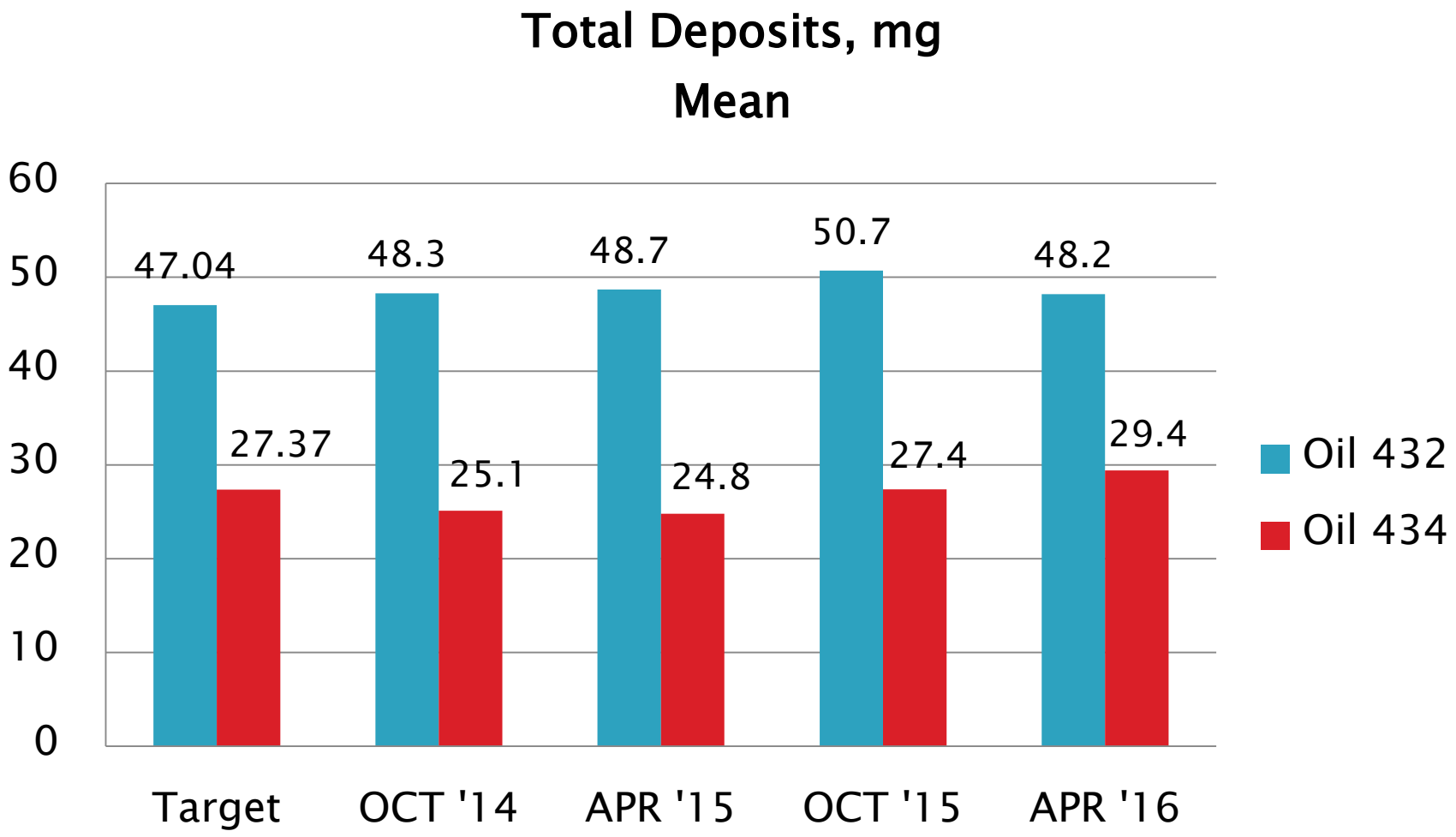


D7097 Performance by Oil

Total Deposits, mg
Performance by Oil

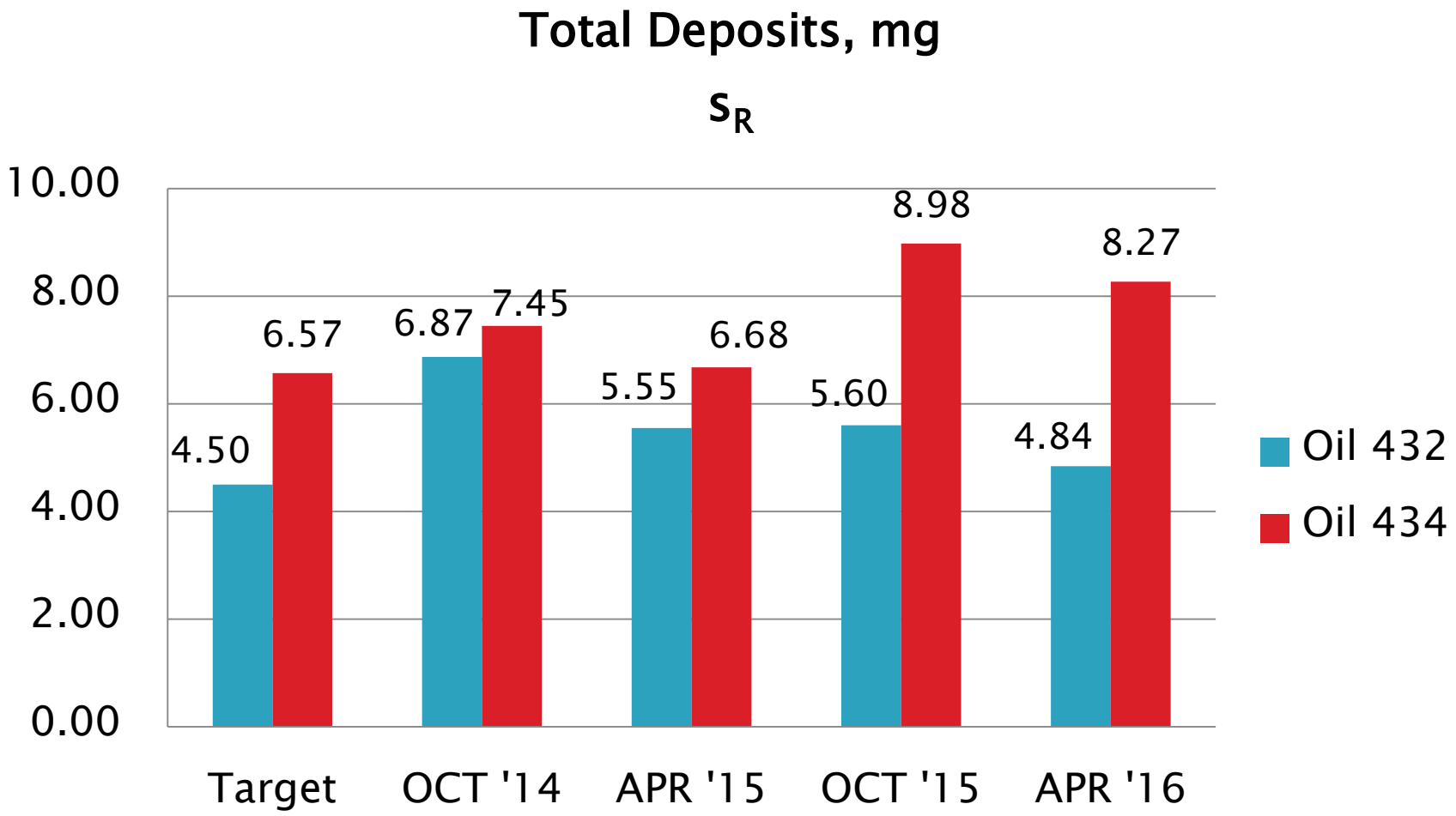
	Targets			10/1/14 – 3/31/15				4/1/15 – 9/30/15				10/1/15 – 3/31/16			
Oil Code	n	Mean	s_R	n	Mean	s_R	Mean Δ/s	n	Mean	s_R	Mean Δ/s	n	Mean	s_R	Mean Δ/s
432	30	47.04	4.50	50	48.7	5.55	0.38	40	50.7	5.60	0.81	44	48.2	4.84	0.27
434	30	27.37	6.57	40	24.8	6.68	-0.39	44	27.4	8.98	0.00	40	29.4	8.27	0.31

D7097 Performance by Oil

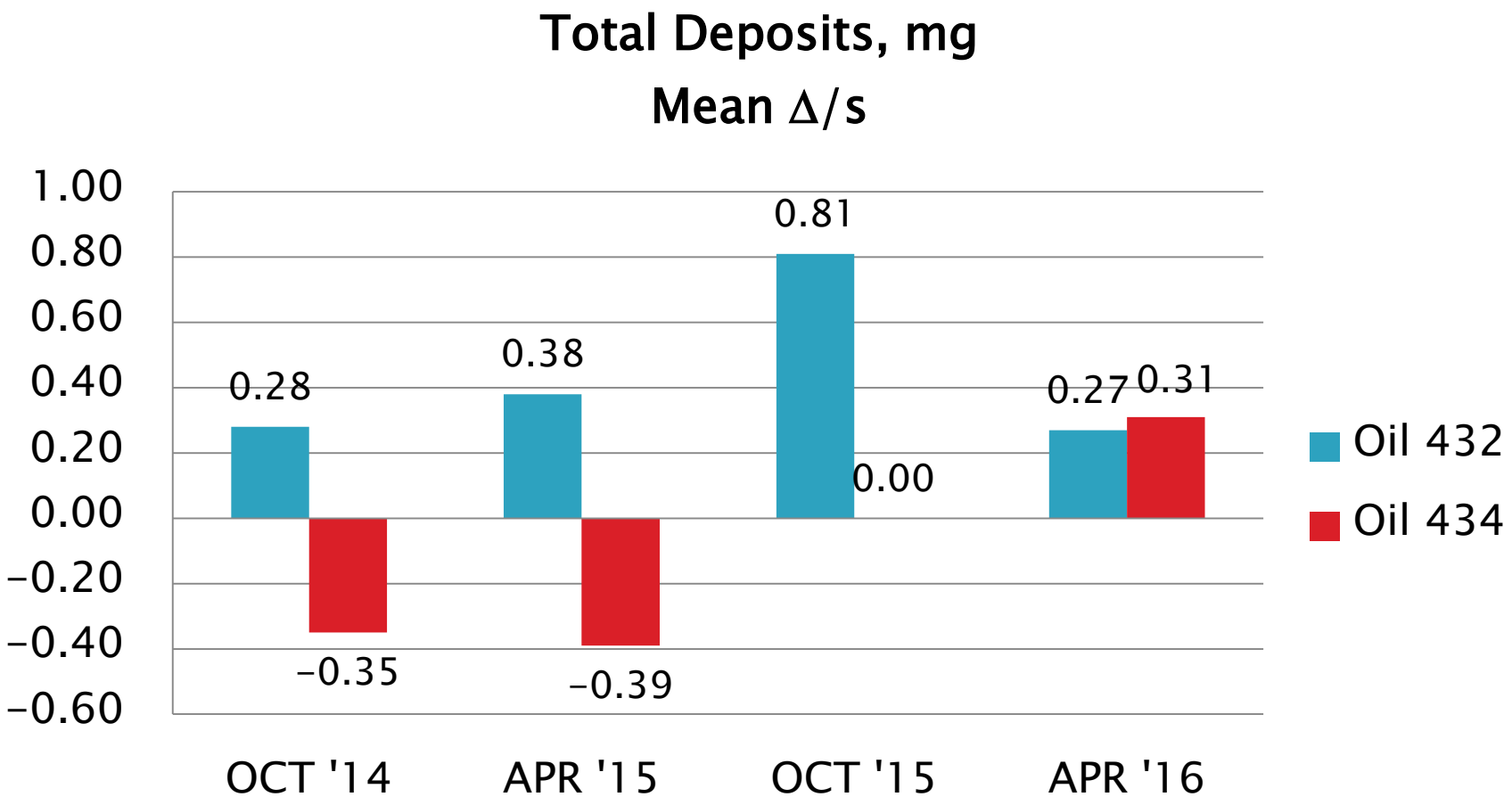


Test Monitoring Center
http://astmtmc.cmu.edu
A Program of ASTM International

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	8
Acceptable Discrimination Test	AS	4
Failed Calibration Test	OC	0
Operationally Invalidated by Lab	LC, XC	1
Operationally Invalidated After Initially Reported as Valid	RC	0
Total		**13**

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

D6082: High Temperature Foam

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

- No statistically invalid tests reported this period
- One aborted test (XC), lab ran wrong test method.
- 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

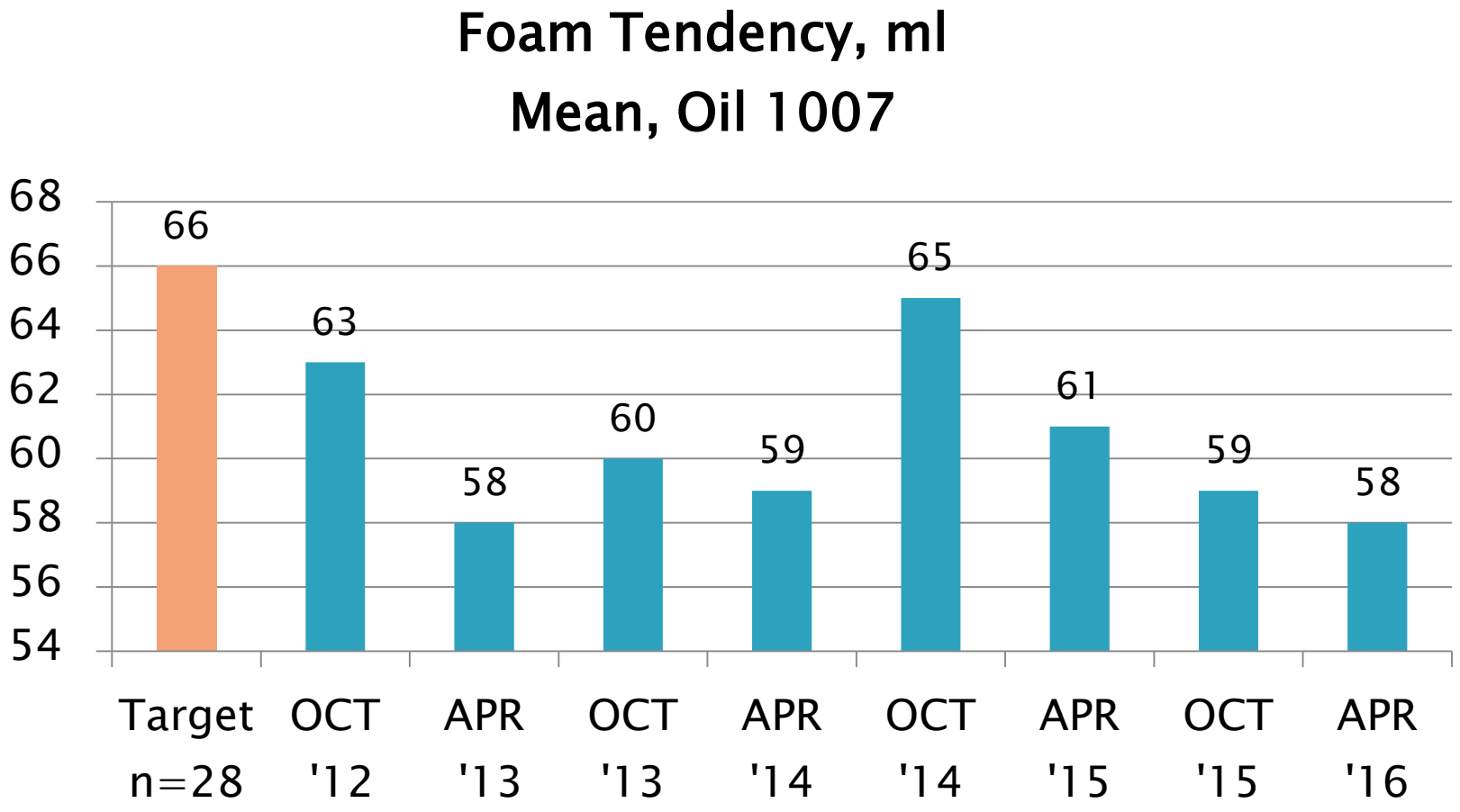
Foam Tendency, ml	n	Mean	Pooled s	Mean Δ/s
Current Targets	28	65.71	19.28	-----
4/1/12 through 9/30/12	9	63	13	-0.14
10/1/12 through 3/31/13	8	58	10	-0.45
4/1/13 through 9/30/13	9	60	7	-0.32
10/1/13 through 3/31/14	11	59	8	-0.39
4/1/14 through 9/30/14	11	65	22	-0.05
10/1/14 through 3/31/15	10	61	12	-0.26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

D6082: High Temperature Foam

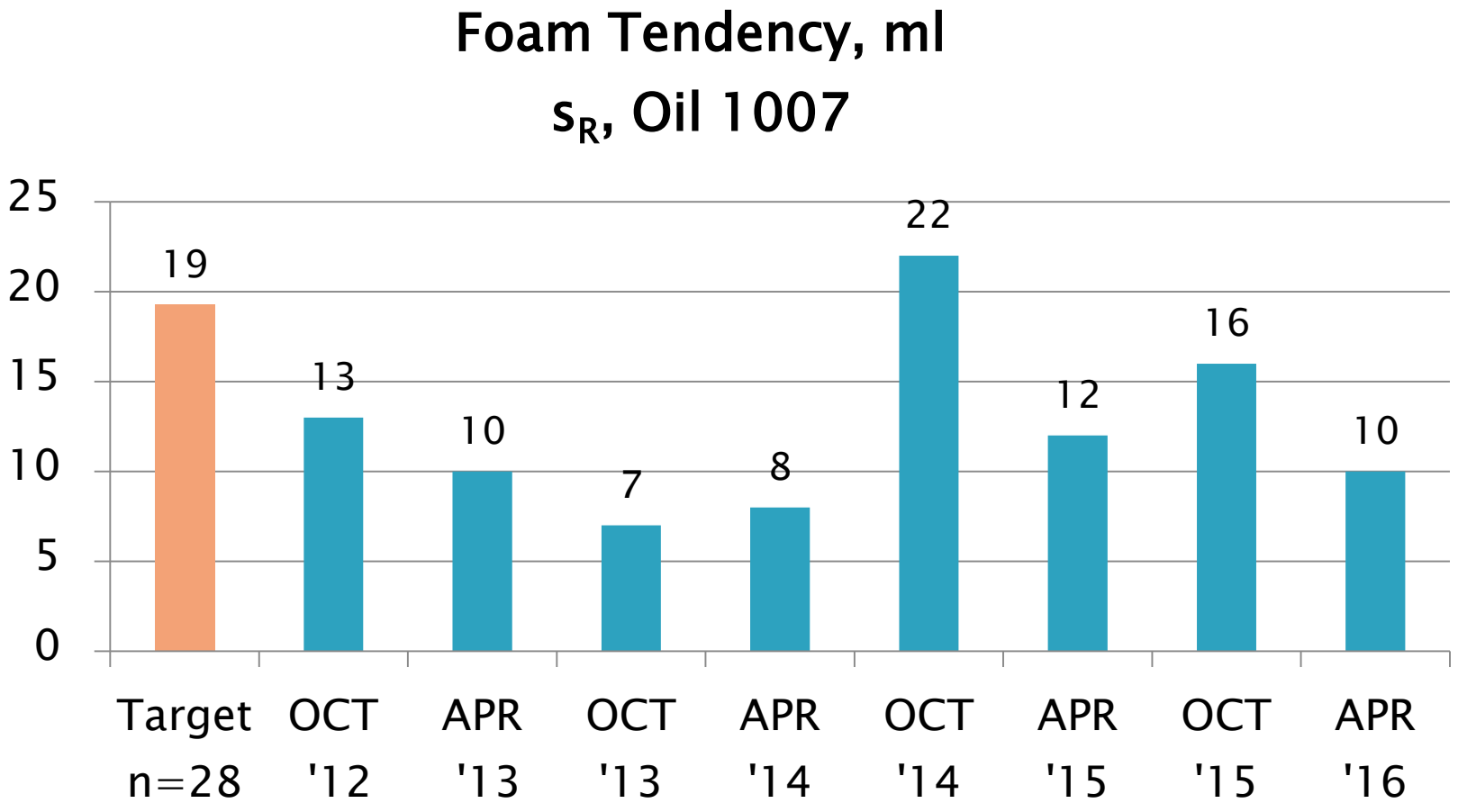
Period Precision and Severity Estimates Oil 1007

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

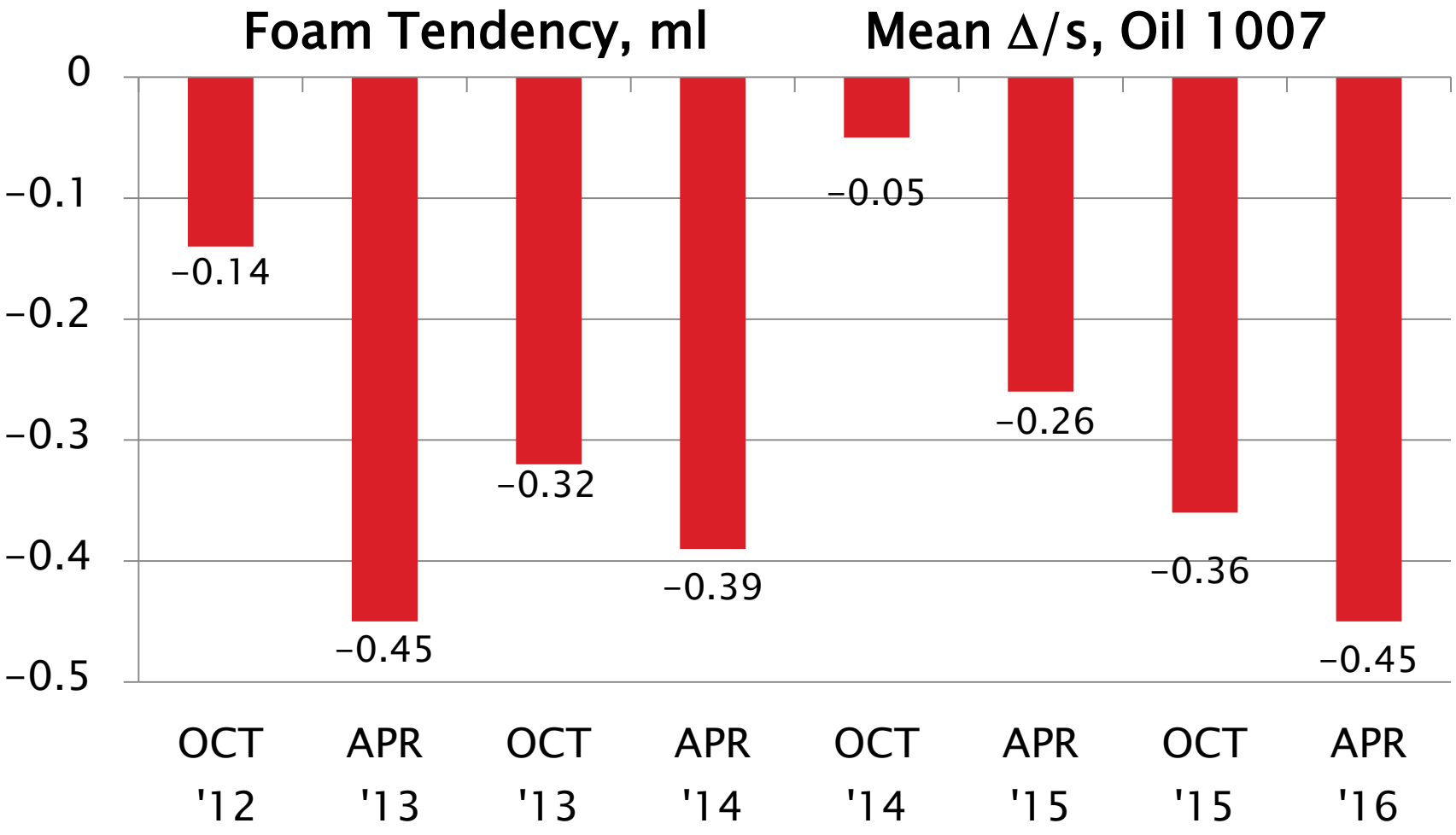
D6082: High Temperature Foam



D6082: High Temperature Foam



D6082: High Temperature Foam



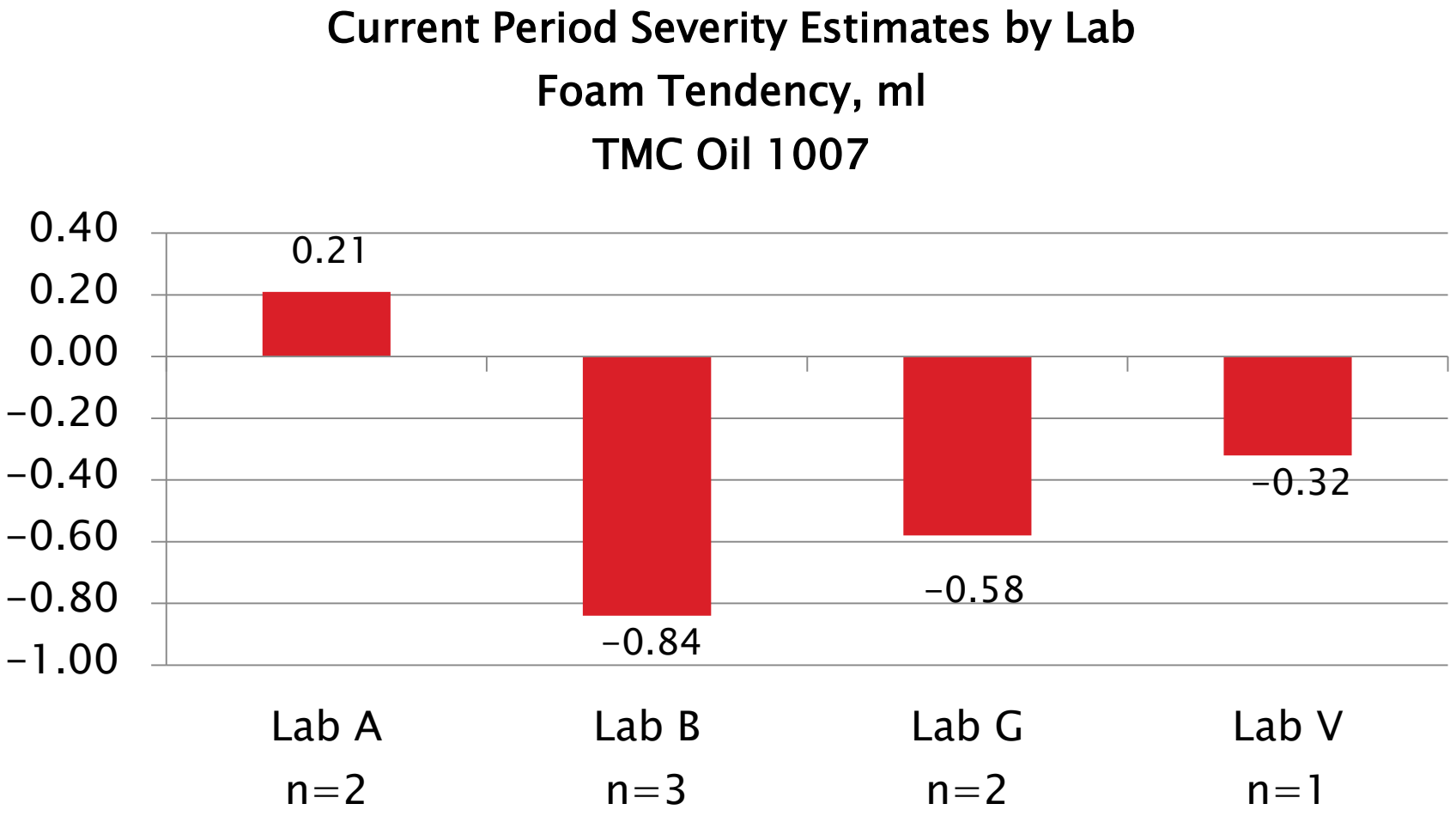
Test Monitoring Center
http://astmtmc.cmu.edu
A Program of ASTM International

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	3	-0.84
Lab G	2	-0.58
Lab V	1	-0.32

D6082: High Temperature Foam



D6082: High Temperature Foam

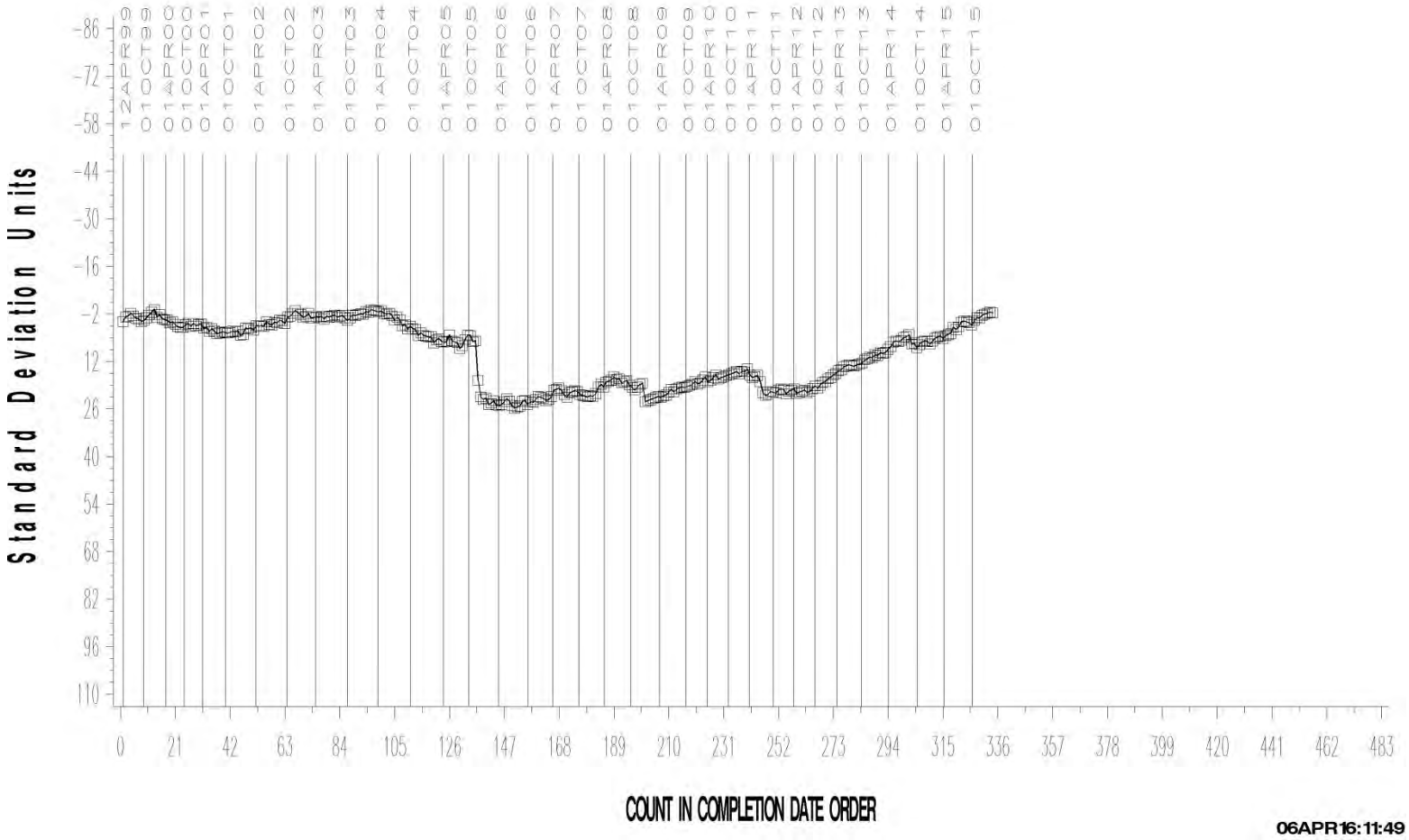
- Foam Tendency Precision (Pooled s) is more precise than prior period
  - More precise than target precision
- Performance (Mean Δ/s) is -0.45 s mild
- No non-zero occurrences of Foam Stability
- All operationally valid discrimination runs demonstrated acceptable discrimination

D6082 HIGH TEMPERATURE FOAM INDUSTRY OPERATIONALLY VALID DATA

IND='1007'

FOAM TENDENCY

CUSUM Severity Analysis



06APR16:11:49

Return to Executive Summary

D874: Sulfated Ash

Test Status	Validity Code	No. Tests
Acceptable Calibration Test	AC	7
Failed Calibration Test	OC	0
Operationally Invalidated by Lab	LC, XC	0
Operationally Invalidated After Initially Reported as Valid	RC	0
Total		**7**

Number of Labs Reporting Data: 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

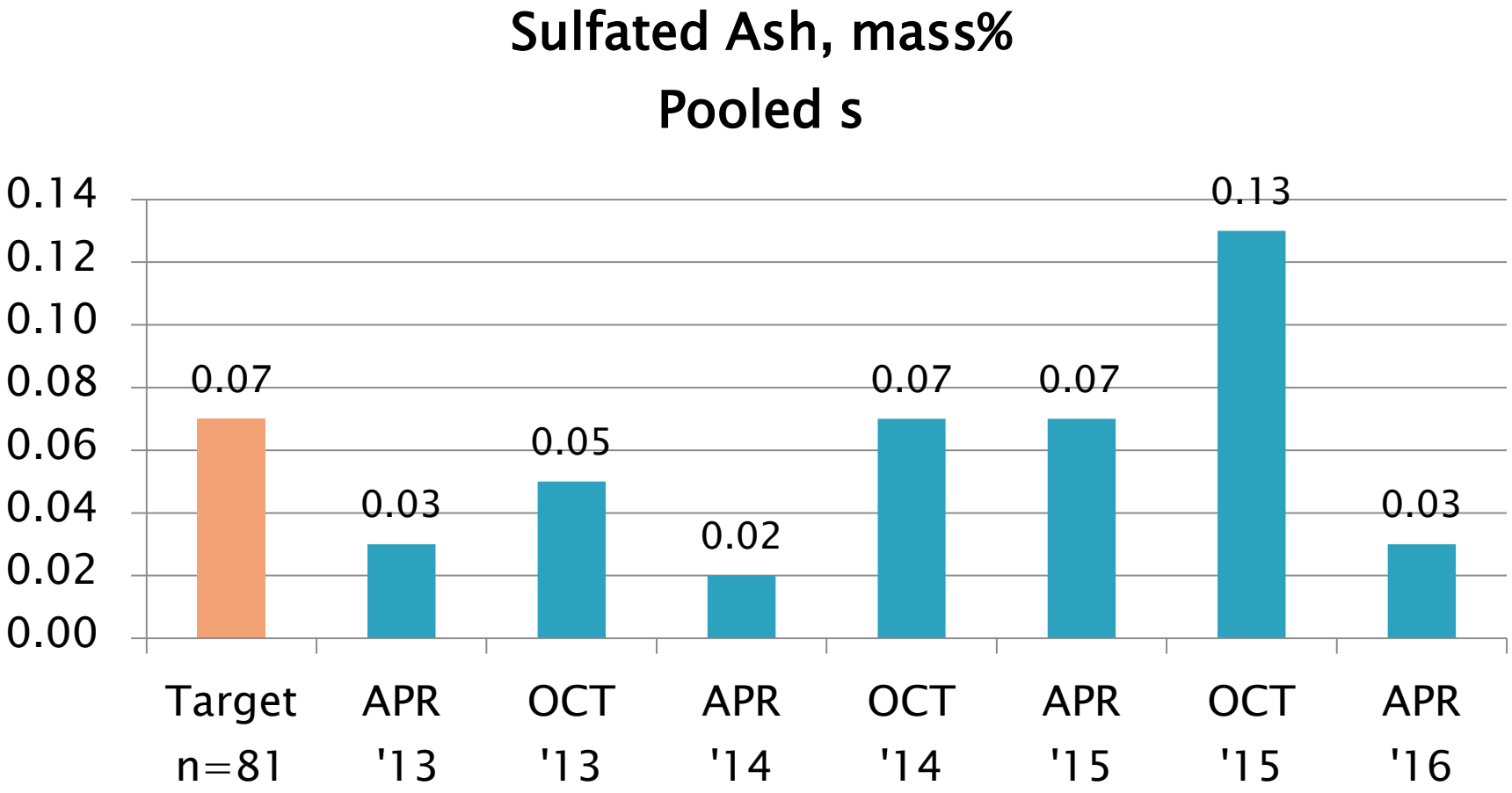
D874: Sulfated Ash

Period Precision and Severity Estimates

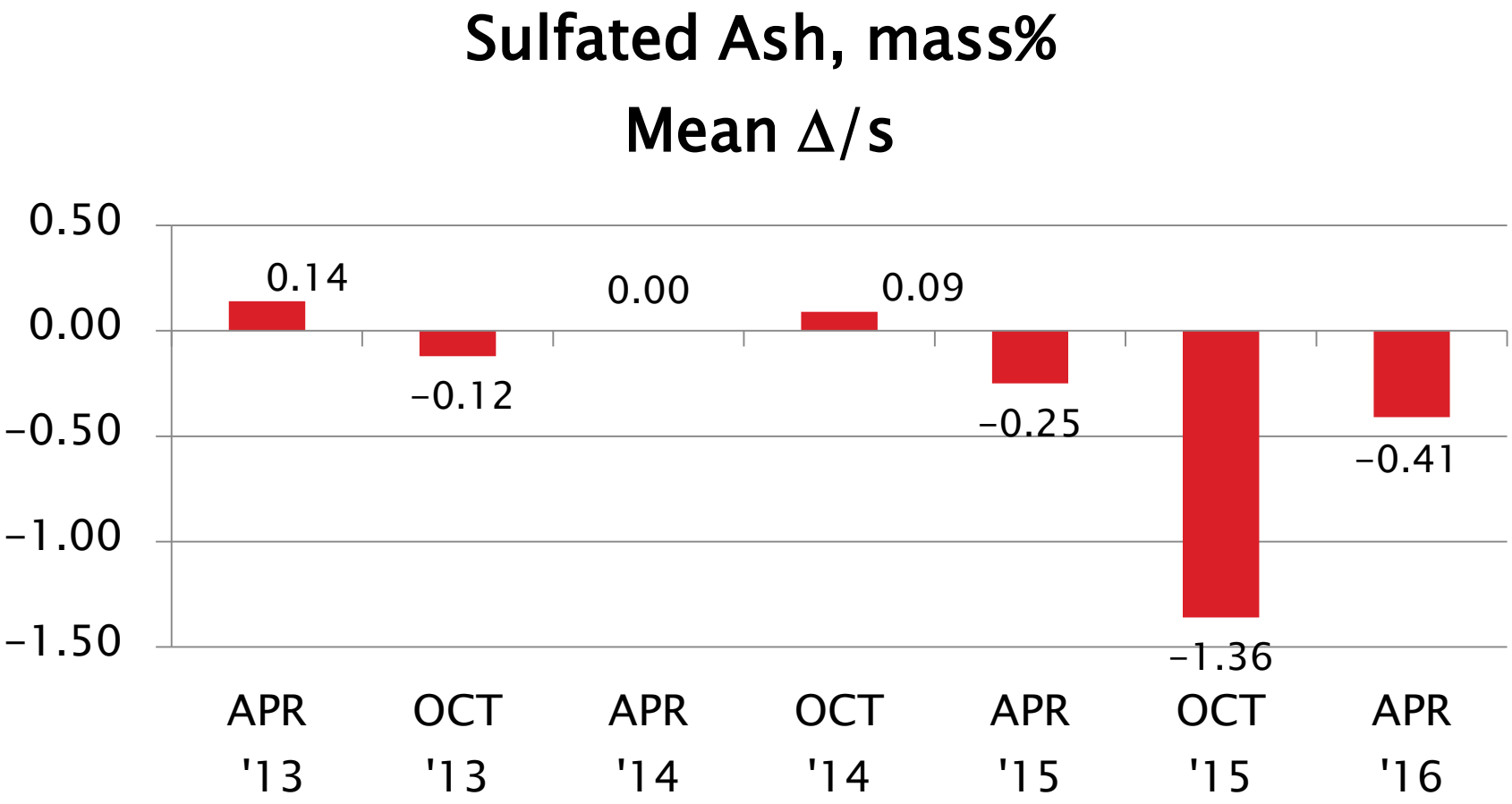
Total Deposits, mg	n	df	Pooled s	Mean Δ/s
Current Targets	81	78	0.07	-----
10/1/12 through 3/31/13	7	4	0.03	0.14
4/1/13 through 9/30/13	6	3	0.05	-0.12
10/1/13 through 3/31/14	5	2	0.02	0.00
4/1/14 through 9/30/14	6	3	0.07	0.09
10/1/14 through 3/31/15	6	4	0.07	-0.25
4/1/15 through 9/30/15* 4/1/15 through 9/30/15*	8 7	5 4	0.13 0.05	-1.36 -0.36
10/1/15 through 3/31/16	7	4	0.03	-0.41

*Period statistics with and without extreme result included

D874: Sulfated Ash



D874: Sulfated Ash

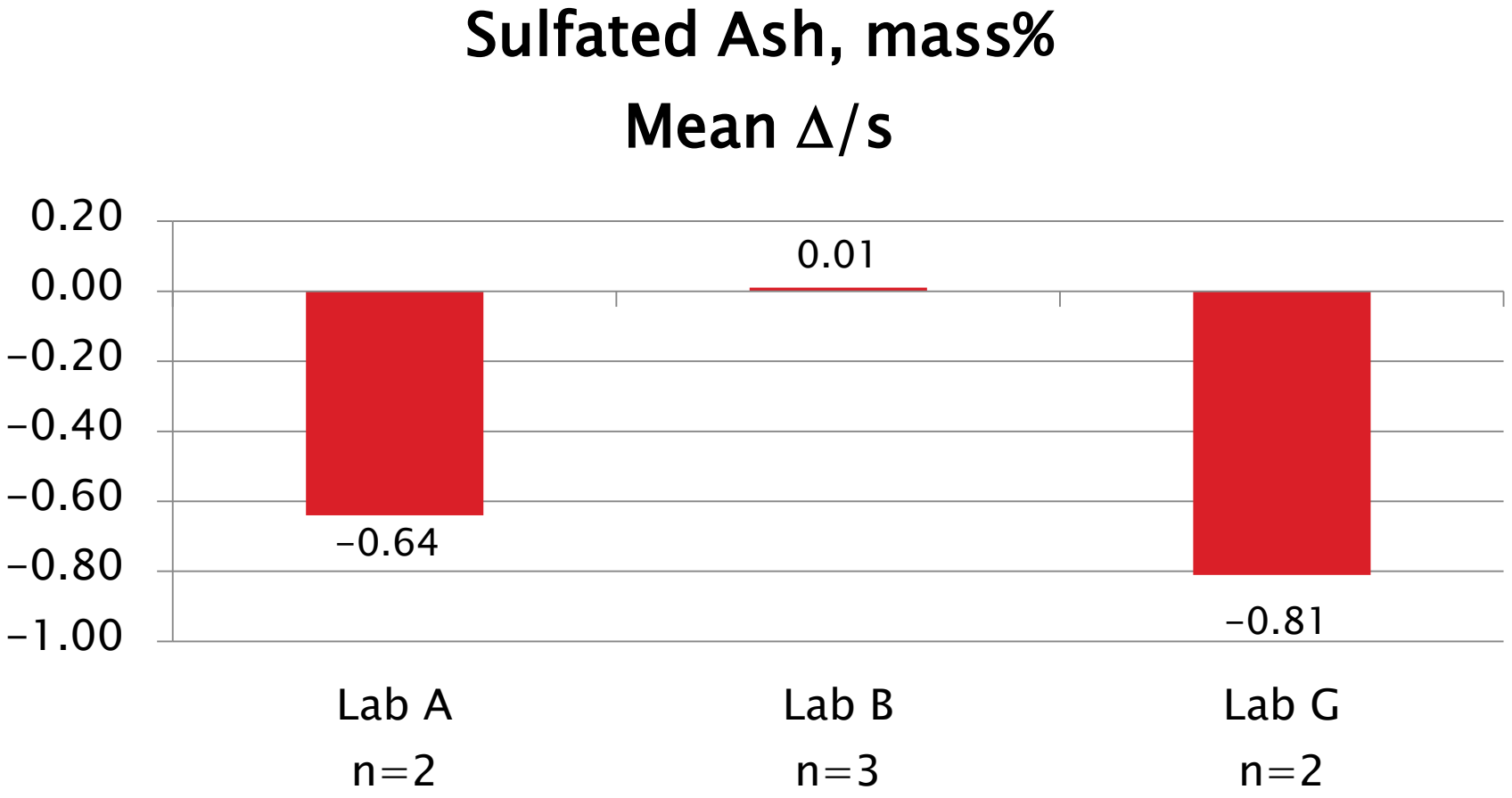


D874: Sulfated Ash

Current Period Severity Estimates by Lab
Sulfated Ash, mass%

	n	Mean Δ/s
Lab A	2	-0.64
Lab B	3	0.01
Lab G	2	-0.81

D874: Sulfated Ash

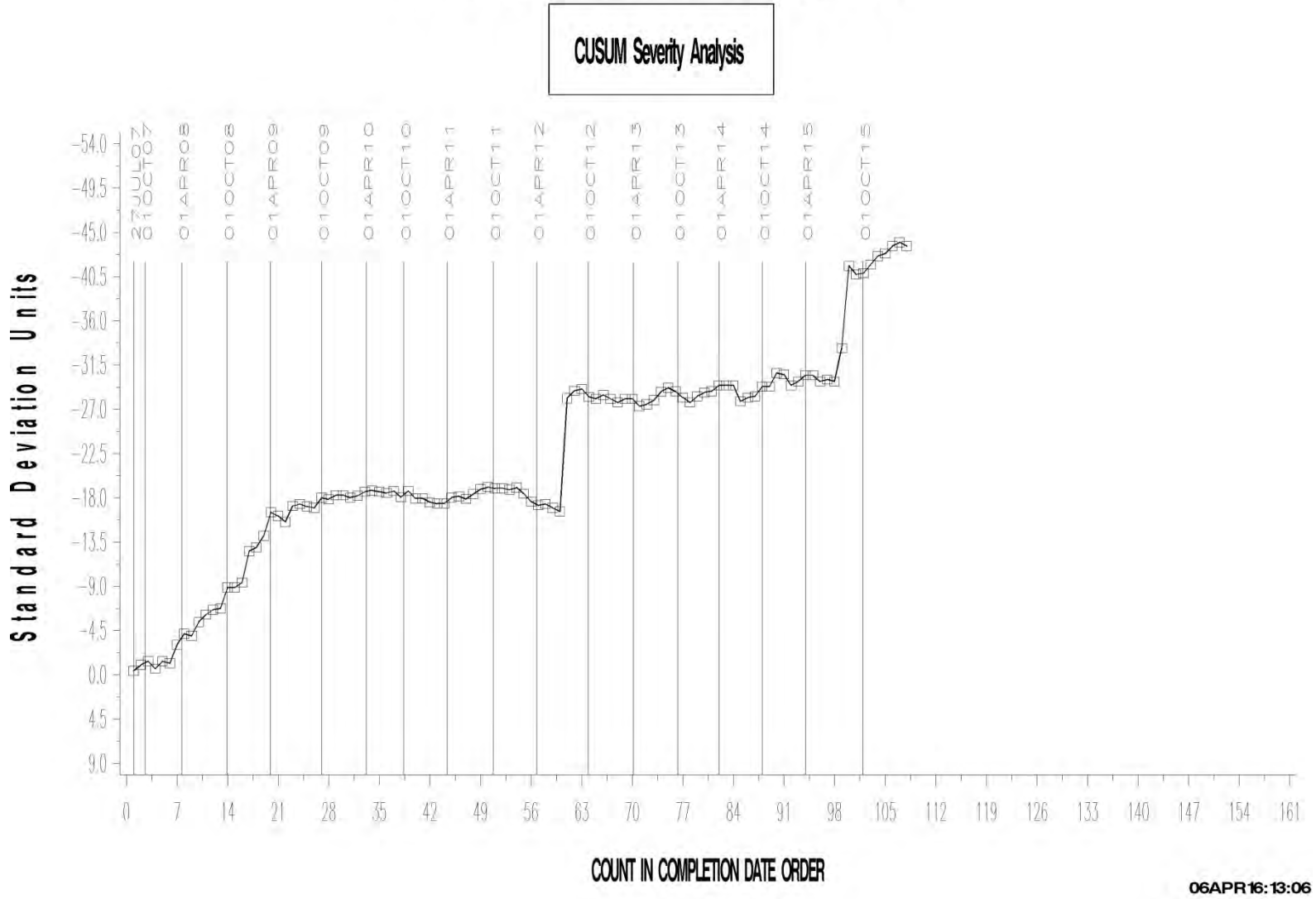


D874: Sulfated Ash

- Precision (Pooled s) is more precise than 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



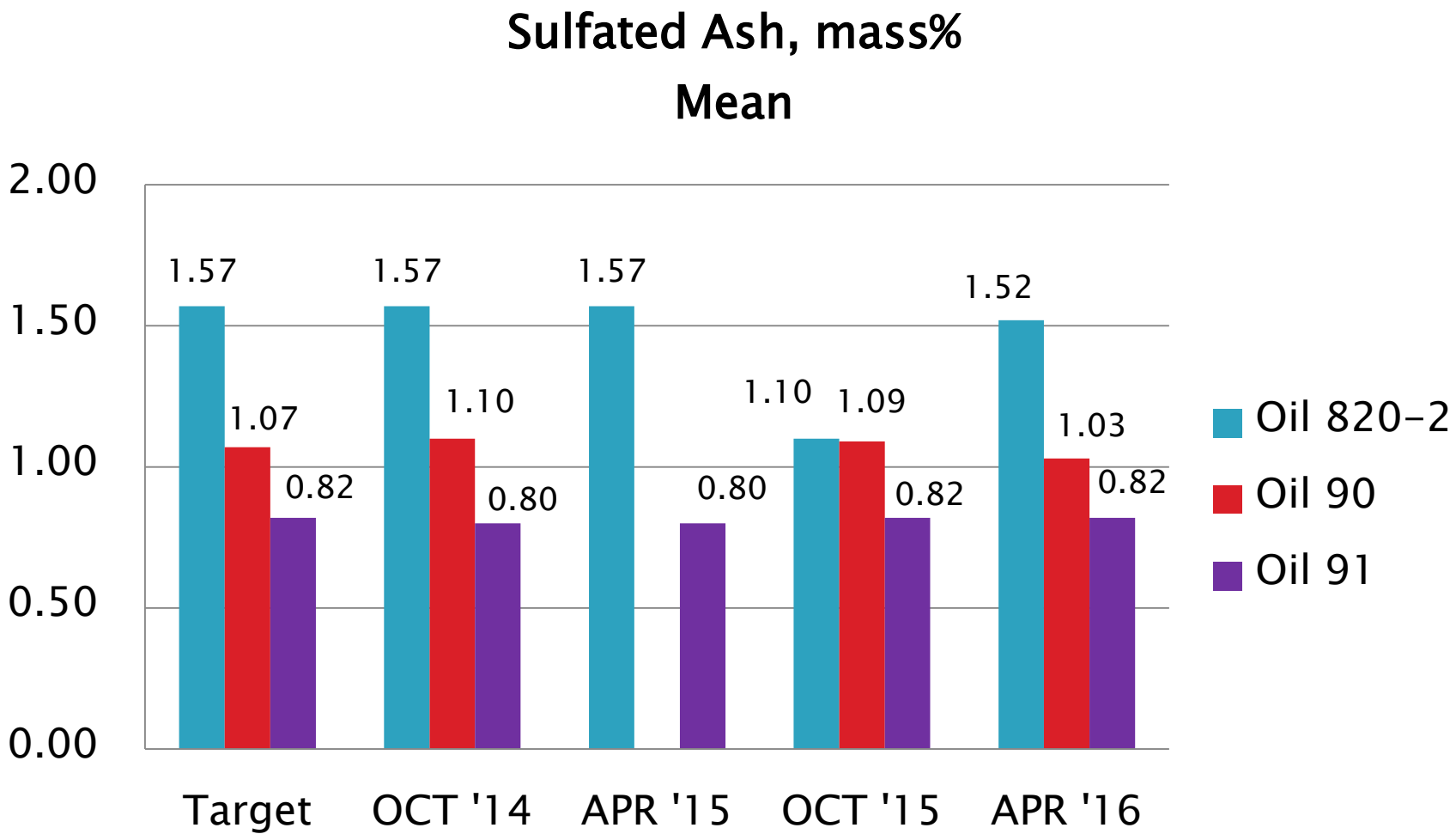
06APR16:13:06

D874: Sulfated Ash

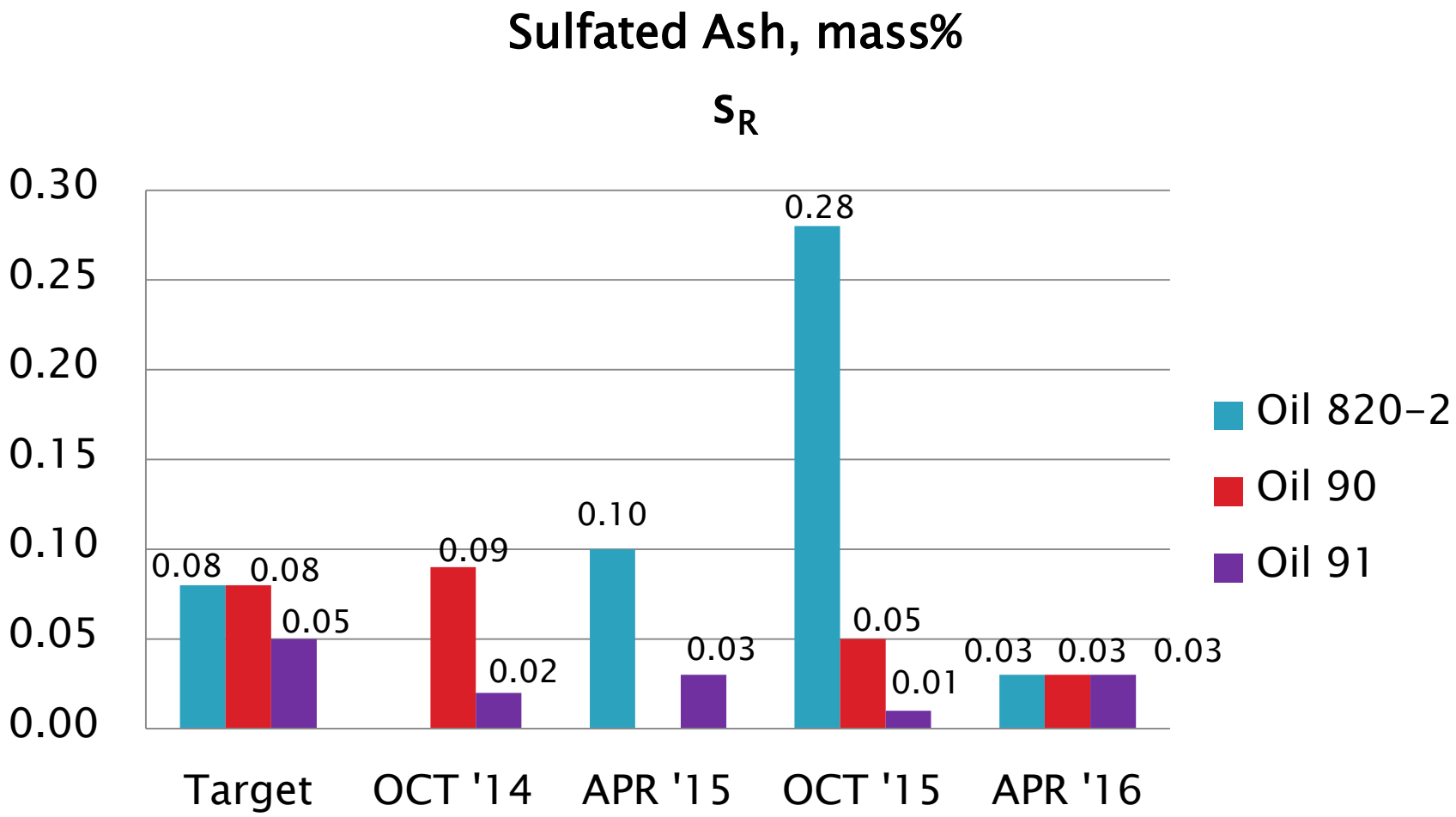
Performance by Oil
Sulfated Ash, mass%

	Targets			10/1/14 – 3/31/15				4/1/15 – 9/30/15				10/1/15 – 3/31/16			
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	3	1.57	0.10	-0.04	2	1.10	0.28	-5.88	3	1.52	0.03	-0.62
90	27	1.07	0.08	0	---	---	---	4	1.09	0.05	0.22	2	1.03	0.03	-0.50
91	27	0.82	0.05	3	0.80	0.03	-0.47	2	0.82	0.01	0.00	2	0.82	0.03	0.00

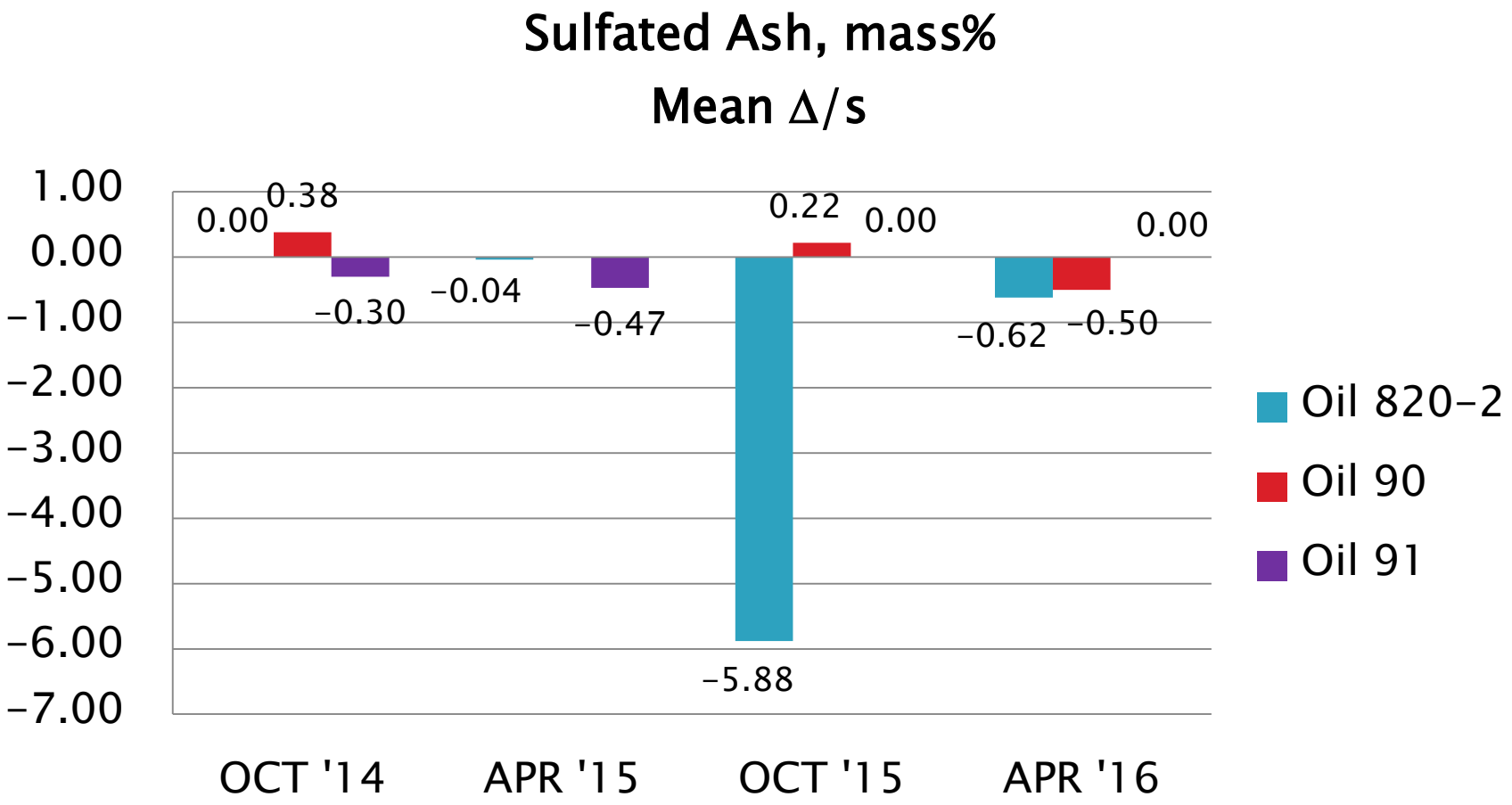
D874: Sulfated Ash



D874: Sulfated Ash



D874: Sulfated Ash



Return to Executive Summary

D7528: Oxidation by ROBO

Test Status	Validity Code	No. Tests
Acceptable Calibration Test	AC	63
Failed Calibration Test	OC	29
Operationally Invalidated by Lab	LC, XC	5
Operationally Invalidated After Initially Reported as Valid	RC	1
Total		**98**

Number of Labs Reporting Data: 6
Fail Rate of Operationally Valid Tests: 32%

D7528: Oxidation by ROBO

Operationally Invalid Tests

- 1 test unexplained high EOT volatiles (RC)
- 3 tests heater or heater control failure (LC, XC)
- 2 tests NO_2 flow problems (LC)

D7528: Oxidation by ROBO

Statistically Unacceptable Tests (OC)	No. Of Tests
Natural Log (MRV Viscosity) Mild	15
Natural Log (MRV Viscosity) Severe	14

- One Information Letter Issued for ROBO This Period:
  - ROBO IL 16-1; March 11, 2016; Numerous Revisions to Test Method D7528

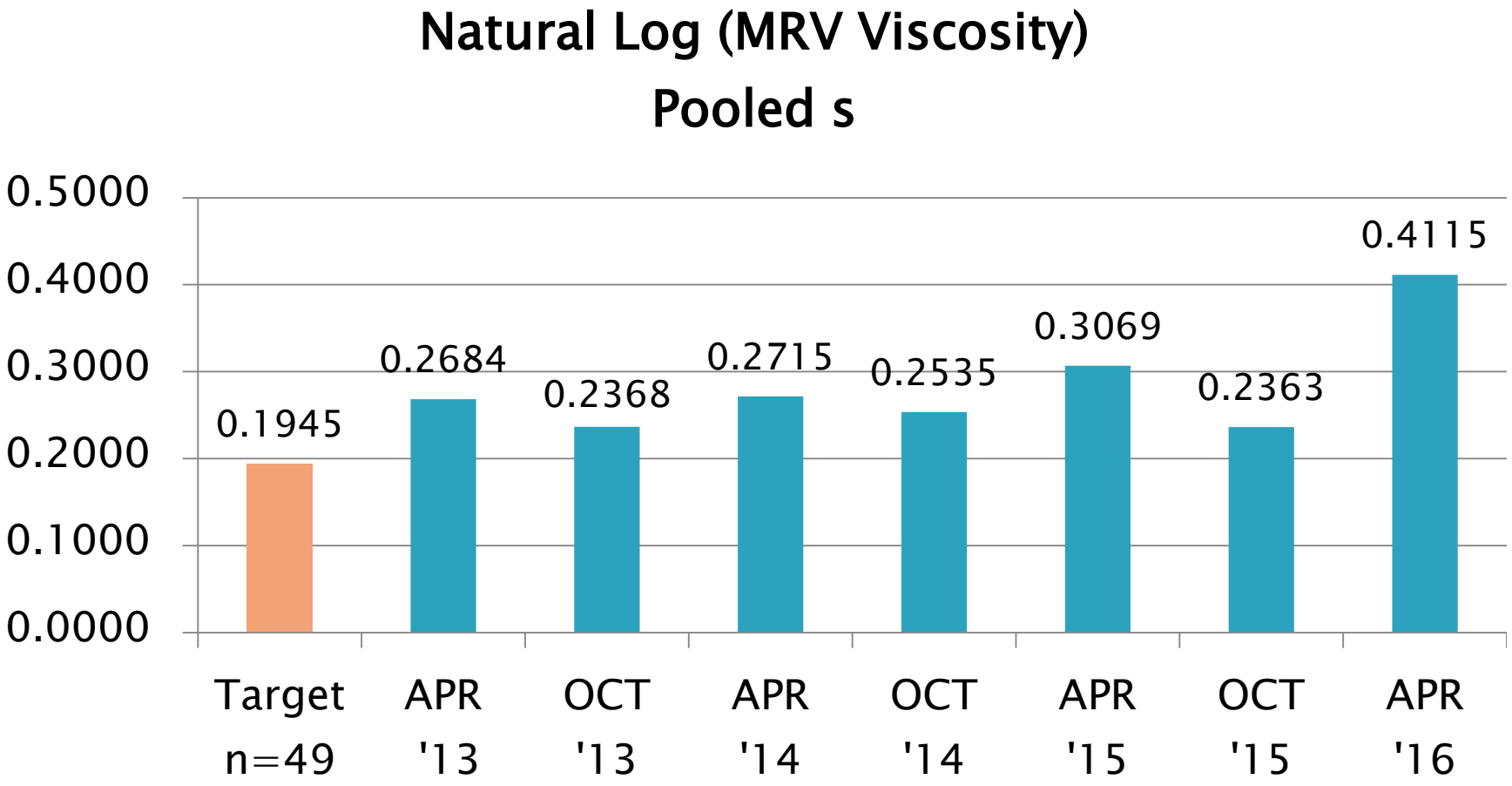
D7528: Oxidation by ROBO

Period Precision and Severity Estimates

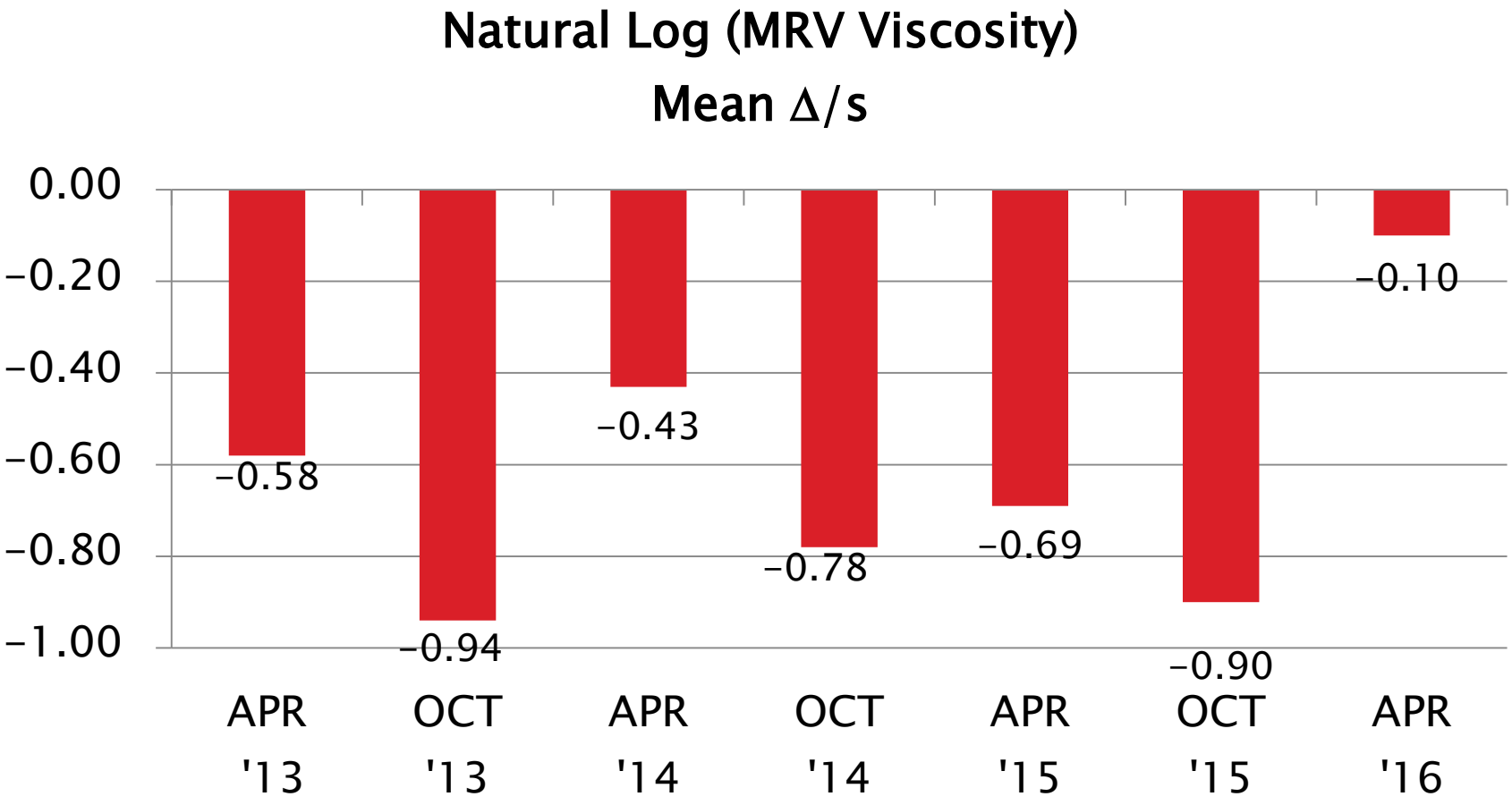
Natural Log (MRV Viscosity)	n	df	Pooled s	Mean Δ/s
Current Targets	49	46	0.1945	-----
10/1/12 through 3/31/13	109	106	0.2684	-0.58
4/1/13 through 9/30/13	90	87	0.2368	-0.94
10/1/13 through 3/31/14	85	82	0.2715	-0.43
4/1/14 through 9/30/14	83	80	0.2535	-0.78
10/1/14 through 3/31/15	97	94	0.3069	-0.69
4/1/15 through 9/30/15	85	82	0.2363	-0.90
10/1/15 through 3/31/16*	92	89	0.4115	-0.10
10/1/15 through 3/31/16*	91	88	0.3661	-0.20

*Period statistics with and without extreme result included

D7528: Oxidation by ROBO



D7528: Oxidation by ROBO



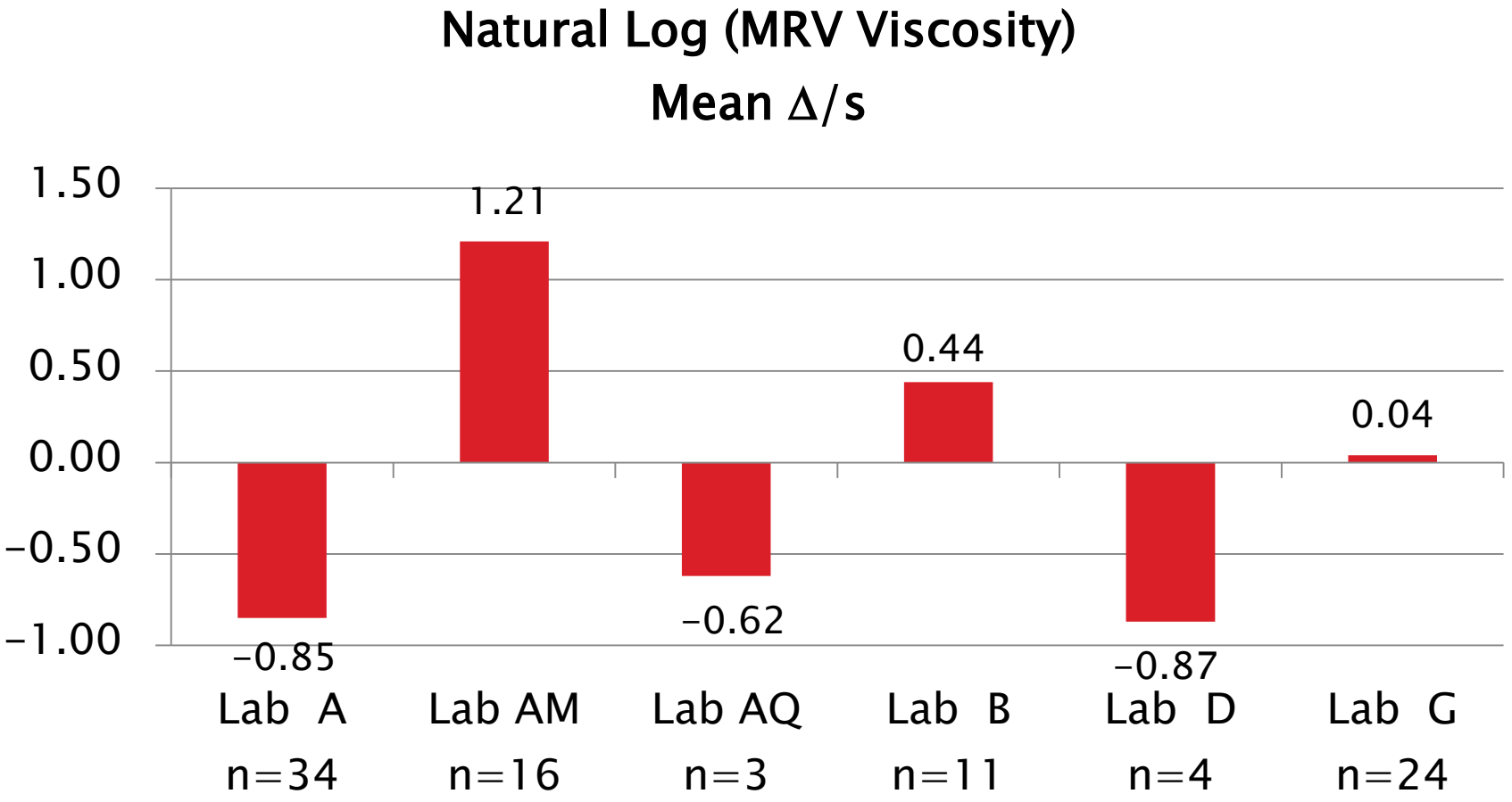
Test Monitoring Center
http://astmtmc.cmu.edu
A Program of ASTM International

D7528: Oxidation by ROBO

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

	n	Mean Δ/s
Lab A	34	-0.85
Lab AM	16	1.21
Lab AQ	3	-0.62
Lab B	11	0.44
Lab D	4	-0.87
Lab G	24	0.04

D7528: Oxidation by ROBO



D7528: Oxidation by ROBO

- Lab B, Instrument 4A, reported a result more than 9 s severe (MRV >400,000 cP). Period overall precision and severity estimates shown with this result included and excluded.
- Exceptionally high OC fail rate this period (32%), with individual rigs failing 3, 4 and 5 times, and 4 tests 5 s or more severe (5.0 s, 5.6 s, 5.6 s and 9.2 s)
- Precision (Pooled s) is less precise than prior period
  - Continues to be less precise than target precision
  - Even with extreme (9 s) result excluded, the worst period precision since at least April 2013
- Performance (Mean Δ/s) is -0.10 s mild (-0.20 s mild with 9 s result excluded)

D7528: Oxidation by ROBO

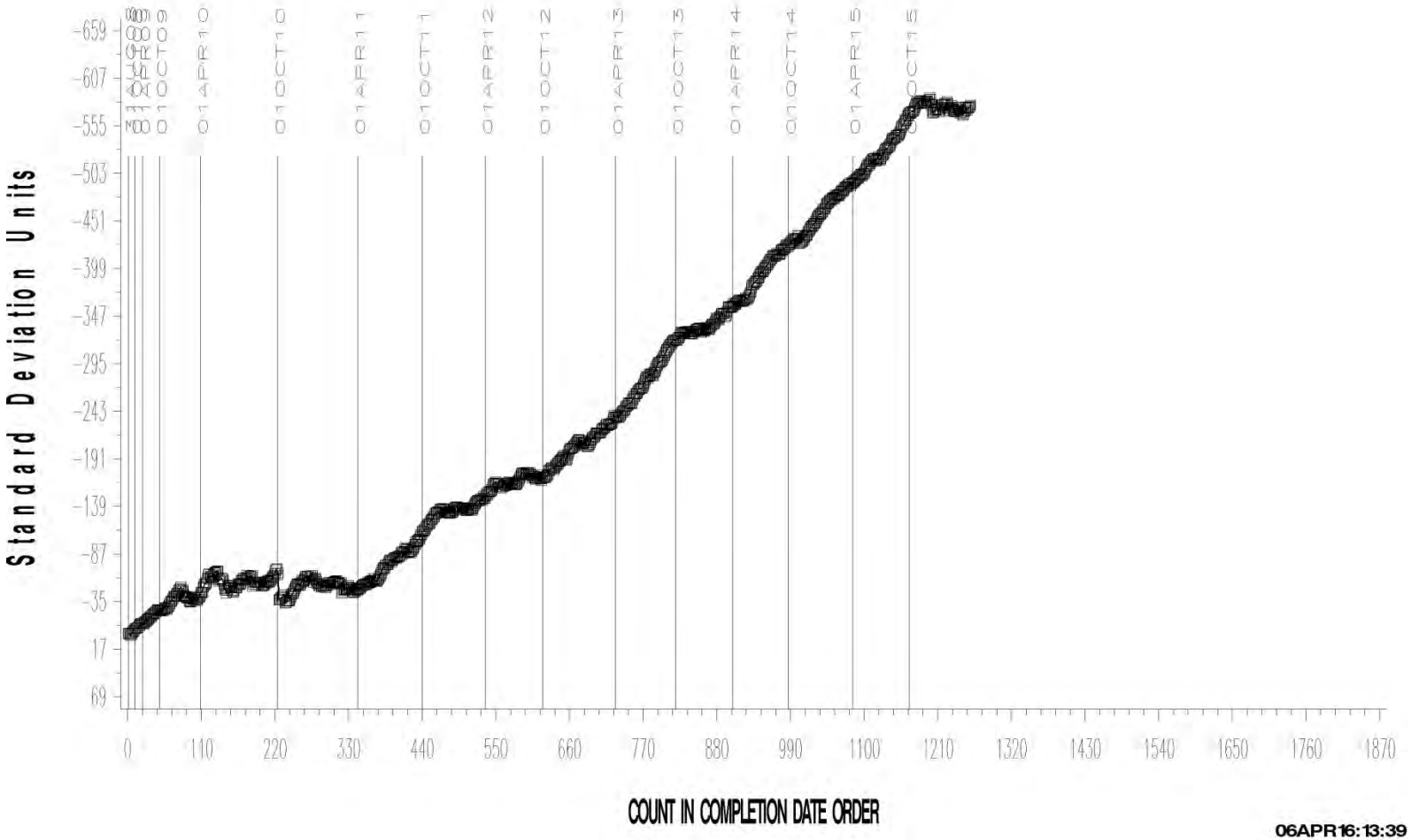
- Oils 434-1 and 435-1 are especially imprecise (even with extreme 9 s result excluded on 435-1)

- 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.

ROBO TEST INDUSTRY OPERATIONALLY VALID DATA

AGED OIL MRV APPARENT VISCOSITY

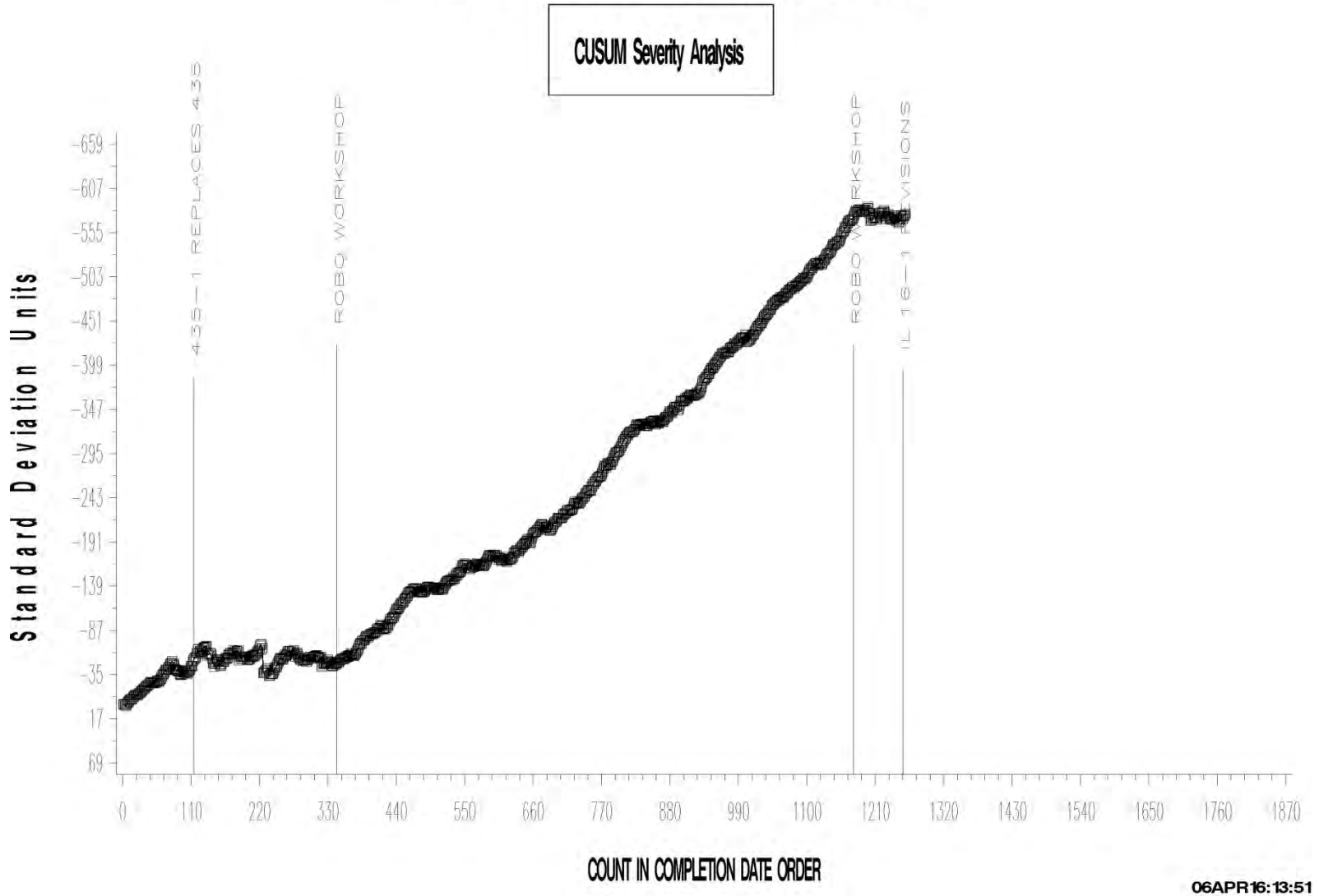
CUSUM Severity Analysis



06APR16:13:39

ROBO TEST INDUSTRY OPERATIONALLY VALID DATA

AGED OIL MRV APPARENT VISCOSITY



06APR16:13:51

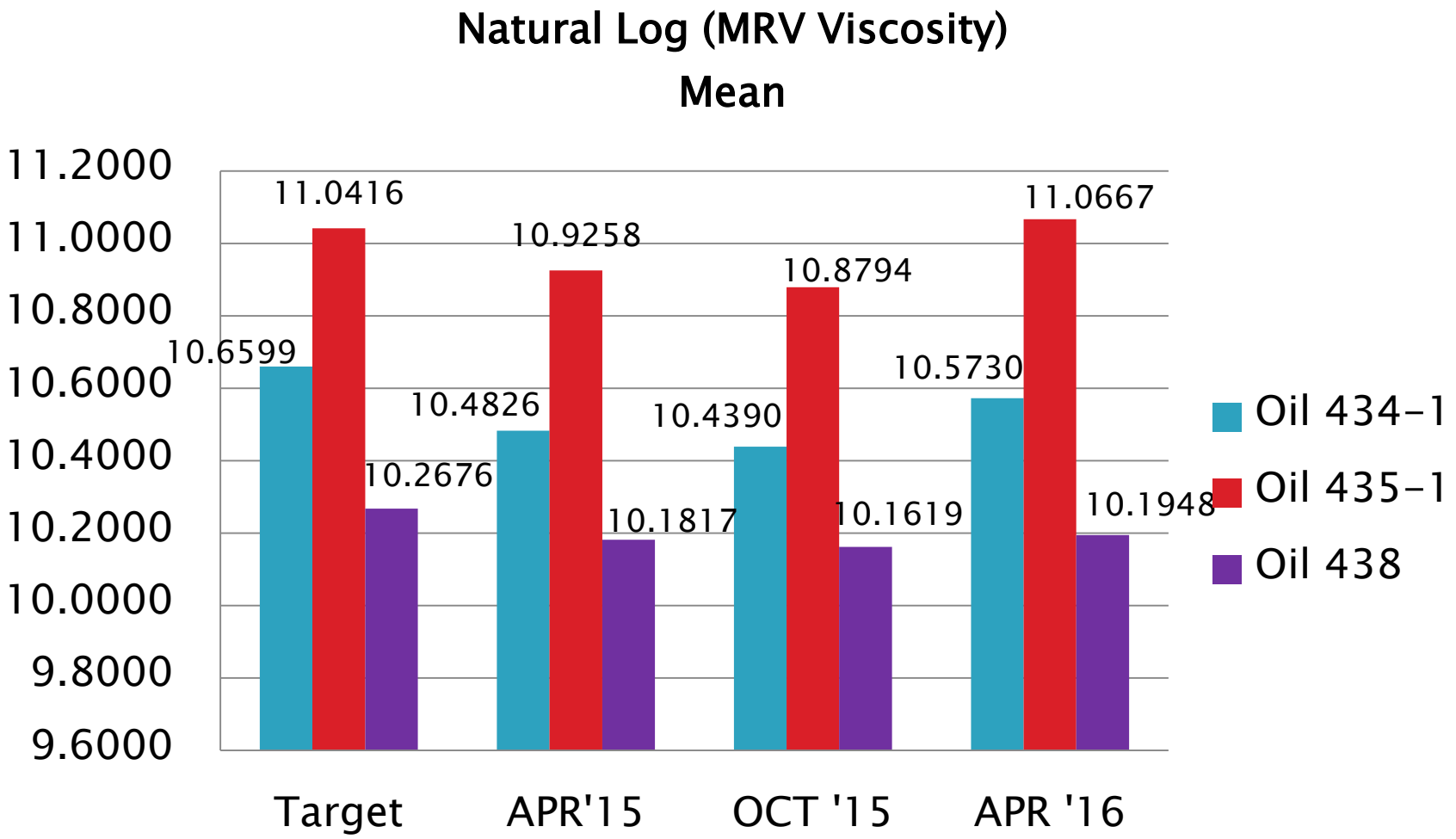
D7528: Oxidation by ROBO

Performance by Oil
Natural Log (MRV Viscosity)

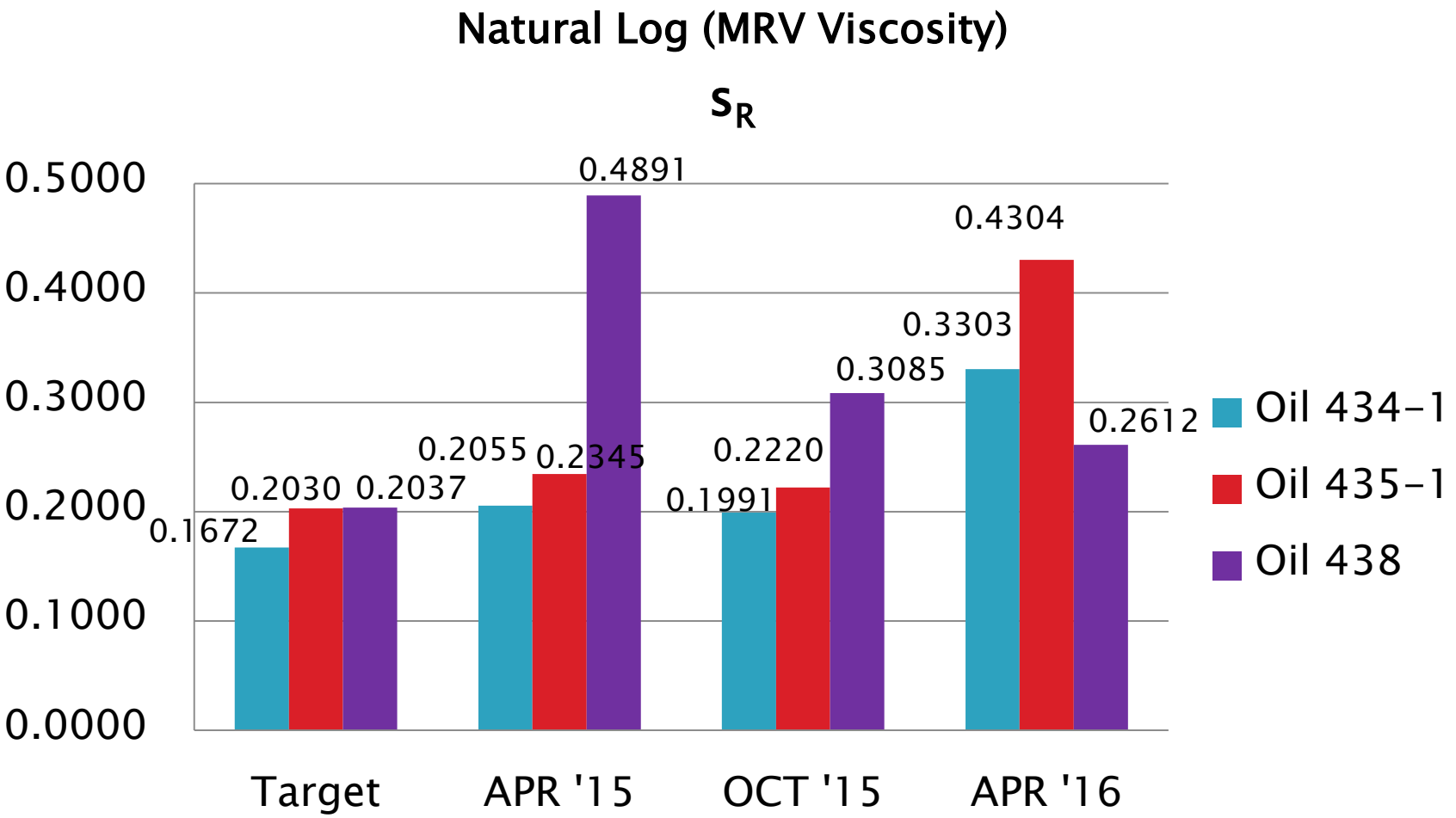
	Targets			10/1/14 - 3/31/15				4/1/15 - 9/30/15				10/1/15 - 3/31/16			
Oil Code	n	Mean	s_R	n	Mean	s_R	Mean Δ/s	n	Mean	s_R	Mean Δ/s	n	Mean	s_R	Mean Δ/s
434-1	13	10.6599	0.1672	30	10.4826	0.2055	-1.06	26	10.4390	0.1991	-1.32	31	10.5730	0.3303	-0.52
435-1	22	11.0416	0.2030	44	10.9258	0.2345	-0.58	41	10.8794	0.2220	-0.80	40*	11.0667	0.4304	0.12
438	14	10.2676	0.2037	23	10.1817	0.4891	-0.42	18	10.1619	0.3085	-0.52	20	10.1948	0.2612	-0.36

*Extreme (9 s) result excluded

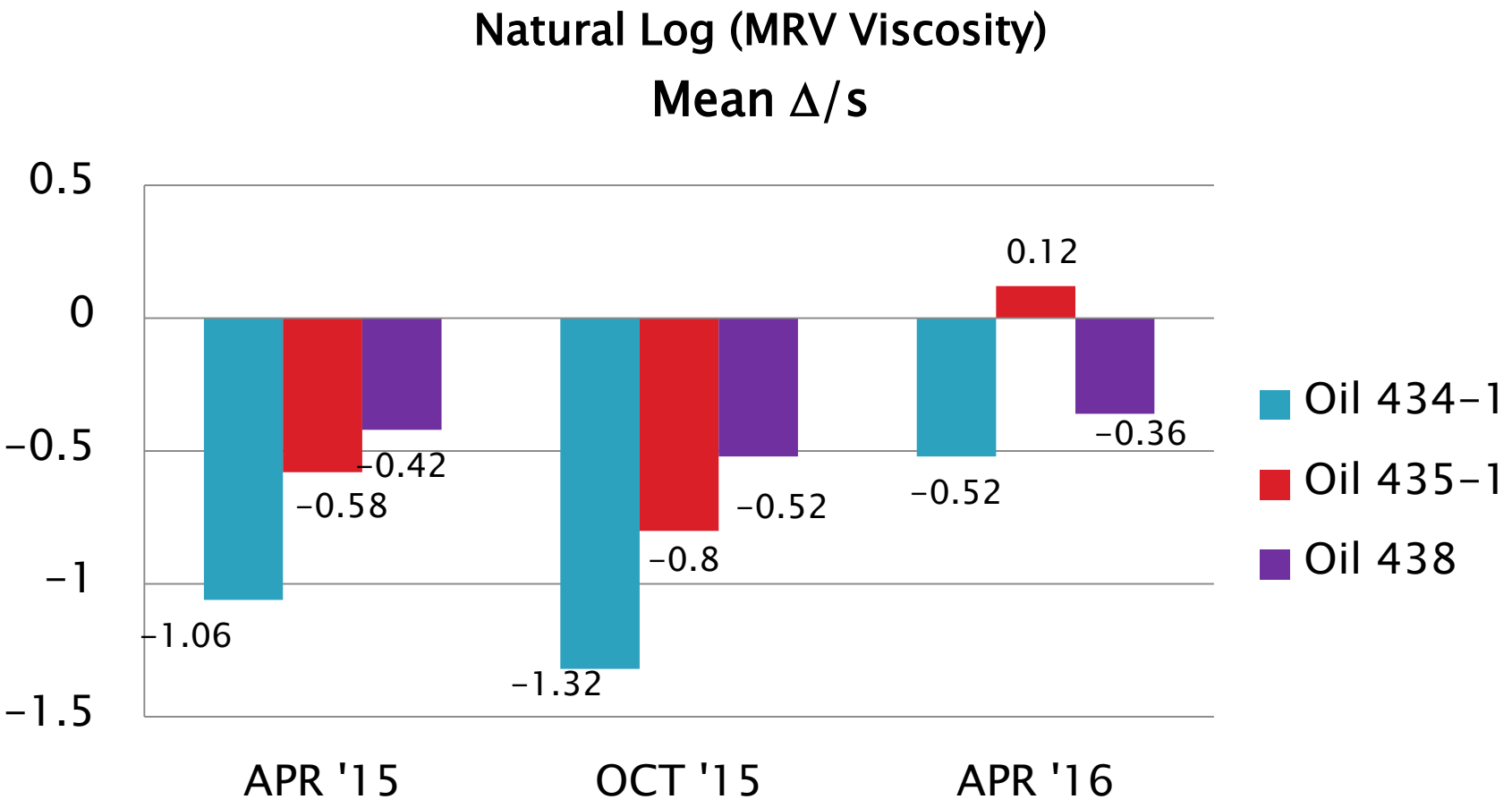
D7528: Oxidation by ROBO



D7528: Oxidation by ROBO



D7528: Oxidation by ROBO



Return to Executive Summary

Non-monitored Bench Tests

- **D6922 Homogeneity and Miscibility**
  - The TMC distributes six D6922 reference oils.
  - The TMC does not collect reference data or monitor test results for this test at this time.
  - **Oils rec'd by TMC 2002 – 2003**
    - **Formulations are at least 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 4/1/2016

Reference Oil Inventory

D5800, D6417, GI

Oil	Year Rec'd By TMC	Tests	TMC Inventory, gallons	Gallons Shipped last 12 months
VOLC12	2013	D5800	47.8	0.9
VOLD12	2013	D5800	49.7	0.6
VOLE12	2013	D5800	48.6	0.7
VOLD14	2014	D5800QC	312	97.4
52	1995	D6417	59.1	0.0
55	1995	D6417	66.2	0.0
58	1998	D6417, GI	116.4	0.4
62	1996	GI	1.0	0.2
1009*	2002	GI	46.7	----

*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	108.7	0.8
434	2003	MTEOS	3.2	0.7
75	2010	TEOST	3.8	0.9
435-2*	2010	TEOST	44.9	----
434-1*	2008	ROBO	1.6	----
435-1	2008	ROBO	454.1	15.3
438*	2003	ROBO	10.9	----

*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	13.1	2.6
66	2002	D6082	88.0	1.1
820-2	2001	D874	10.2	0.1
90	2005	D874	25.5	3.8
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	133.6	6.1
HMB	2002	H&M	137.1	6.1
HMC	2003	H&M	123.9	6.1
HMD	2002	H&M	131.4	6.1
HME	2002	H&M	117.6	6.1
HMF	2002	H&M	140.1	6.1

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

A Program of ASTM International