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Test Monitoring Center

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ASTM D02.B2 Semi-Annual Report Heavy Duty Reference Oil Testing

October 2017

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Heavy Duty Testing

Executive Summary

- ▶ Reference Oils
 - 833
 - COAT reference oil re-blend secured. New blend is 833-1.
 - 832
 - Re-blend request has been made.
- ▶ Test Issues
 - CAT 1N Test Severity Investigation ongoing by Surveillance Panel
 - COAT testing resumed and improvement plan in place to standardize aeration enclosure by the end of the year.

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Calibrated Labs and Stands*

| Test | Labs | Stands |
|------------|------|--------|
| 1K | 1 | 1 |
| 1N | 4 | 8 |
| 1M-PC | 0 | 0 |
| 1P | 3 | 3 |
| 1R | 1 | 1 |
| C13 | 3 | 3 |
| ISB | 3 | 5 |
| ISM | 5 | 5 |
| EOAT | 1 | 1 |
| RFWT | 2 | 2 |
| T-8/E | 2 | 4 |
| T-11 | 1 | 1 |
| T-12/T-12A | 4/4 | 6/6 |
| T-13 | 4 | 5 |
| COAT | 3 | 3 |
| DD13 | 3 | 4 |

*As of 09/30/2017

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1 K Test Activity

| Test Status | Validity Code | # |
|-----------------------------|---------------|----------|
| Acceptable Calibration Test | AC | 1 |
| Failed Calibration Test | OC | 0 |
| Operationally Invalid | LC | 0 |
| Aborted | XC | 0 |
| Total | | 1 |

1 K Failed Tests

| Failed Parameter | Number of Tests |
|------------------|-----------------|
| No failed tests | 0 |
| Total | 0 |

1 K Lost Tests*

| Status | Cause | # |
|--------------|------------------|----------|
| Invalid | No invalid tests | 0 |
| Aborted | No aborted tests | 0 |
| Total | | 0 |

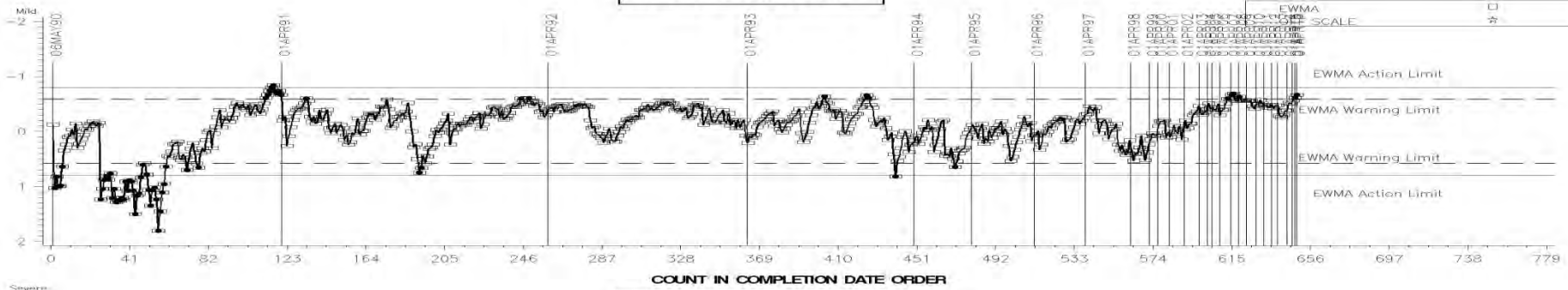
*Invalid and aborted tests

1 K Test Severity

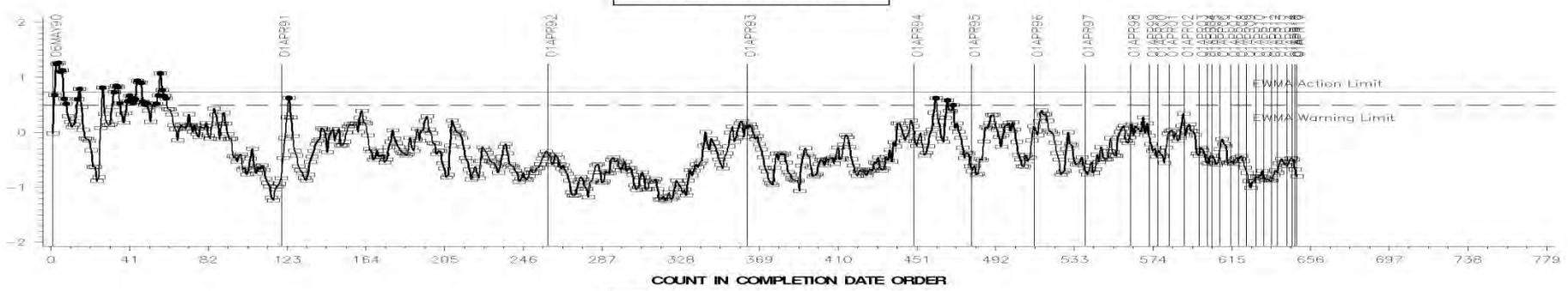
- ▶ WD, TLHC, ETOC are in control
- ▶ TGF in severity warning alarm mild direction
- ▶ BSOC in severity action alarm in mild direction

FINAL TGF

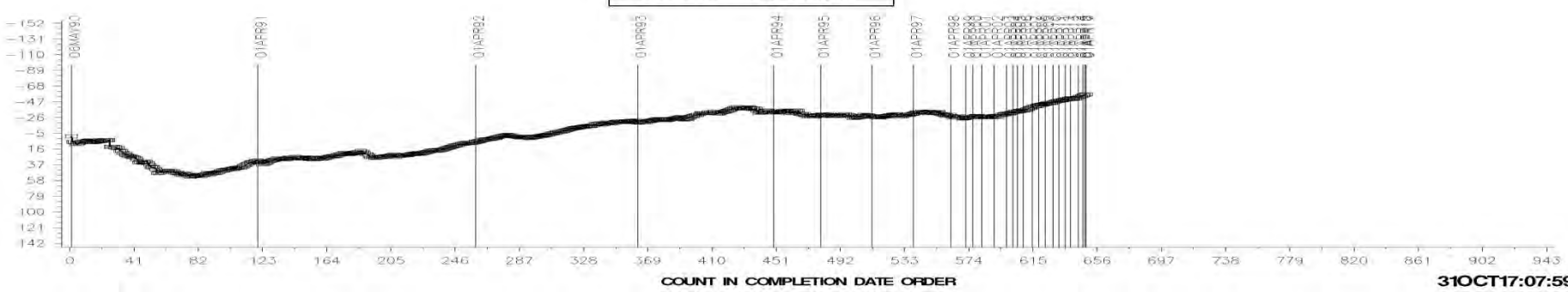
LTMS Severity Analysis



LTMS Precision Analysis



CUSUM Severity Analysis



FINAL Weighted Total Demerits

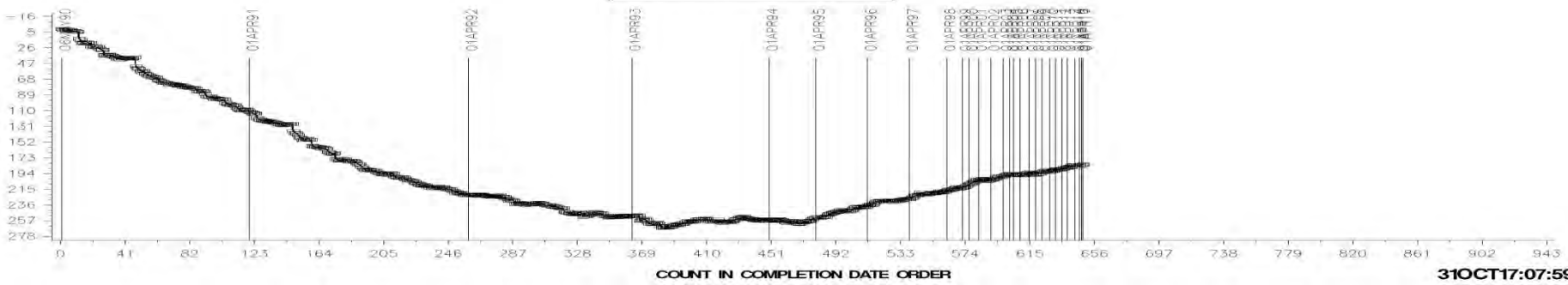
LTMS Severity Analysis



LTMS Precision Analysis



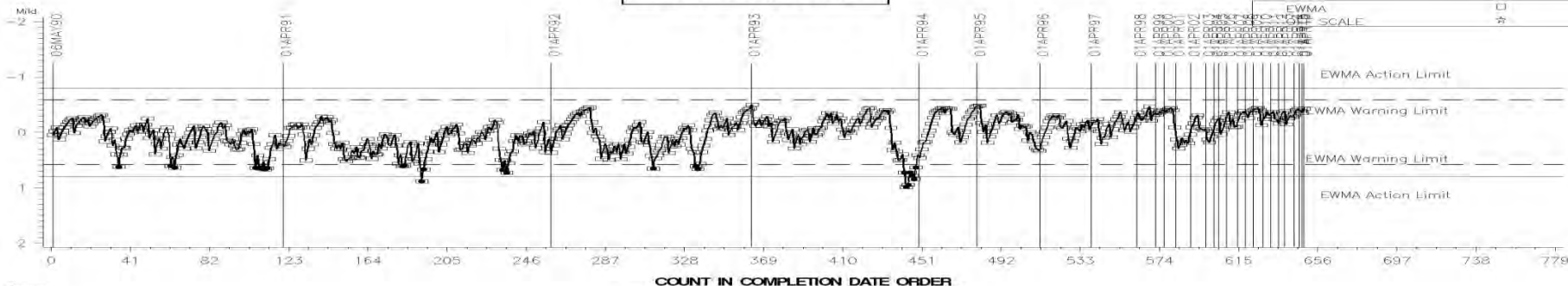
CUSUM Severity Analysis



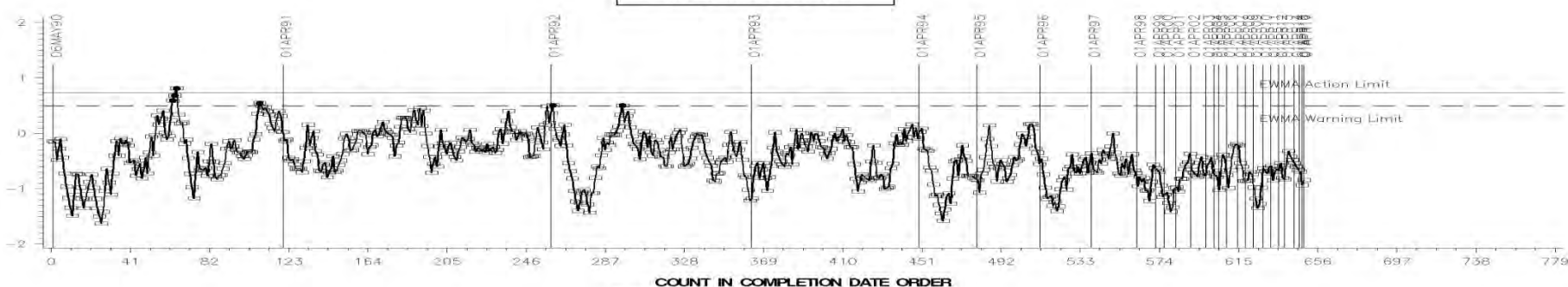
31OCT17:07:59

FINAL TLHC

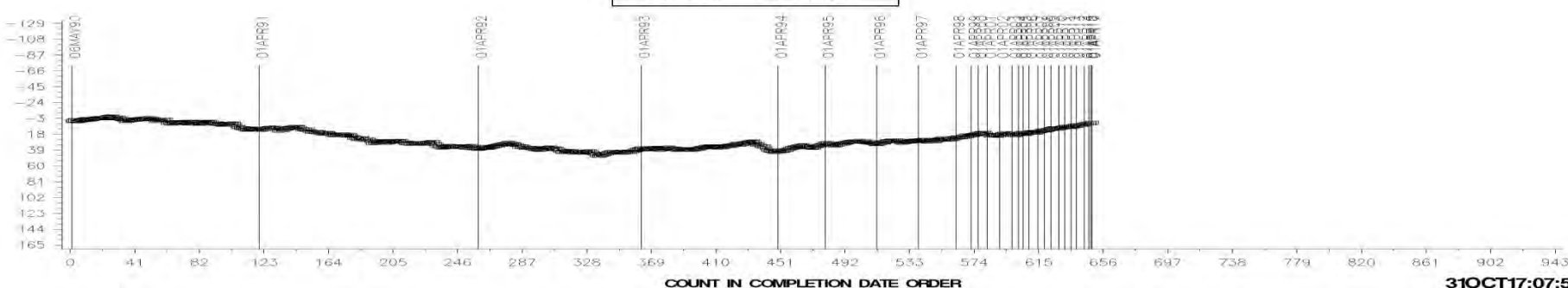
LTMS Severity Analysis



LTMS Precision Analysis



CUSUM Severity Analysis



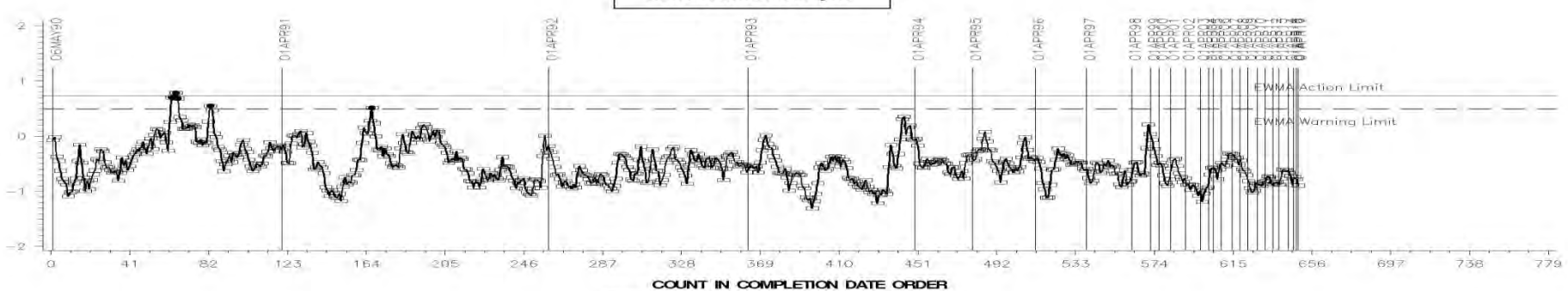
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FINAL BSOC

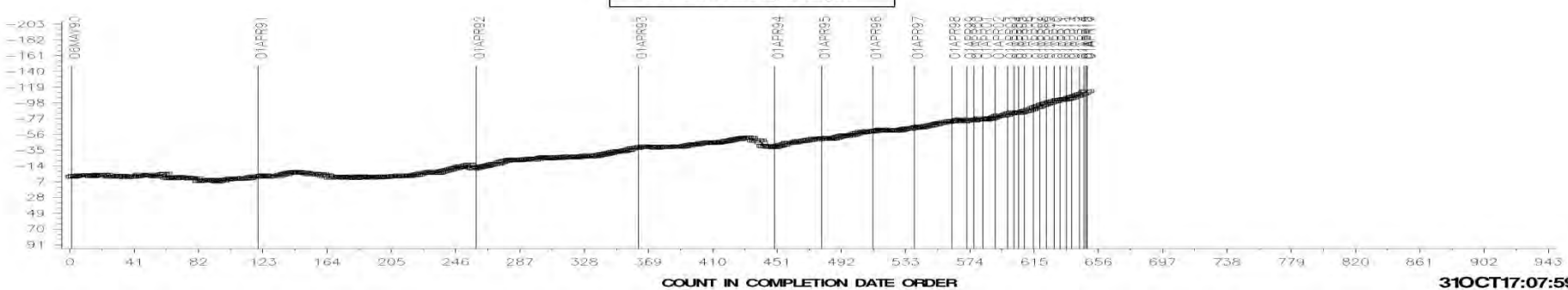
LTMS Severity Analysis



LTMS Precision Analysis

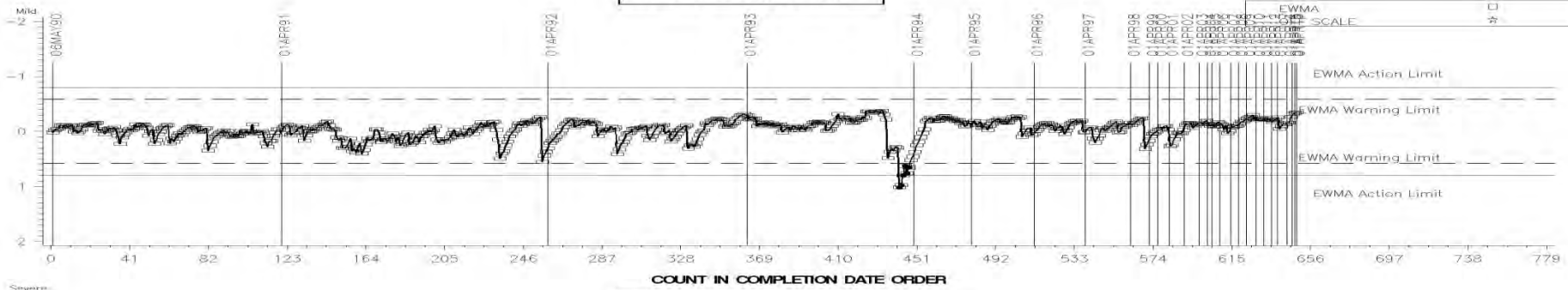


CUSUM Severity Analysis

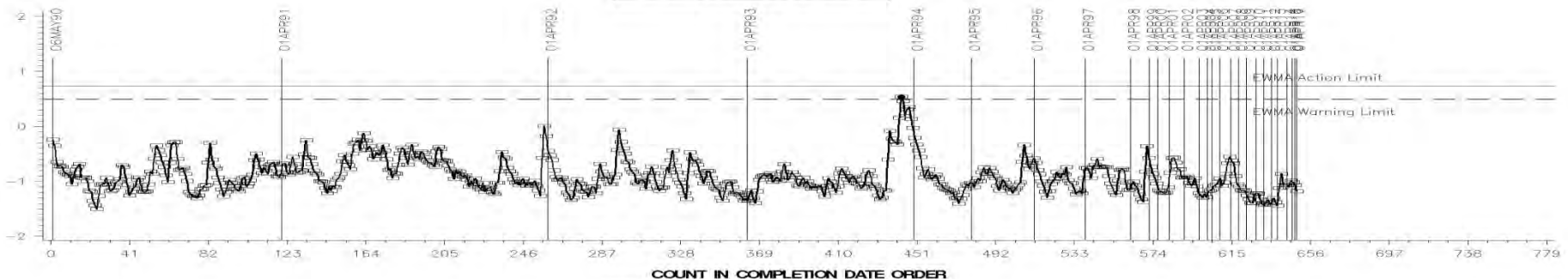


31OCT17:07:59

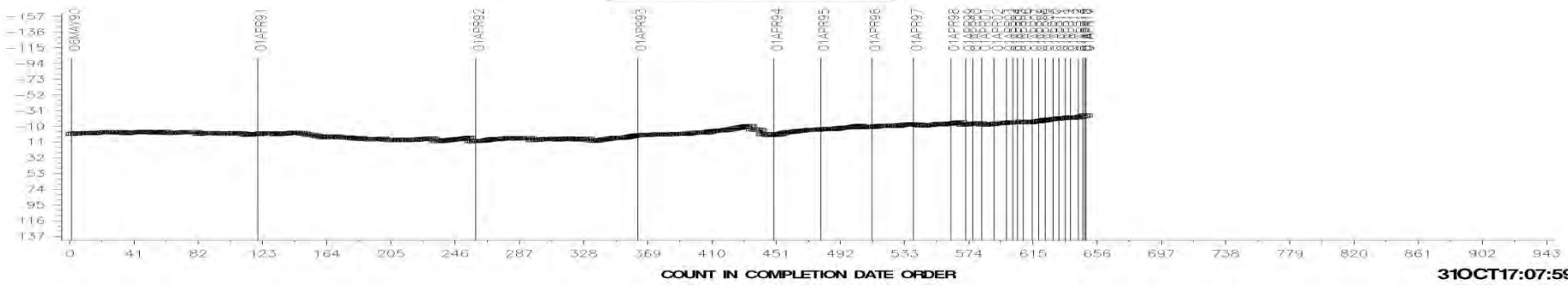
FINAL EOTC
LTMS Severity Analysis



LTMS Precision Analysis

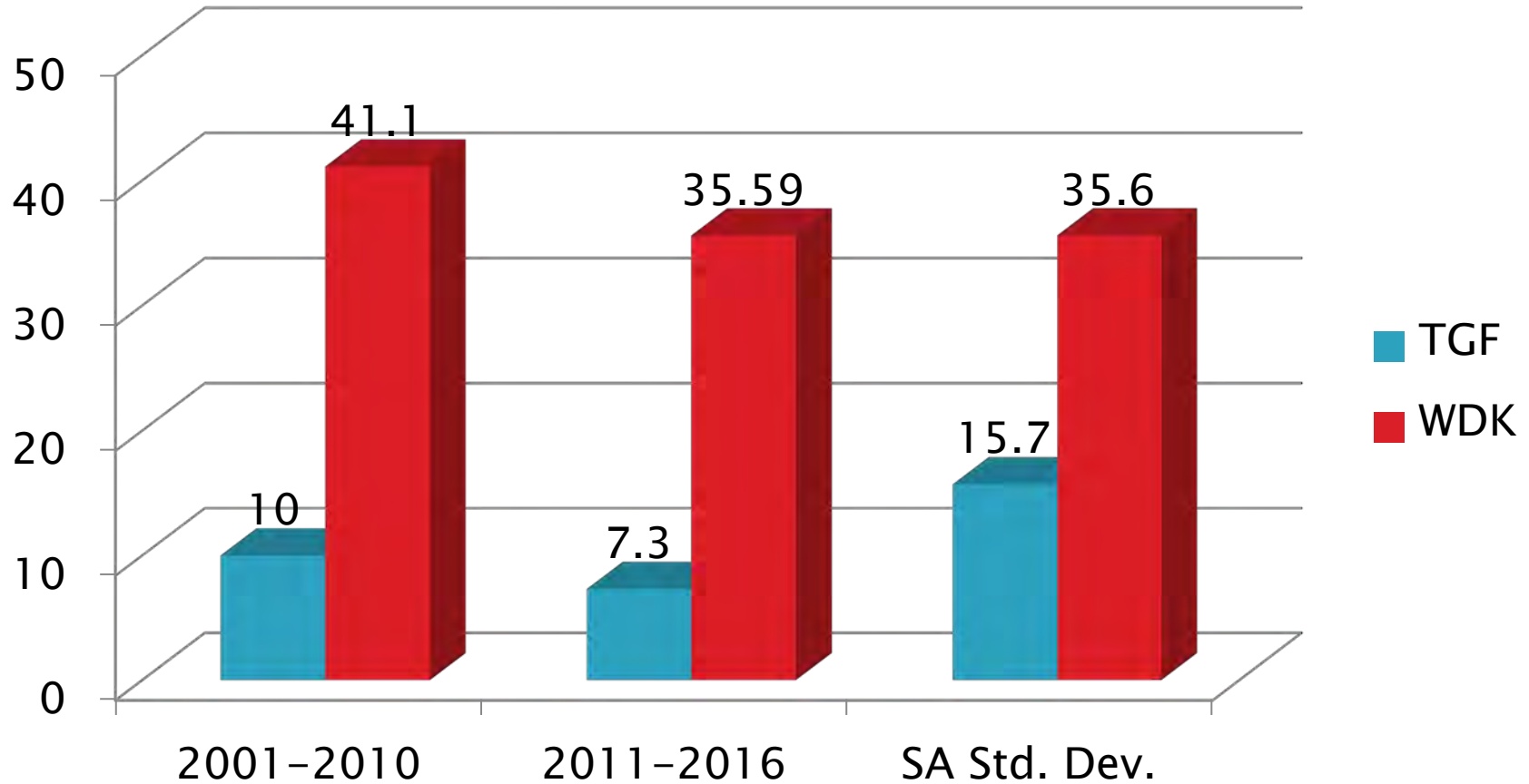


CUSUM Severity Analysis

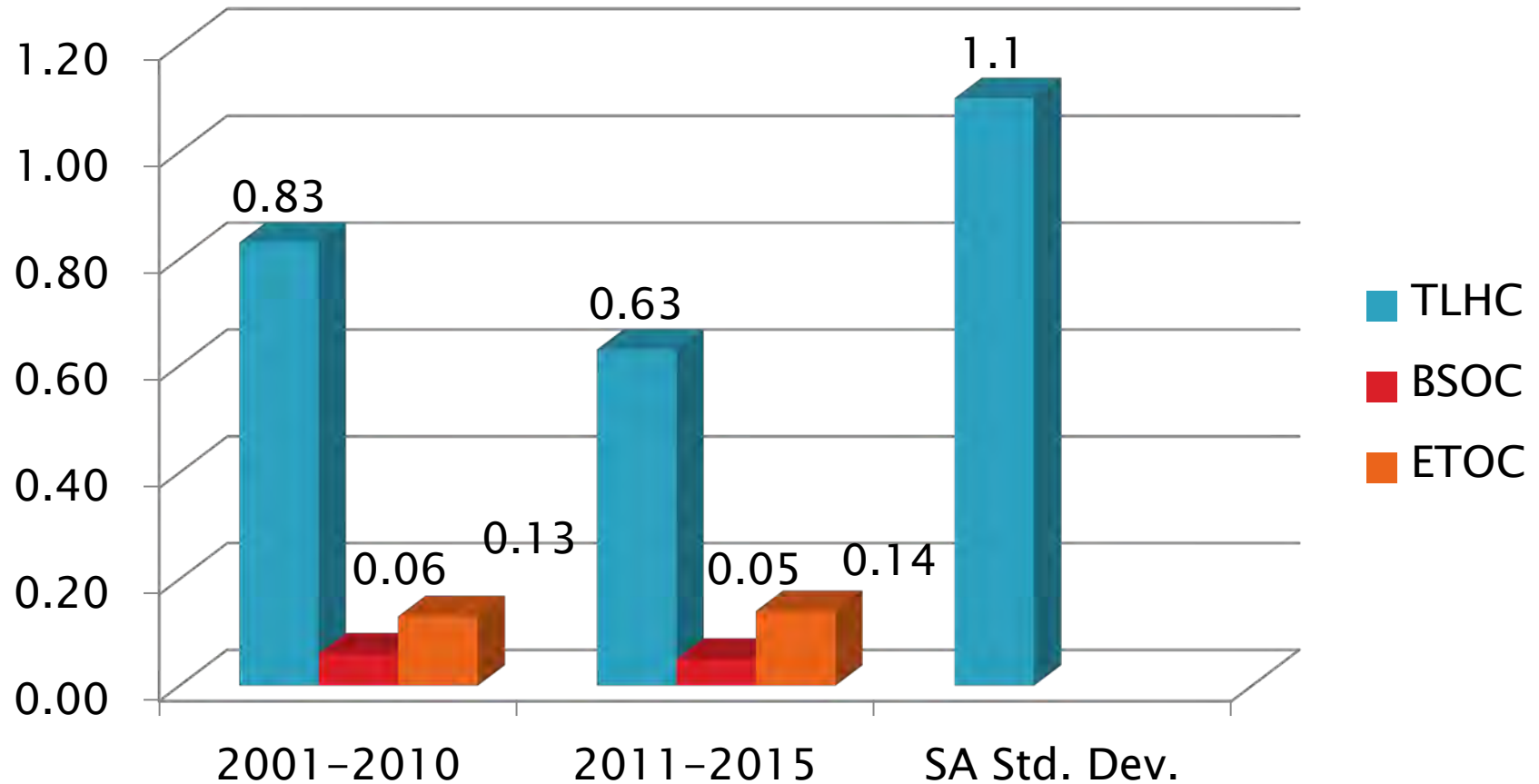


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1 K Precision Estimates



1K Precision Estimates



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1 N Test Activity

| Test Status | Validity Code | # |
|-----------------------------|---------------|----------|
| Acceptable Calibration Test | AC | 4 |
| Failed Calibration Test | OC | 0 |
| Operationally Invalid | LC | 0 |
| Aborted | XC | 0 |
| Informational | NN | 0 |
| Total | | 4 |

1 N Failed Tests

| Failed Parameter | Number of Tests |
|------------------|-----------------|
| No failed tests | 0 |
| Total | 0 |

1 N Lost Tests*

| Status | Cause | # |
|--------------|------------------|----------|
| Invalid | No invalid tests | 0 |
| Aborted | No aborted tests | 0 |
| Total | | 0 |

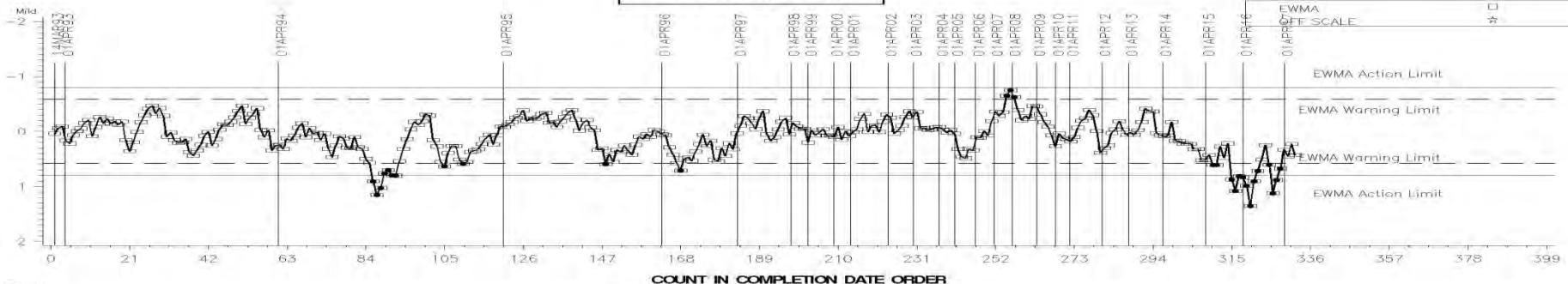
*Invalid and aborted tests

1 N Test Severity

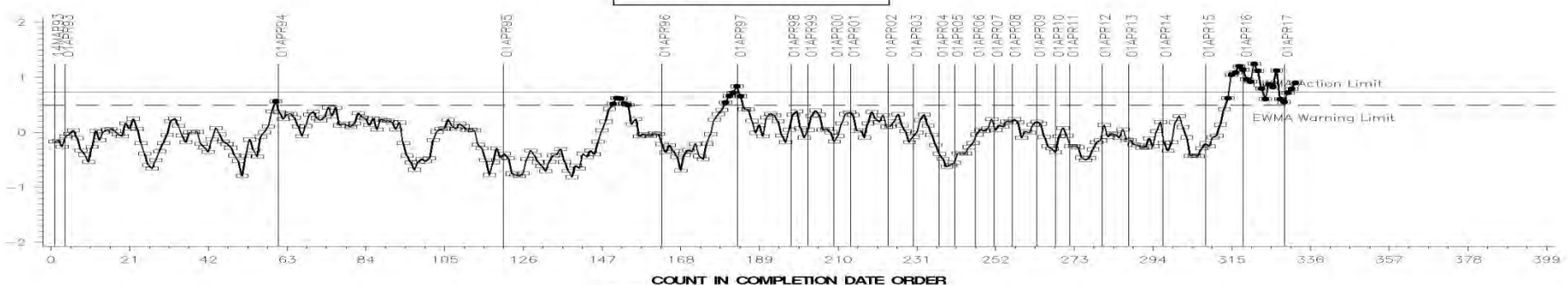
- ▶ WDN in severity action alarm mild direction.
- ▶ TGF in precision action alarm.
- ▶ TLHC and BSOC in control
- ▶ Severity trends are being evaluated by surveillance panel

FINAL CORRECTED TGF

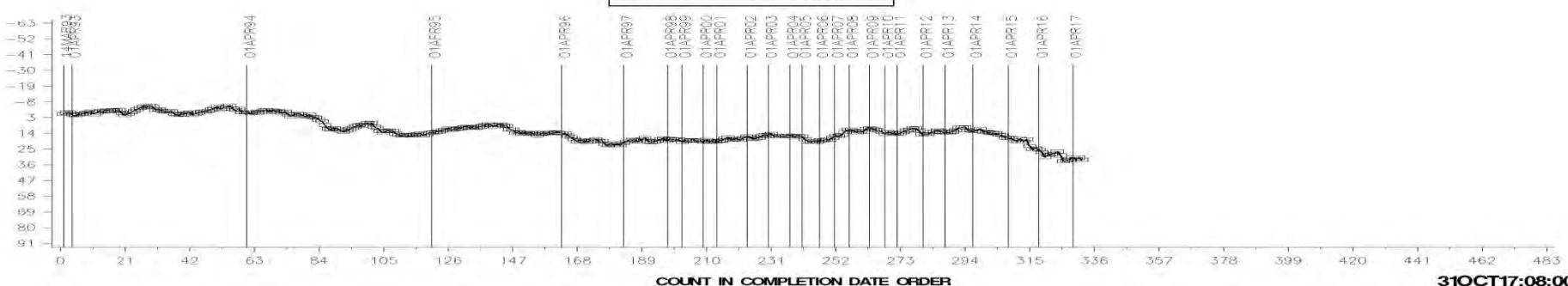
LTMS Severity Analysis



LTMS Precision Analysis



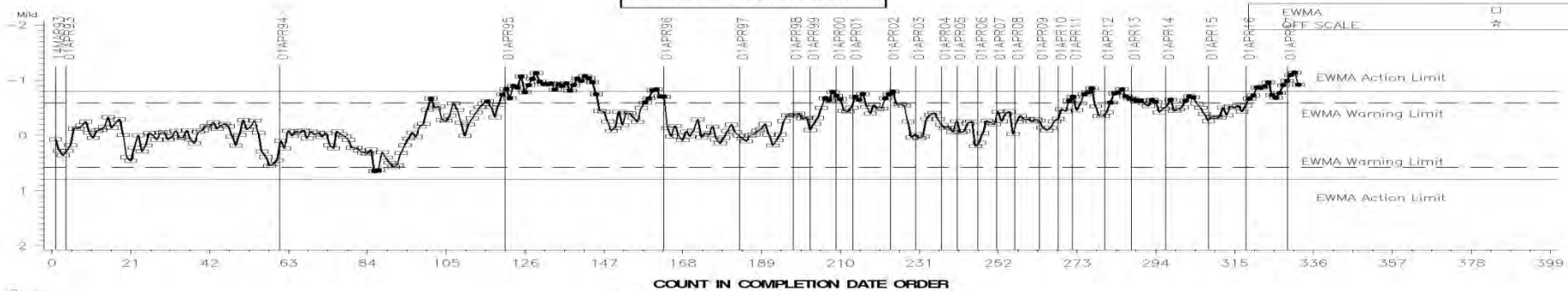
CUSUM Severity Analysis



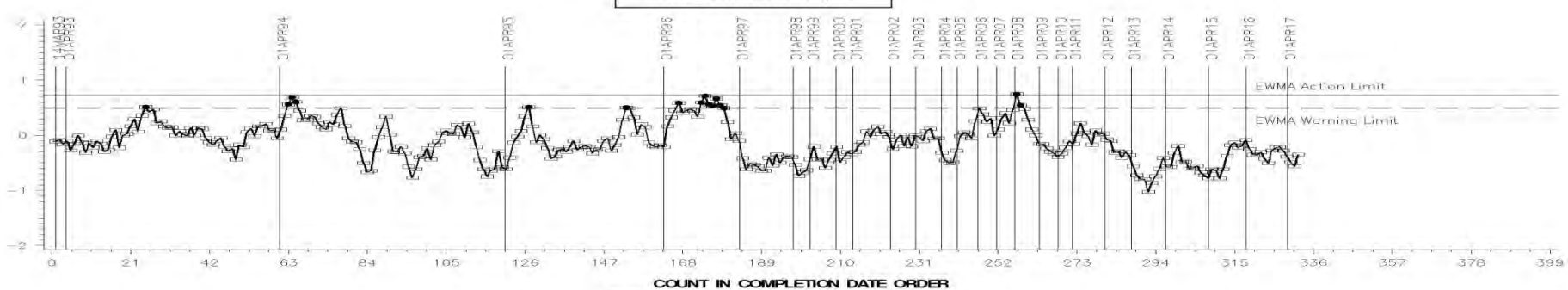
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Weighted Total Demerits

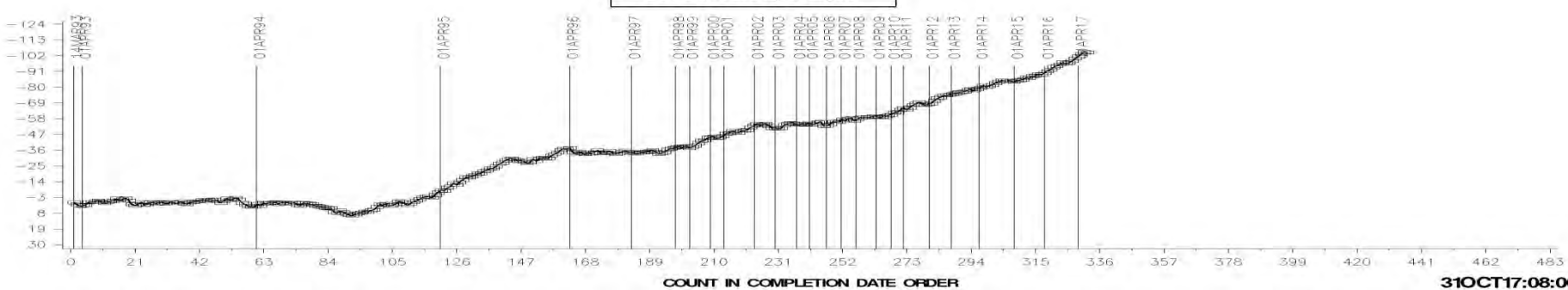
LTMS Severity Analysis



LTMS Precision Analysis



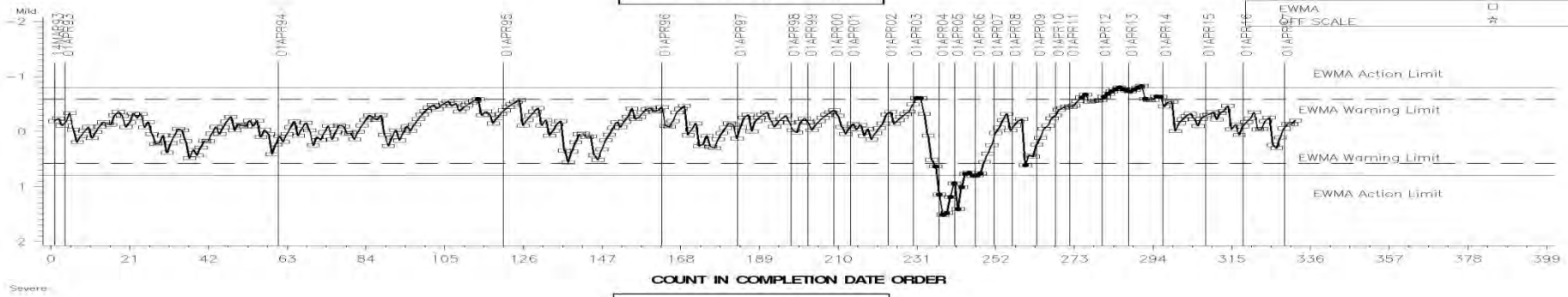
CUSUM Severity Analysis



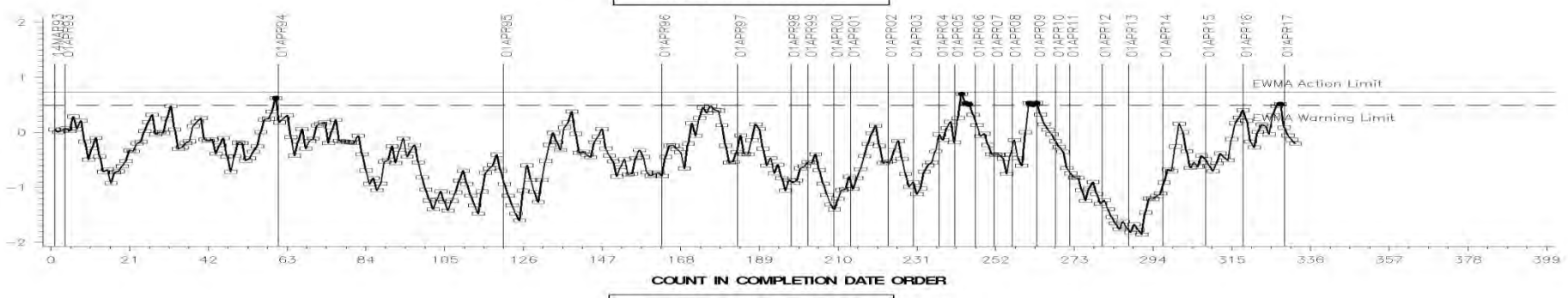
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Top Land Heavy Carbon

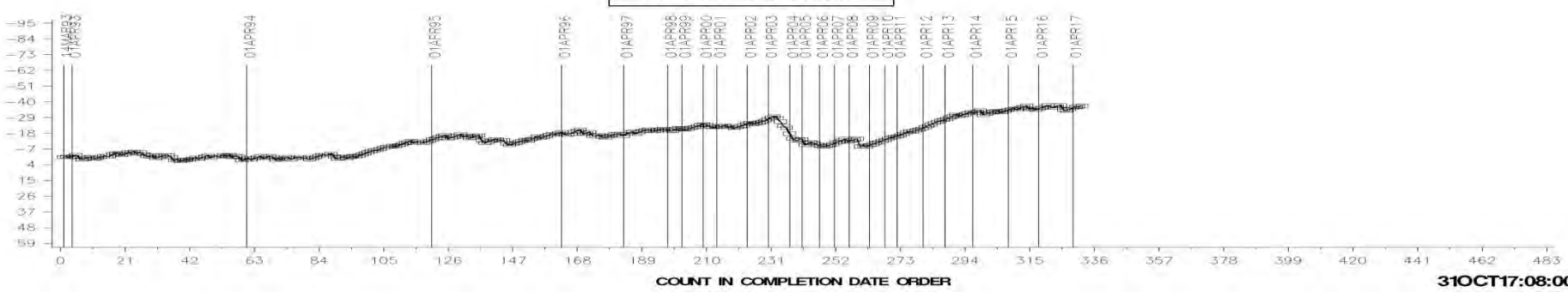
LTMS Severity Analysis



LTMS Precision Analysis



CUSUM Severity Analysis



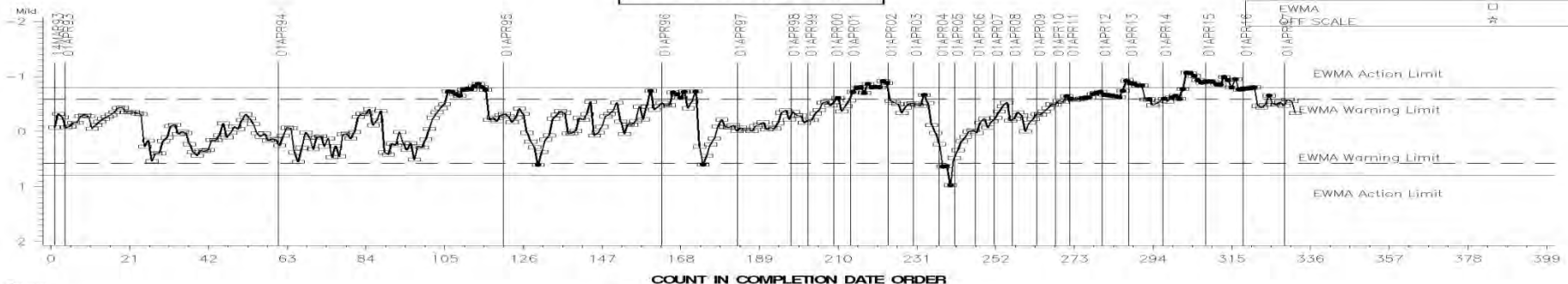
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CATERPILLAR 1N INDUSTRY OPERATION VALID DATA

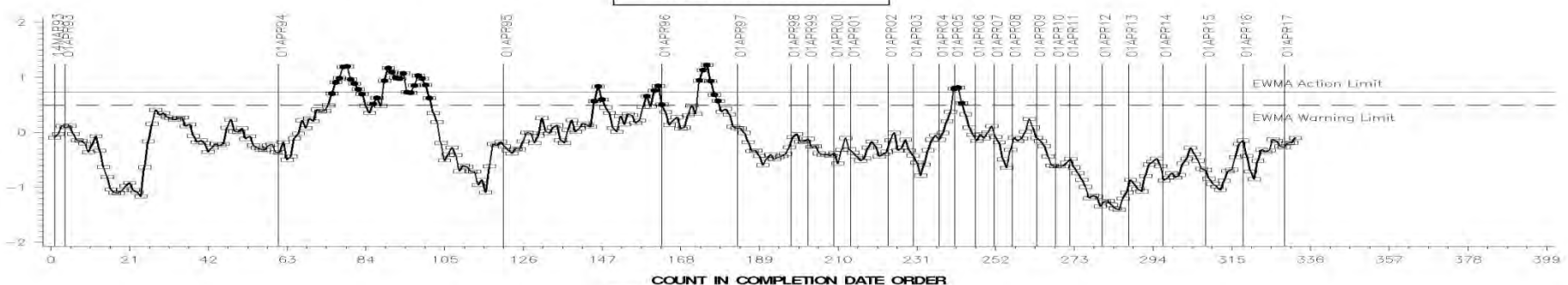


BSOC

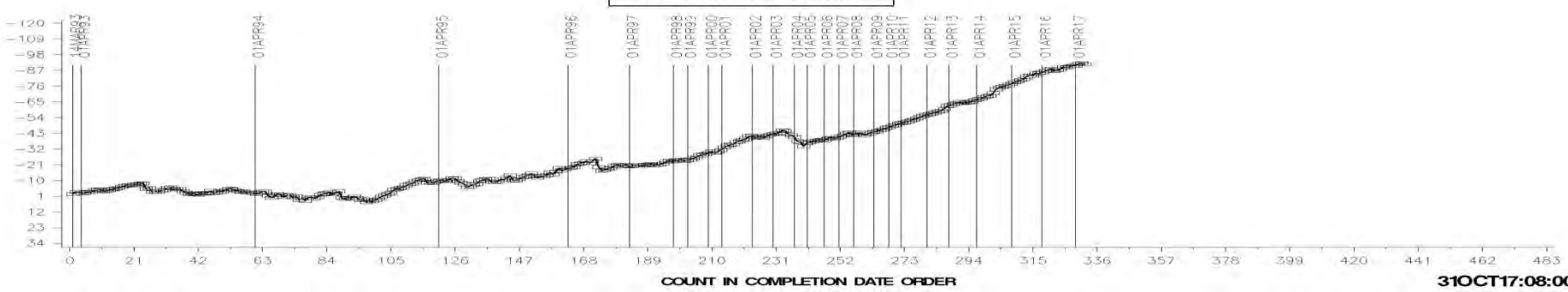
LTMS Severity Analysis



LTMS Precision Analysis



CUSUM Severity Analysis

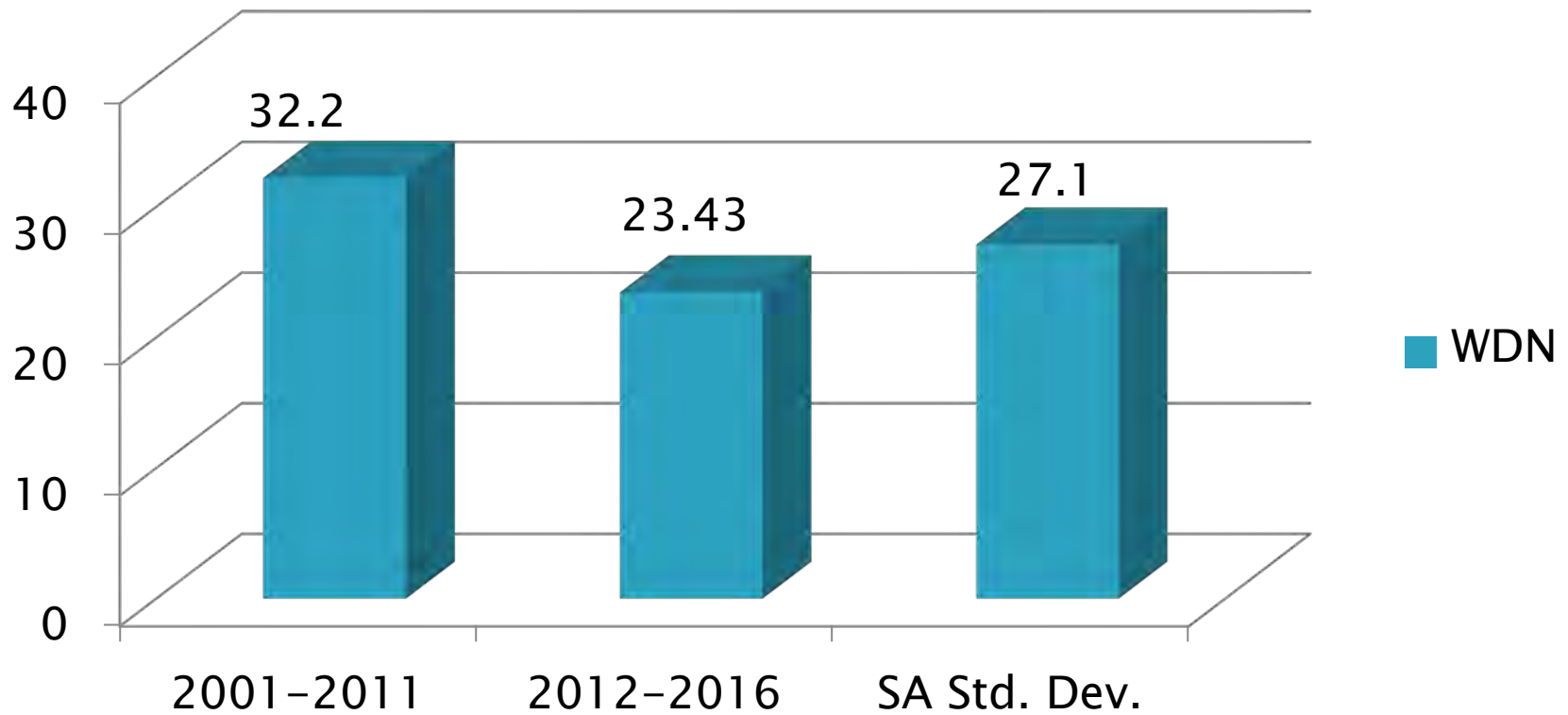


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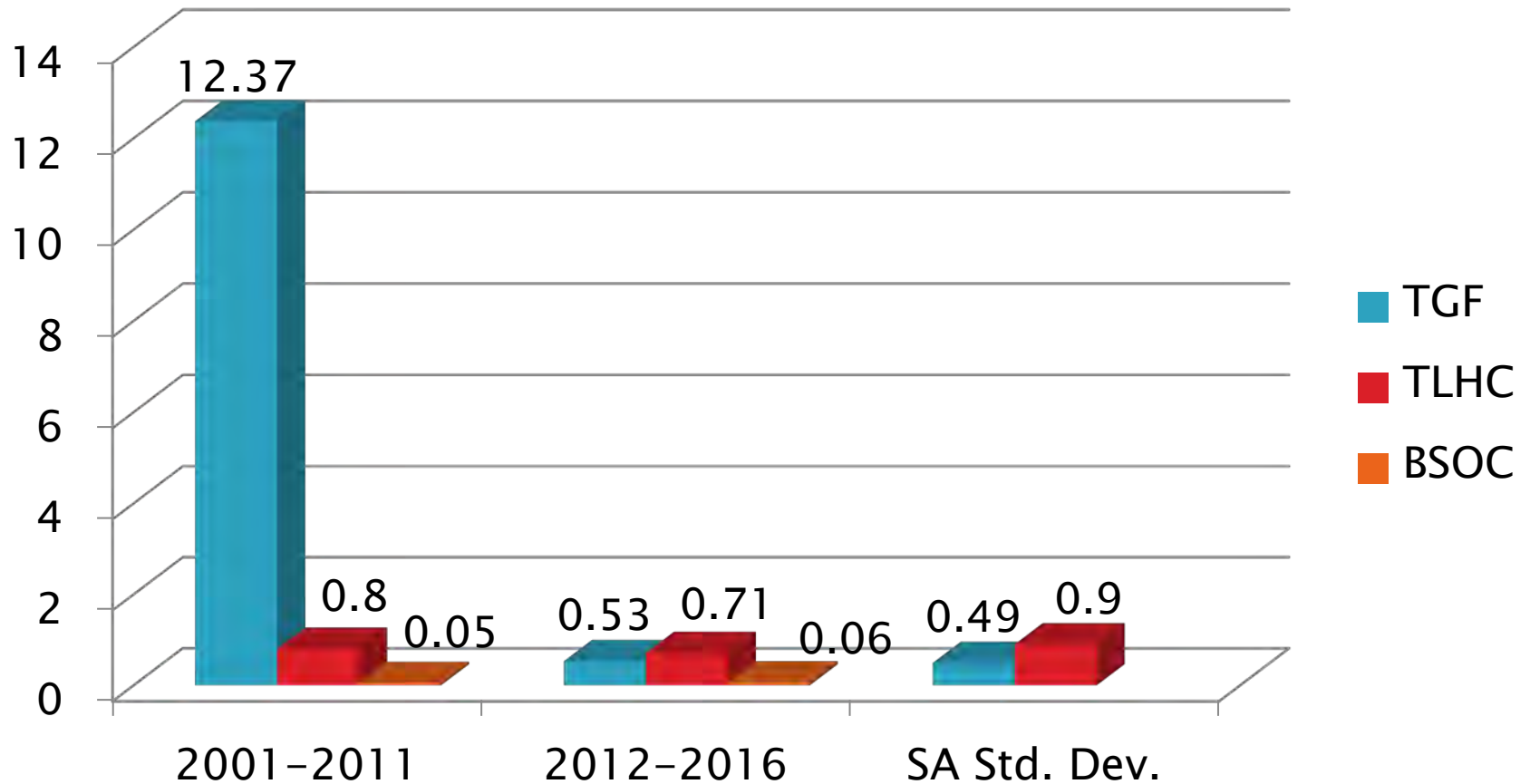


1 N Precision Estimates

WDN



1N Precision Estimates



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1 M-PC Test Activity

| Test Status | Validity Code | # |
|-----------------------------|---------------|----------|
| Acceptable Calibration Test | AC | 0 |
| Failed Calibration Test | OC | 0 |
| Operationally Invalid | LC | 0 |
| Total | | 0 |

1 M-PC Failed Tests

| Failed Parameter | Number of Tests |
|------------------|-----------------|
| No Failed Test | 0 |
| Total | 0 |

1 M-PC Lost Tests*

| Status | Cause | # |
|--------------|------------------|----------|
| Invalid | No invalid tests | 0 |
| Aborted | No aborted tests | 0 |
| Total | | 0 |

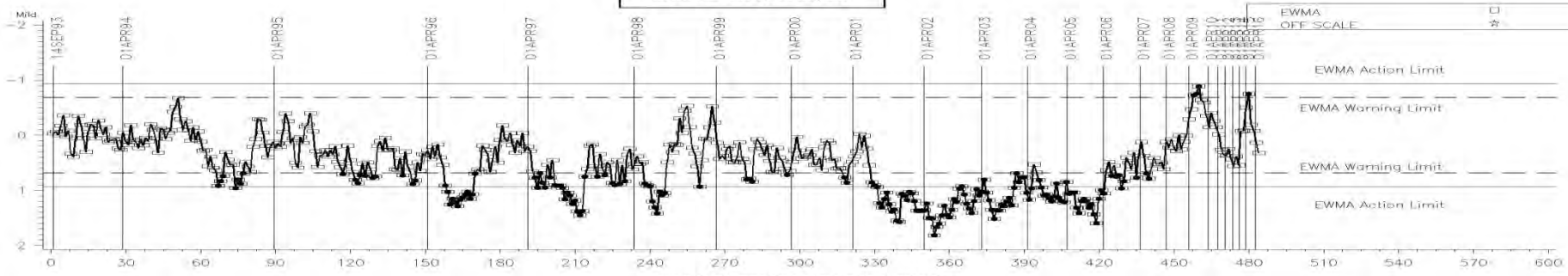
*Invalid and aborted tests

1 M-PC Test Severity

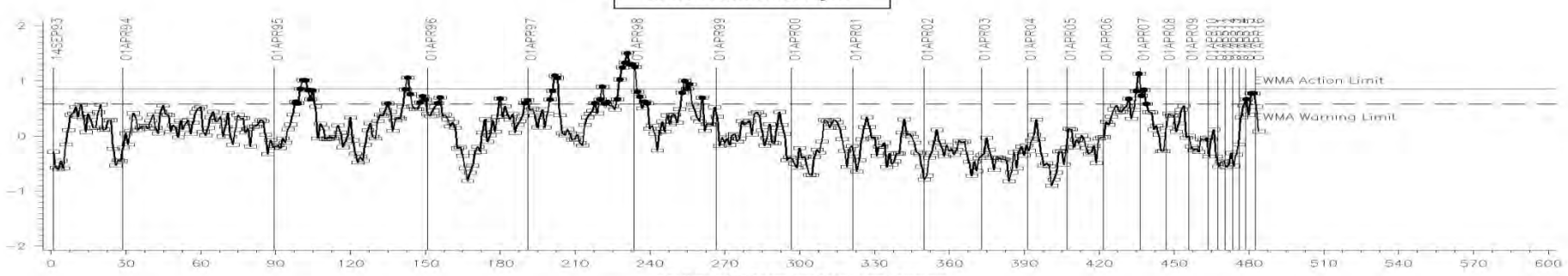
- ▶ As no 1 MPC tests were run during this period no statement about test severity can be made.

FINAL TOP GROOVE FILLING

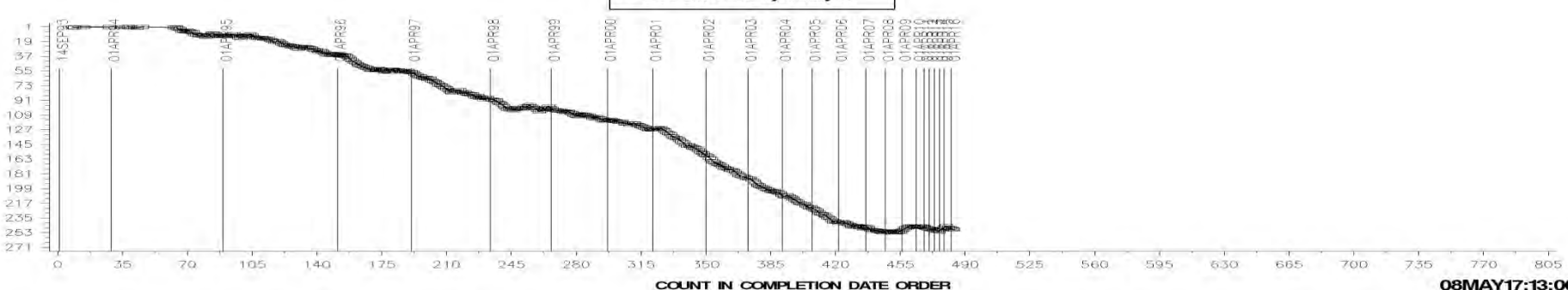
LTMS Severity Analysis



LTMS Precision Analysis



CUSUM Severity Analysis



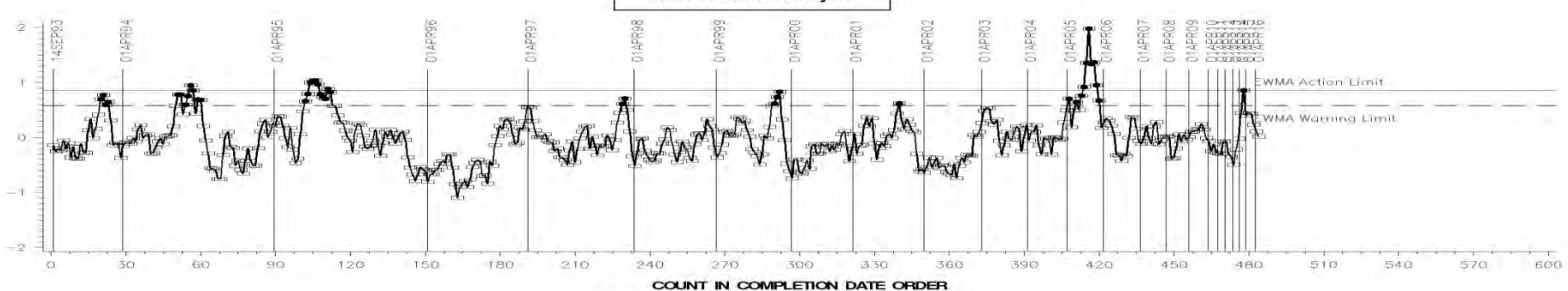
08MAY17:13:00

Weighted Total Demerits

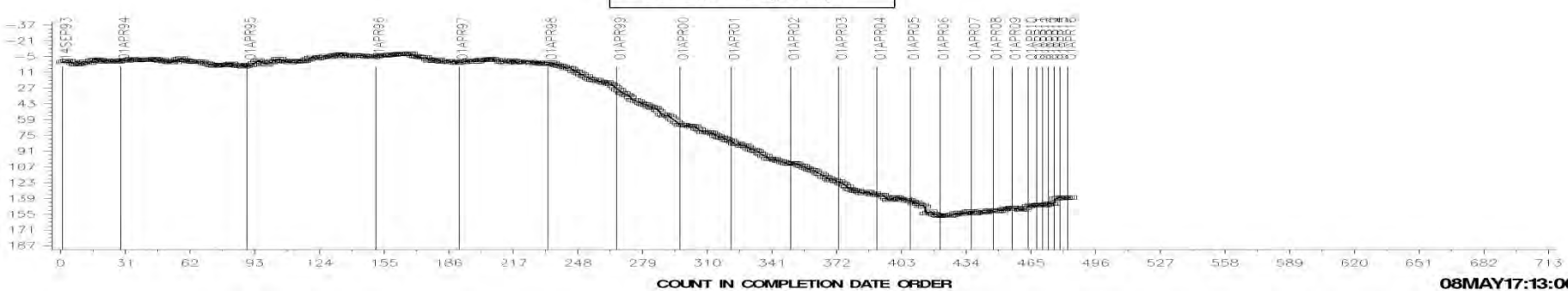
LTMS Severity Analysis



LTMS Precision Analysis

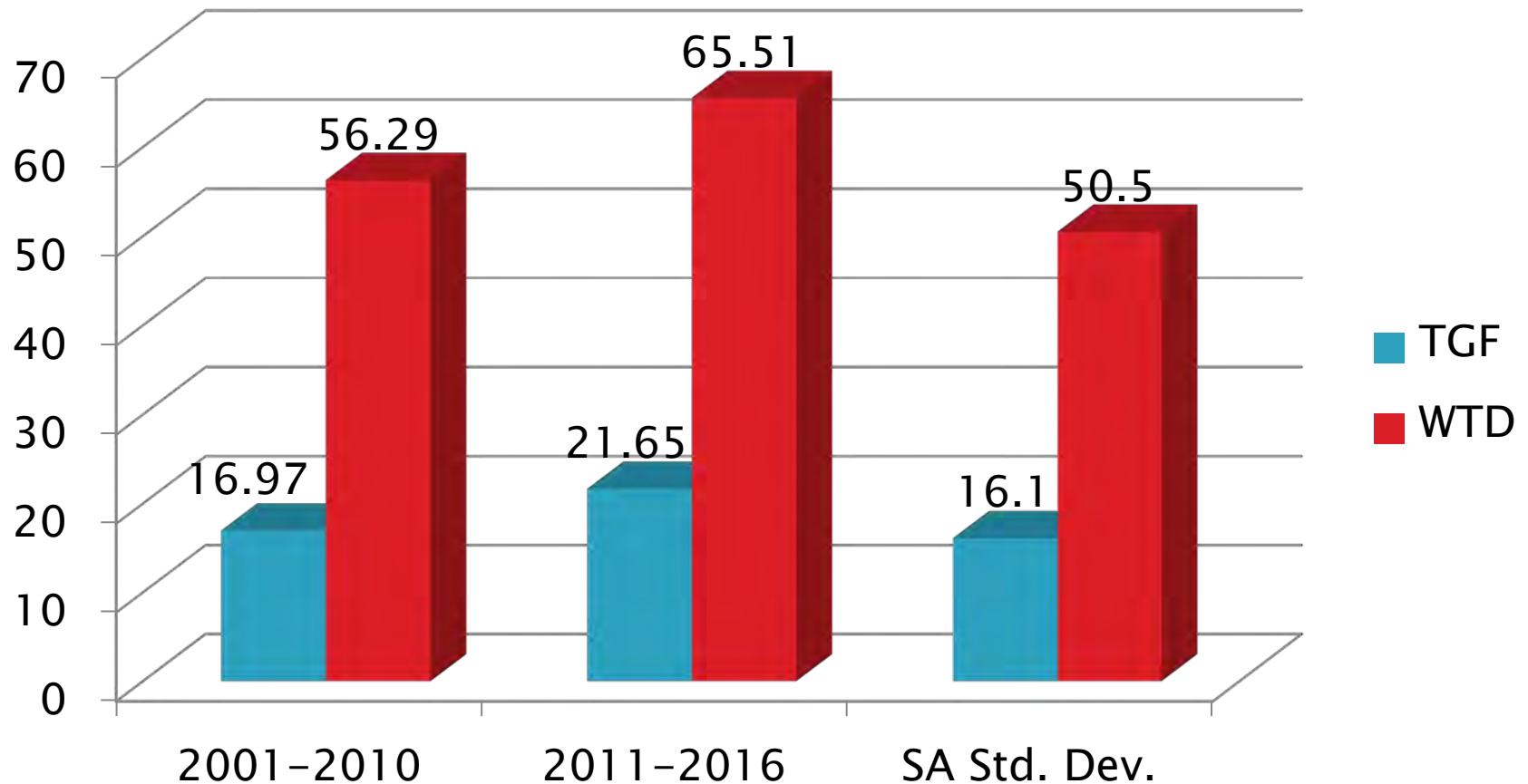


CUSUM Severity Analysis



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1 MPC Precision Estimates



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1P Test Activity

| Test Status | Validity Code | # |
|-----------------------------|---------------|----------|
| Acceptable Calibration Test | AC | 2 |
| Failed Calibration Test | OC | 0 |
| Operationally Invalid | LC | 0 |
| Aborted | XC | 0 |
| Donated | AG | 0 |
| Total | | 2 |

1 P Failed Tests

| Failed Parameter | Number of Tests |
|------------------|-----------------|
| No failed tests | 0 |
| Total | 0 |

1P Lost Tests*

| Status | Cause | # |
|--------------|------------------|----------|
| Invalid | No invalid tests | 0 |
| Aborted | No aborted tests | 0 |
| Total | | 0 |

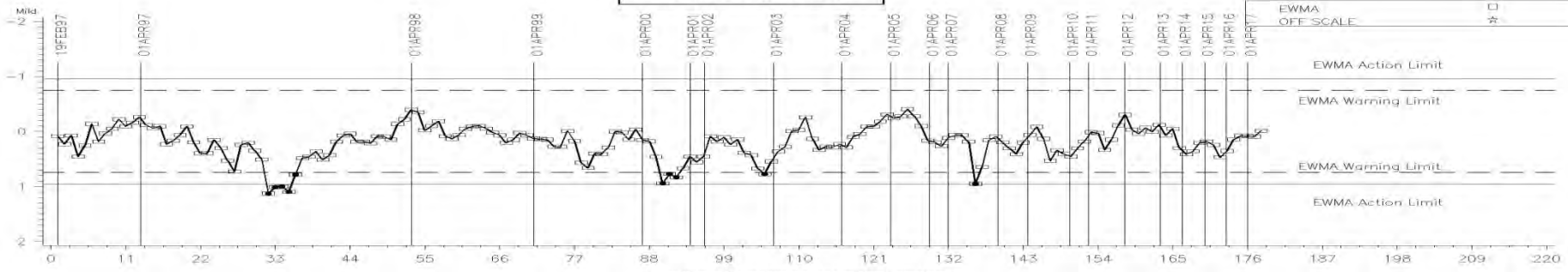
*Invalid and aborted tests

1 P Test Severity

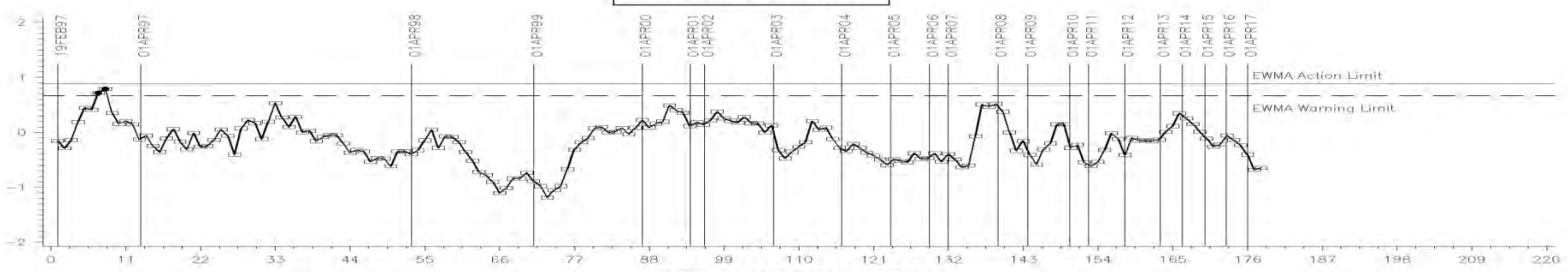
- ▶ EOTOC is in warning alarm severe direction.
- ▶ TGC, TLC, OC and WD are in control.

WEIGHTED TOTAL DEMERITS

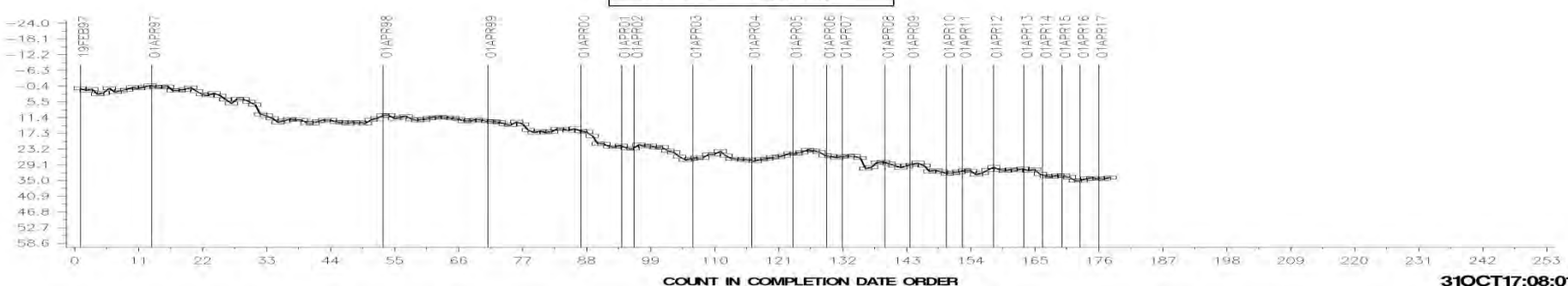
LTMS Severity Analysis



LTMS Precision Analysis



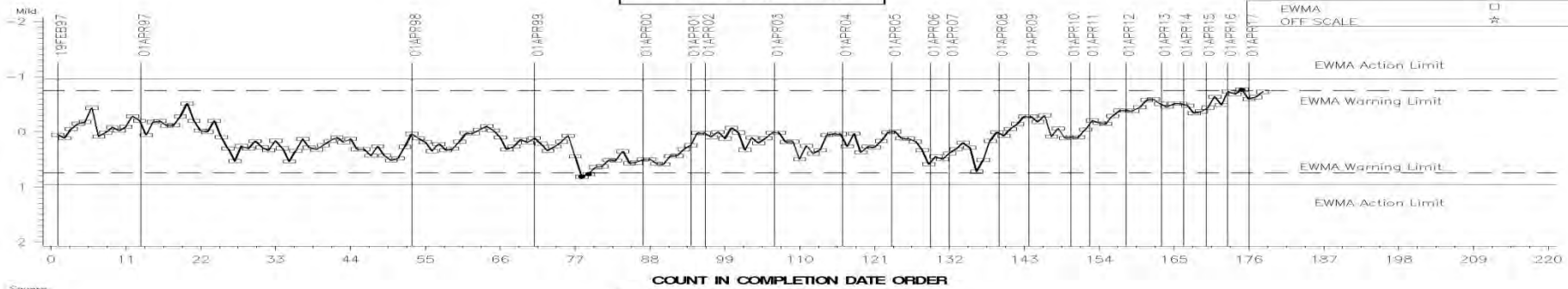
CUSUM Severity Analysis



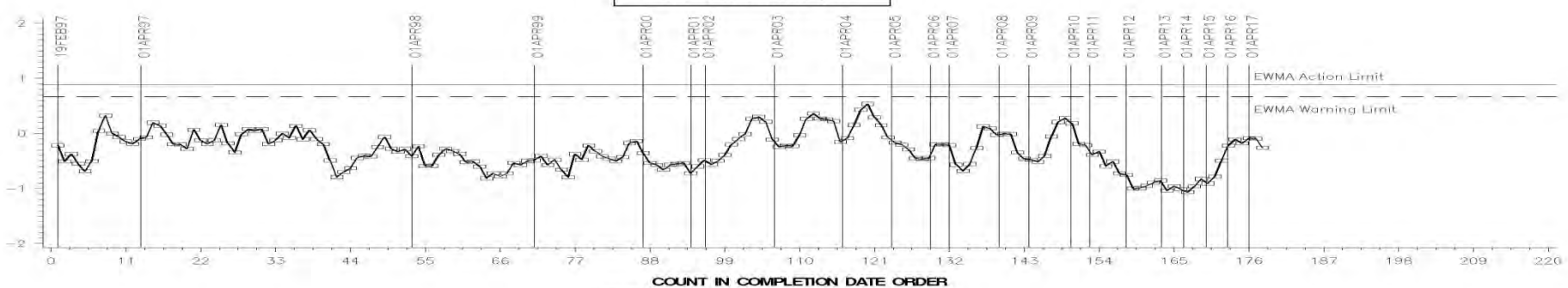
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TOP LAND CARBON

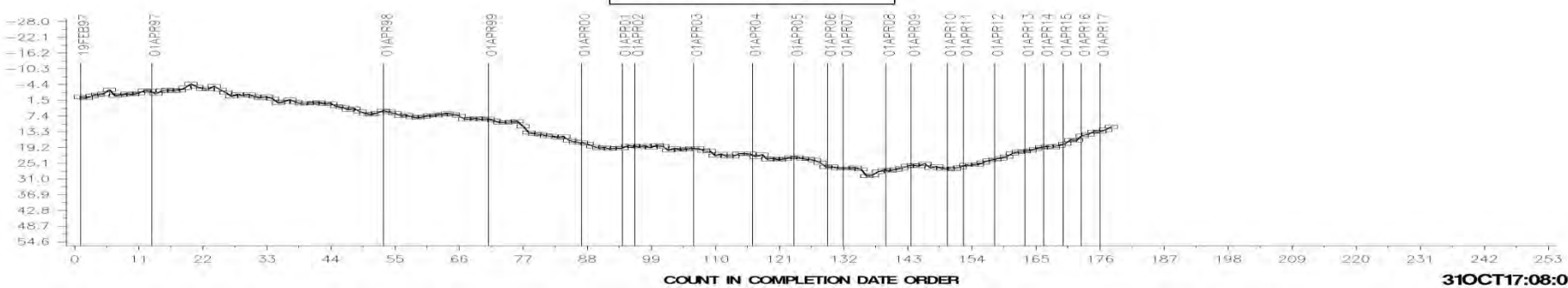
LTMS Severity Analysis



LTMS Precision Analysis



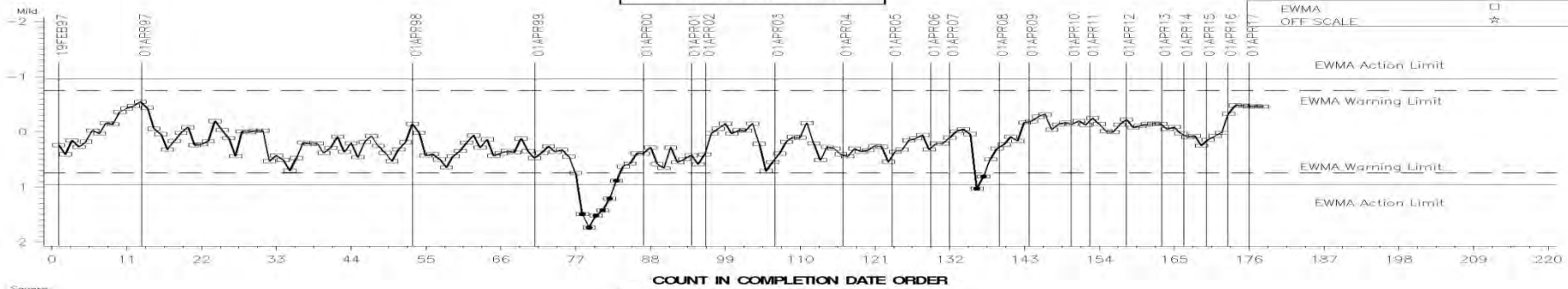
CUSUM Severity Analysis



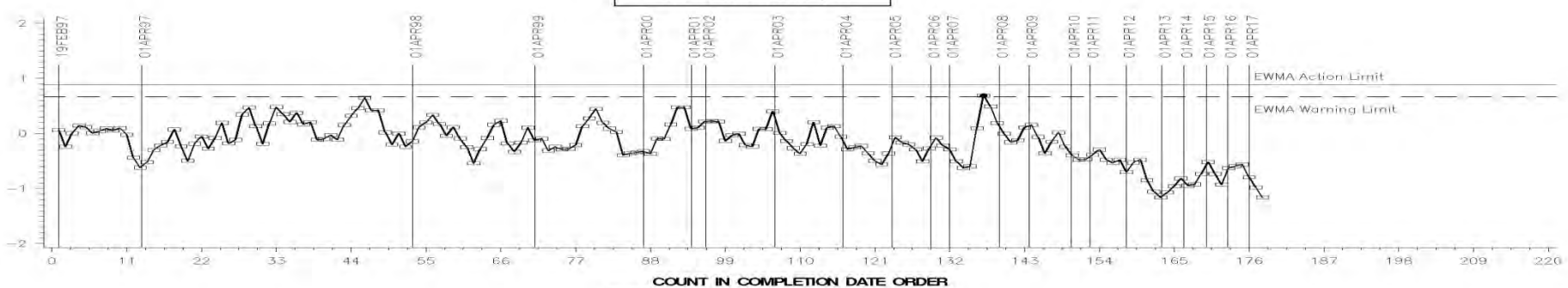
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TOP GROOVE CARBON

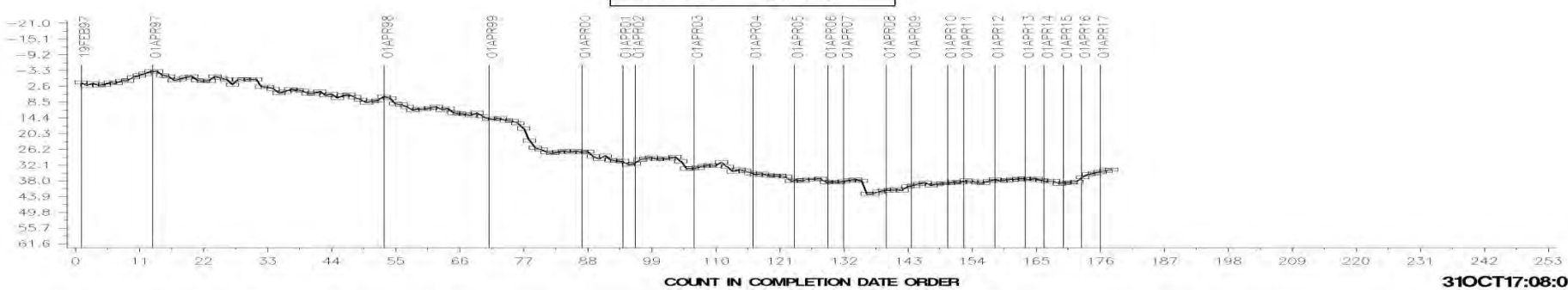
LTMS Severity Analysis



LTMS Precision Analysis



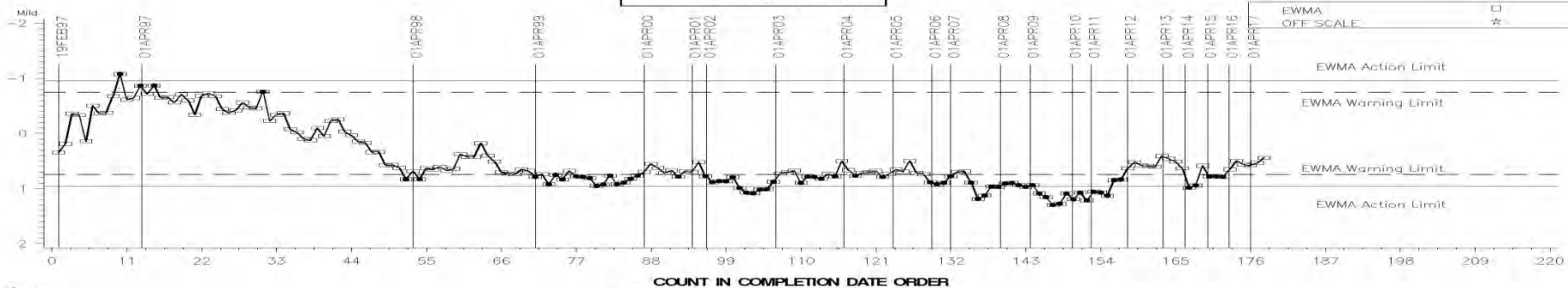
CUSUM Severity Analysis



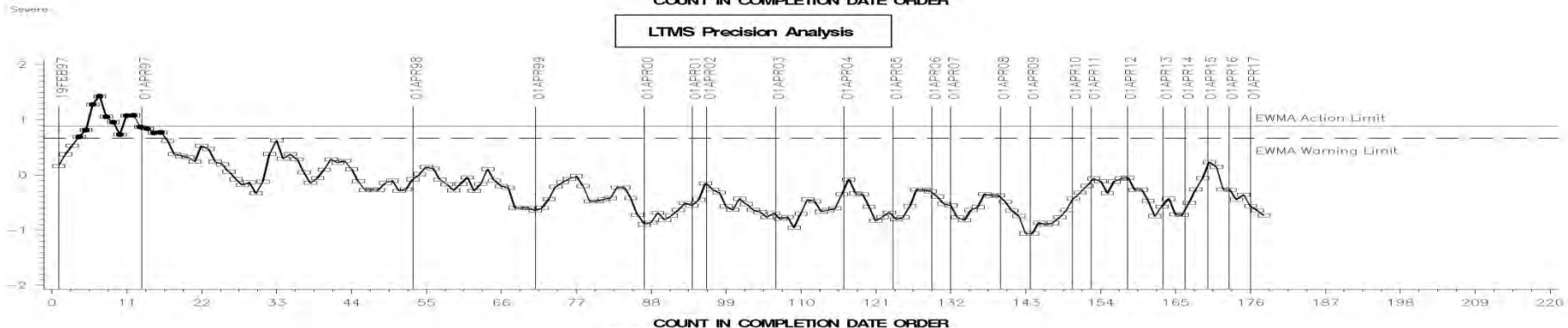
31OCT17:08:01

OIL CONSUMPTION

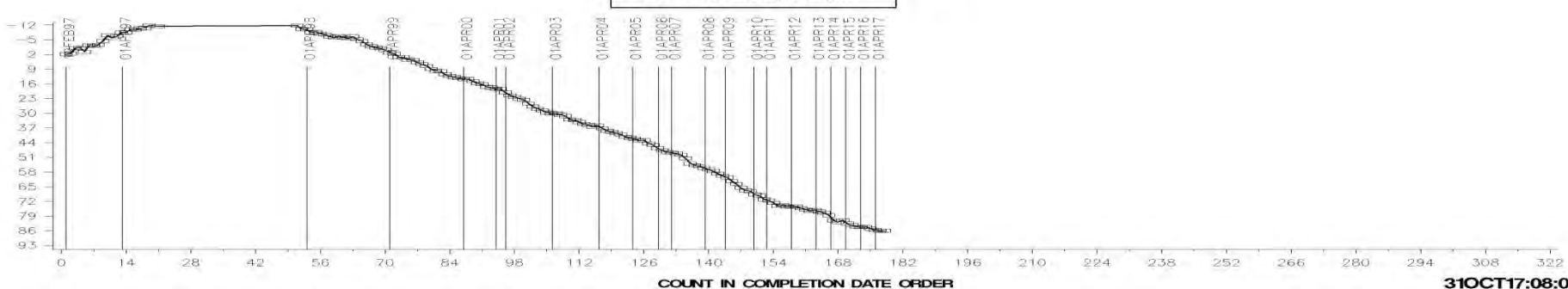
LTMS Severity Analysis



LTMS Precision Analysis



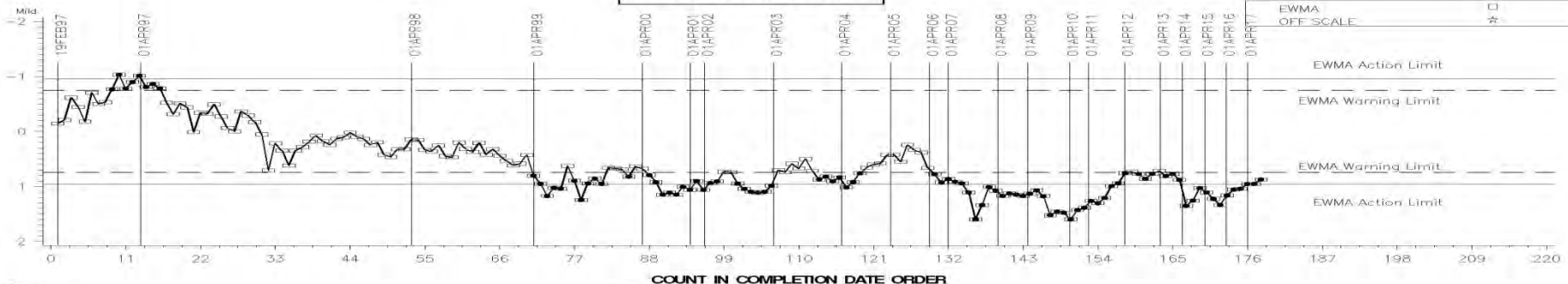
CUSUM Severity Analysis



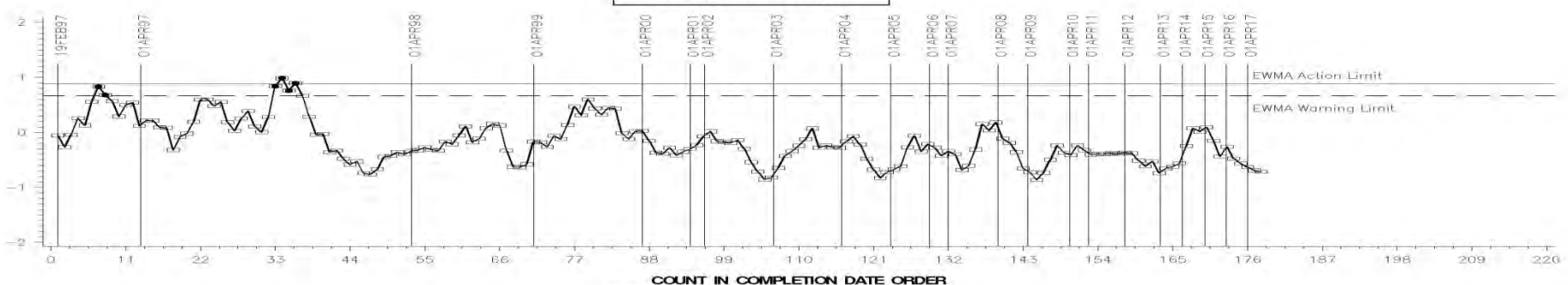
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EOTOC

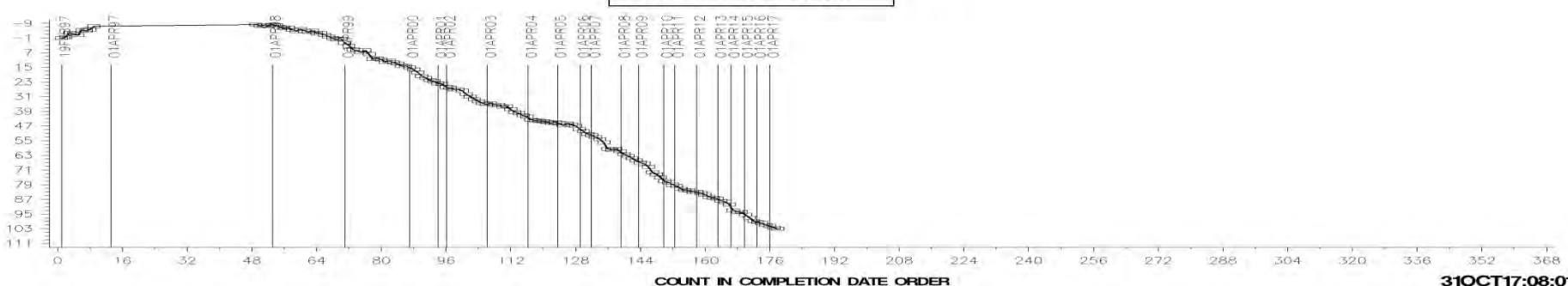
LTMS Severity Analysis



LTMS Precision Analysis

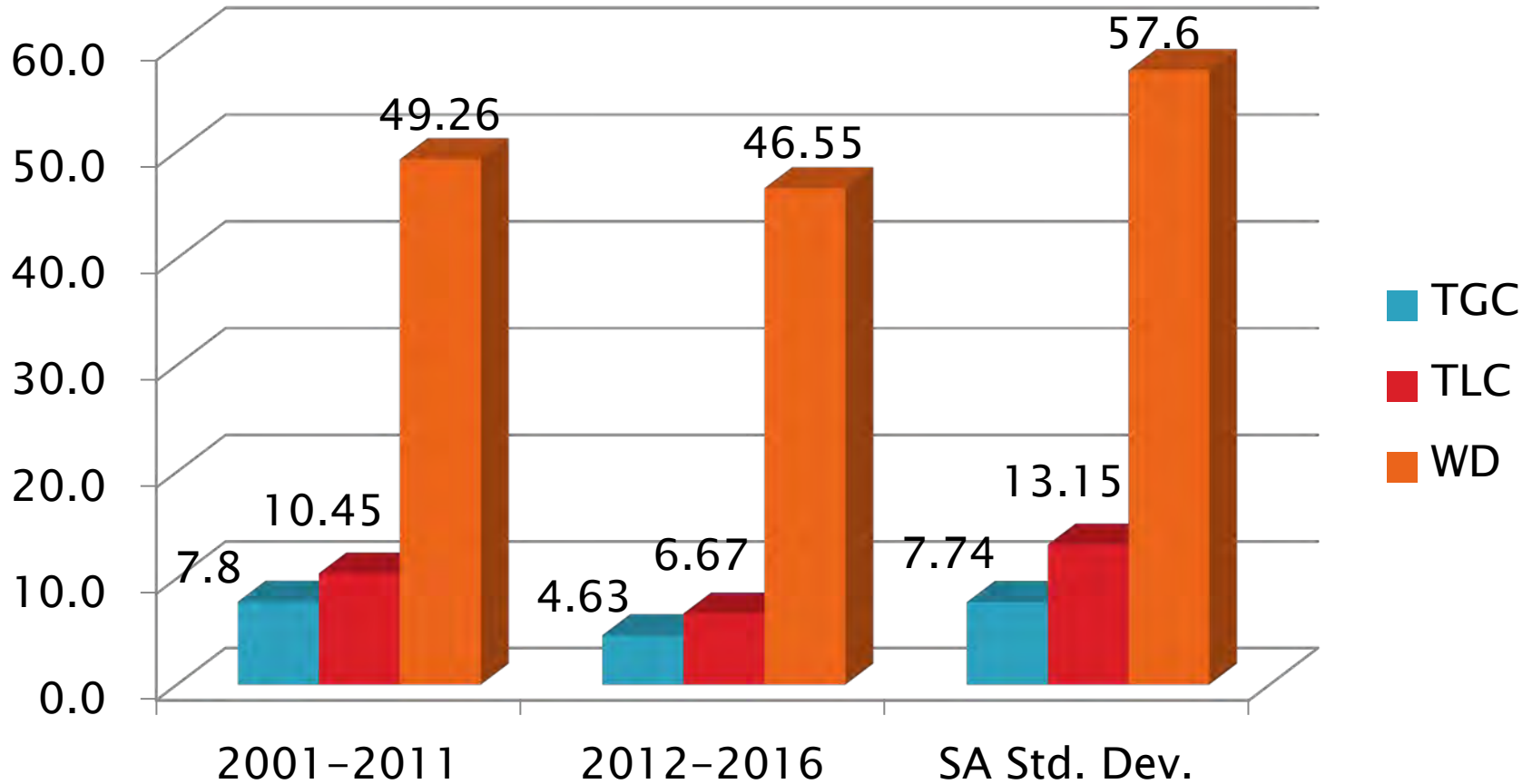


CUSUM Severity Analysis

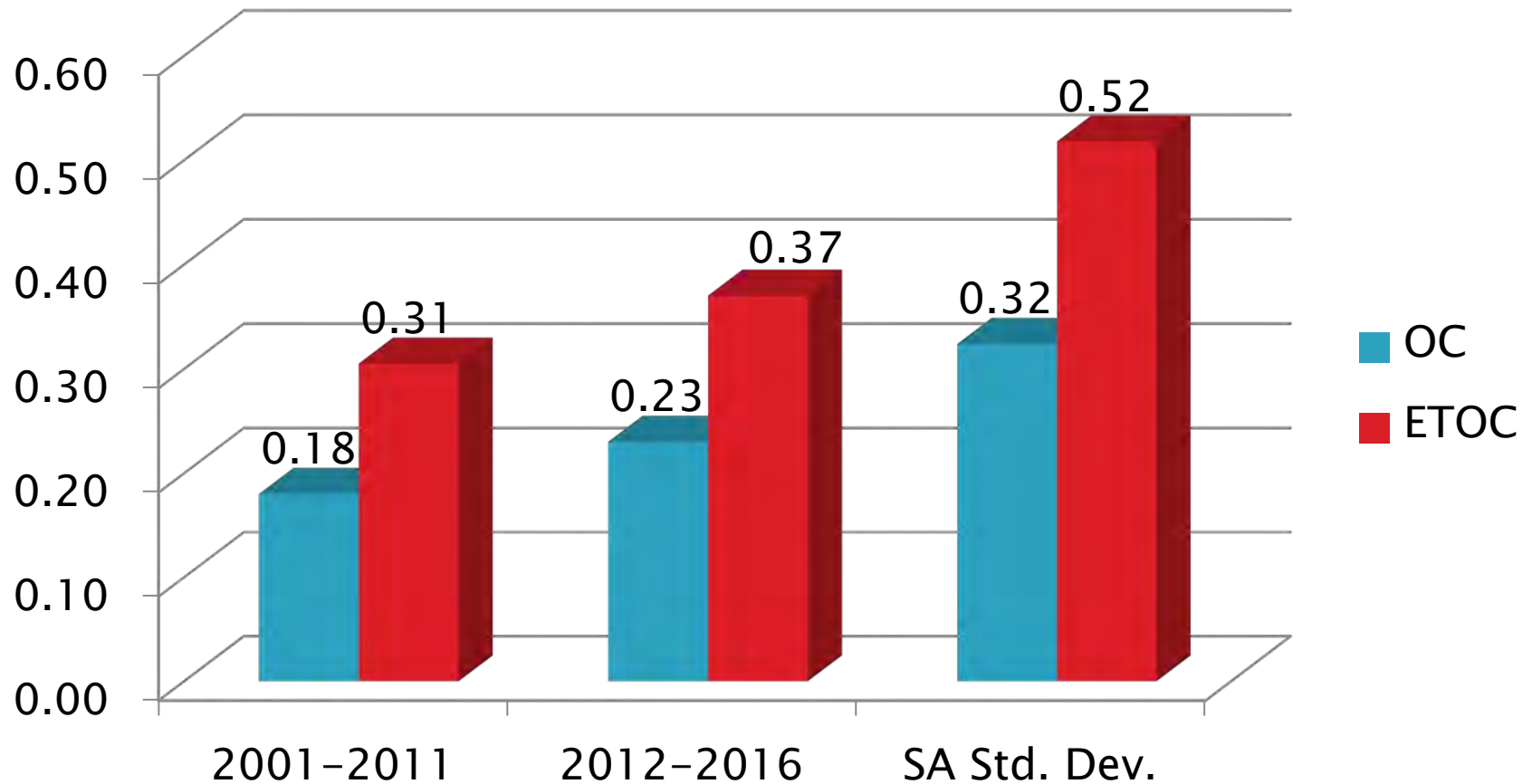


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1P Precision Estimates



1P Precision Estimates



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1 R Test Activity

| Test Status | Validity Code | # |
|-----------------------------|---------------|----------|
| Acceptable Calibration Test | AC | 1 |
| Failed Calibration Test | OC | 1 |
| Operationally Invalid | LC | 0 |
| Aborted | XC | 1 |
| Total | | 3 |

1 R Failed Tests

| Failed Parameter | Number of Tests |
|--------------------------|-----------------|
| Weighted demerits severe | 1 |
| Total | 1 |

1 R Lost Tests*

| Status | Cause | # |
|--------------|------------------|----------|
| Invalid | No invalid tests | 0 |
| Aborted | High OC | 1 |
| Total | | 1 |

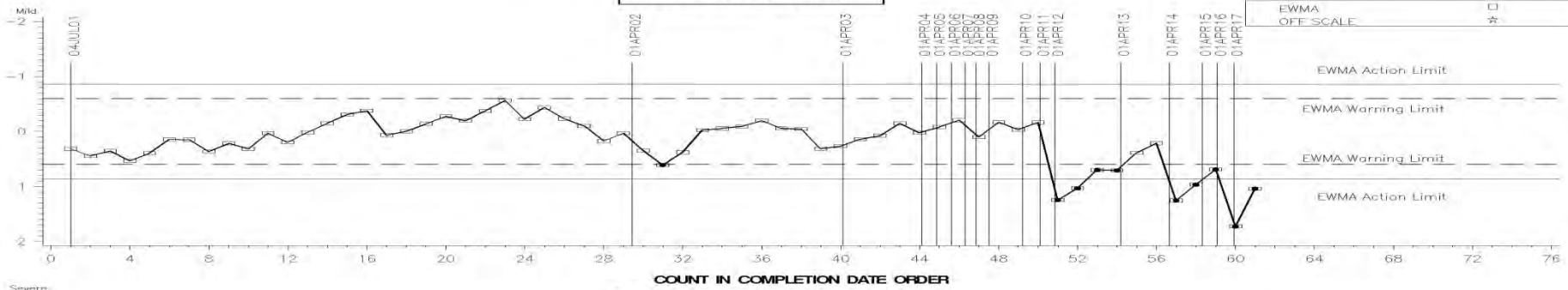
*Invalid and aborted tests

1 R Test Severity

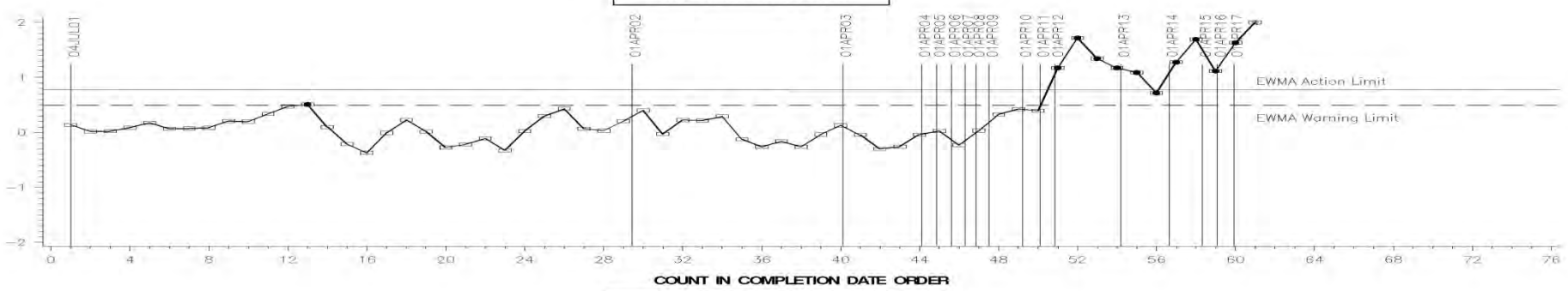
- ▶ WD in severity action alarm severe direction
- ▶ TLC and BTOC in severity warning alarm mild direction
- ▶ WD and TGC in precision action alarm
- ▶ ETOC in control

FINAL WEIGHTED TOTAL DEMERITS (DEMERITS)

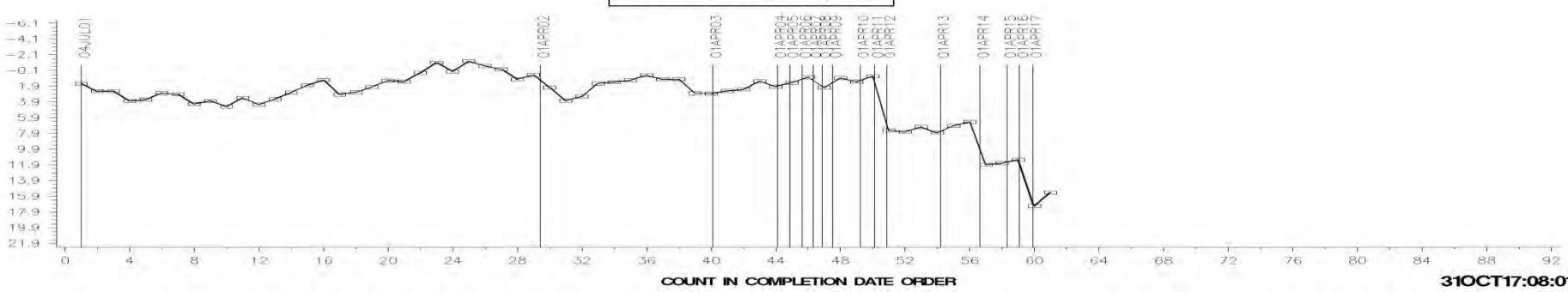
LTMS Severity Analysis



LTMS Precision Analysis



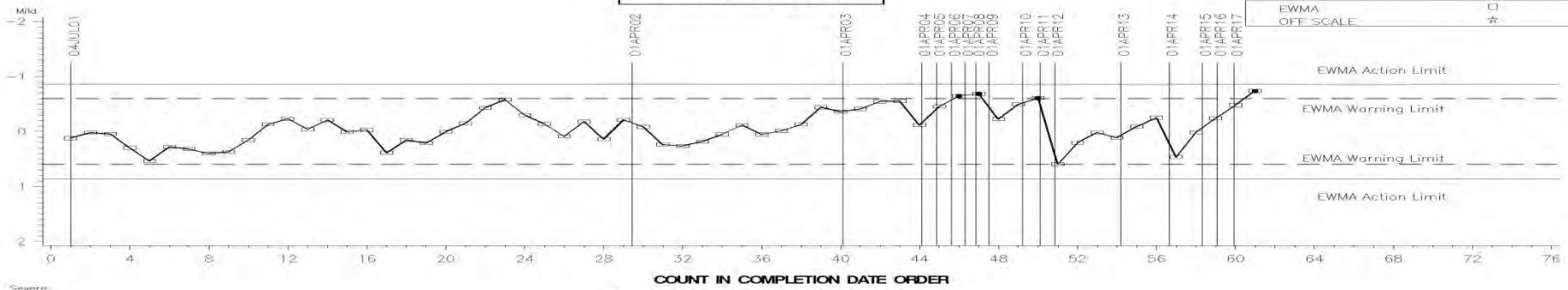
CUSUM Severity Analysis



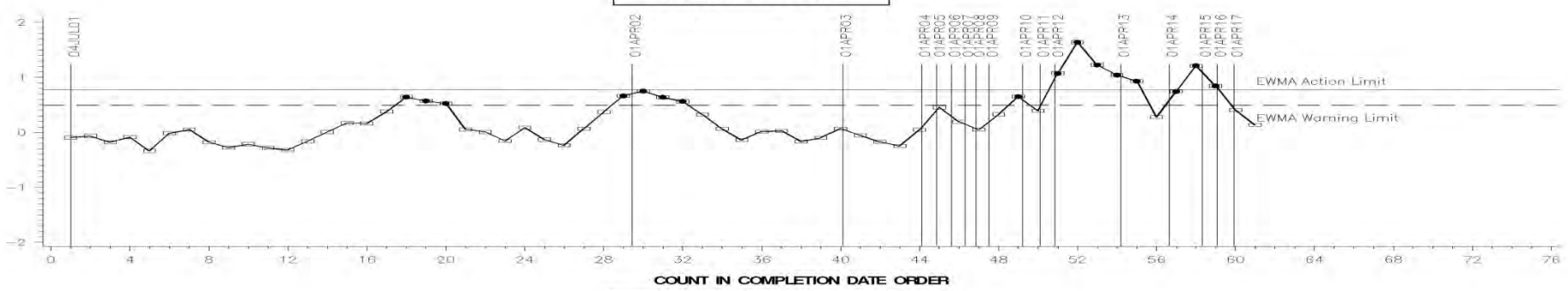
31OCT17:08:01

FINAL TOP LAND CARBON (DEMERITS)

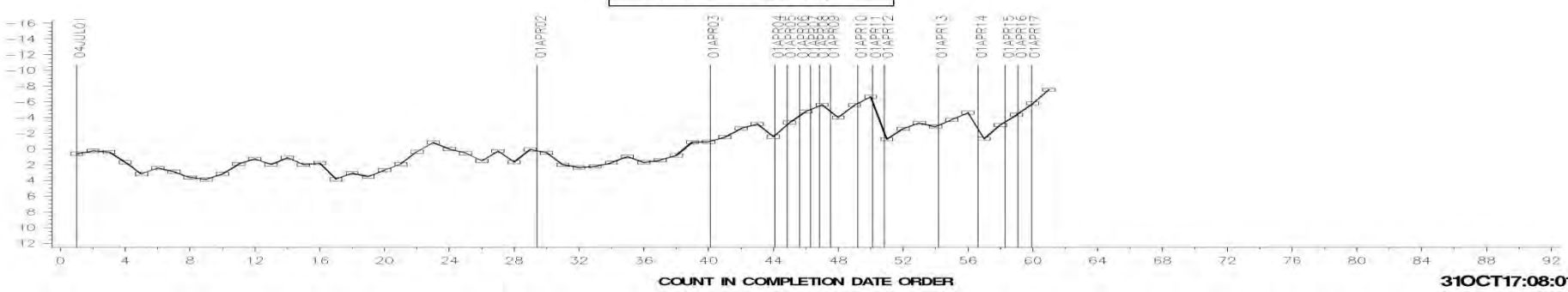
LTMS Severity Analysis



LTMS Precision Analysis



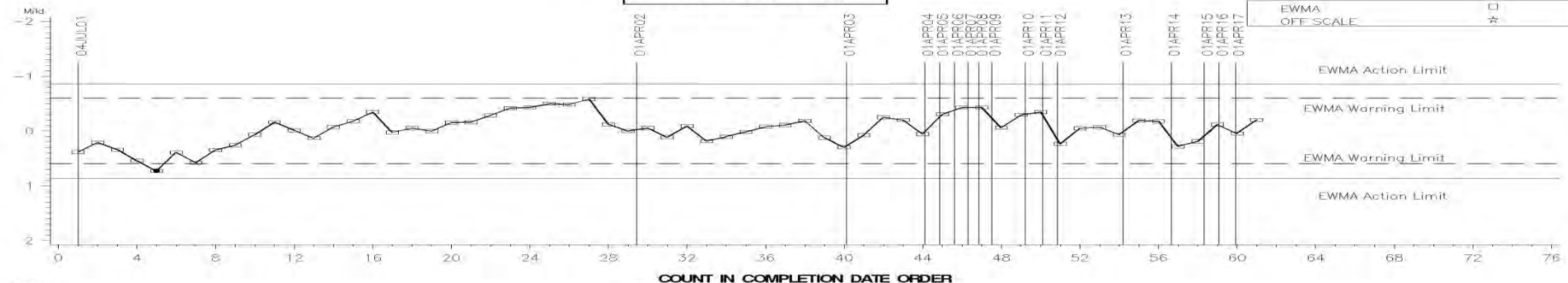
CUSUM Severity Analysis



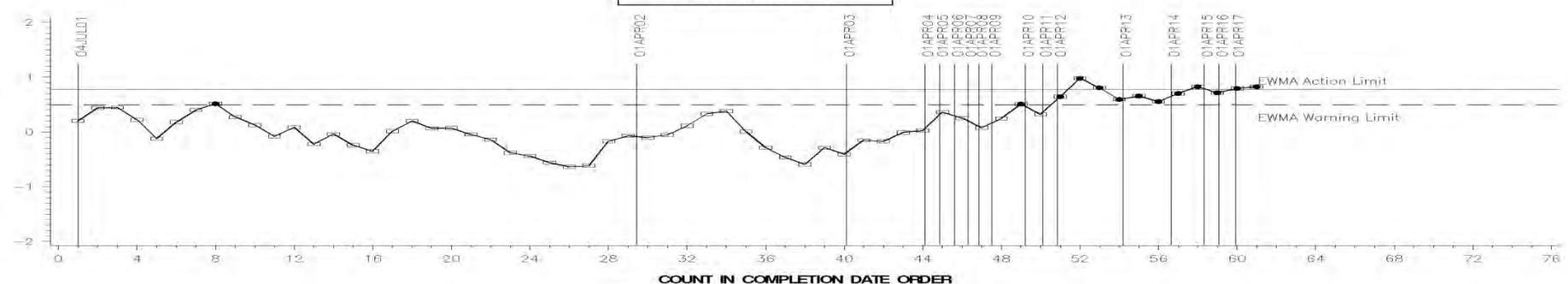
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FINAL TOP GROOVE CARBON (DEMERITS)

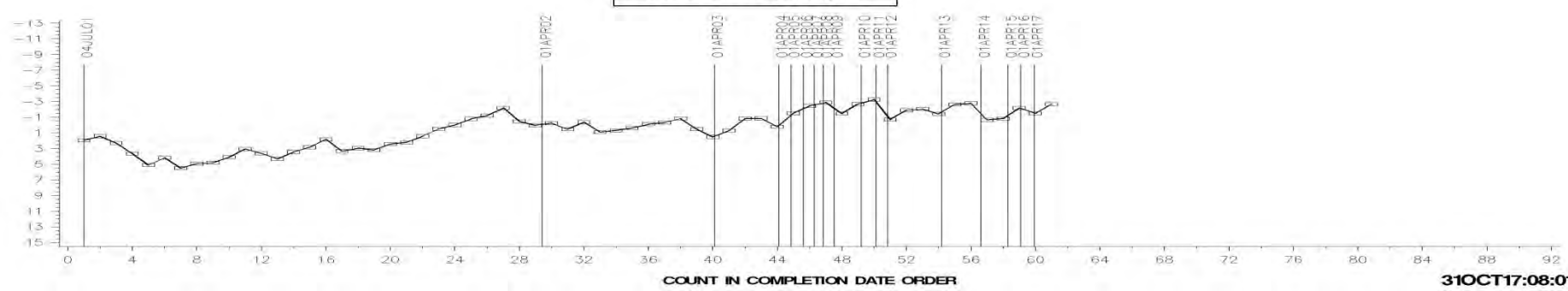
LTMS Severity Analysis



LTMS Precision Analysis



CUSUM Severity Analysis



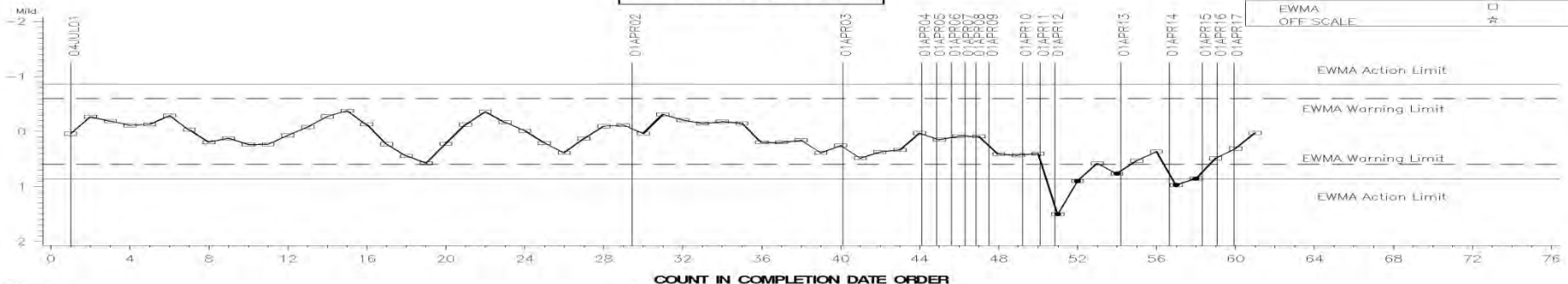
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CATERPILLAR 1R INDUSTRY OPERATIONAL VALID DATA

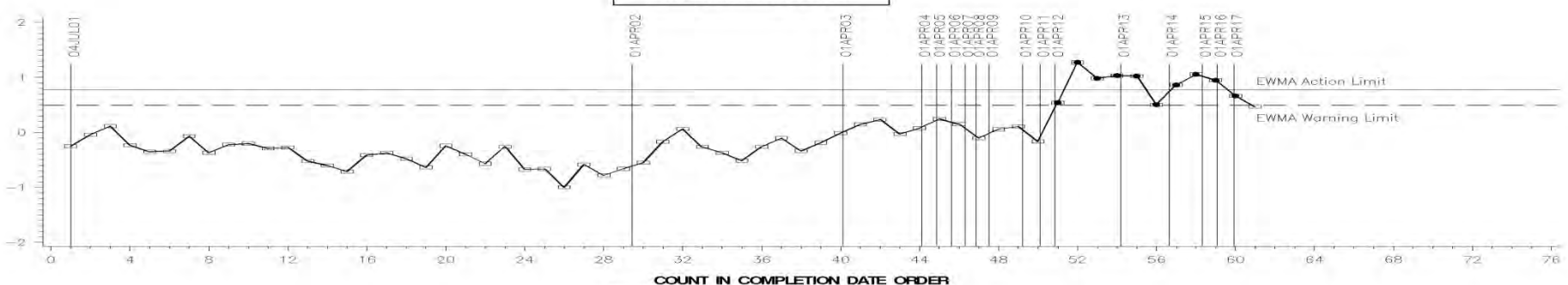


FINAL EOTOC (g/h)

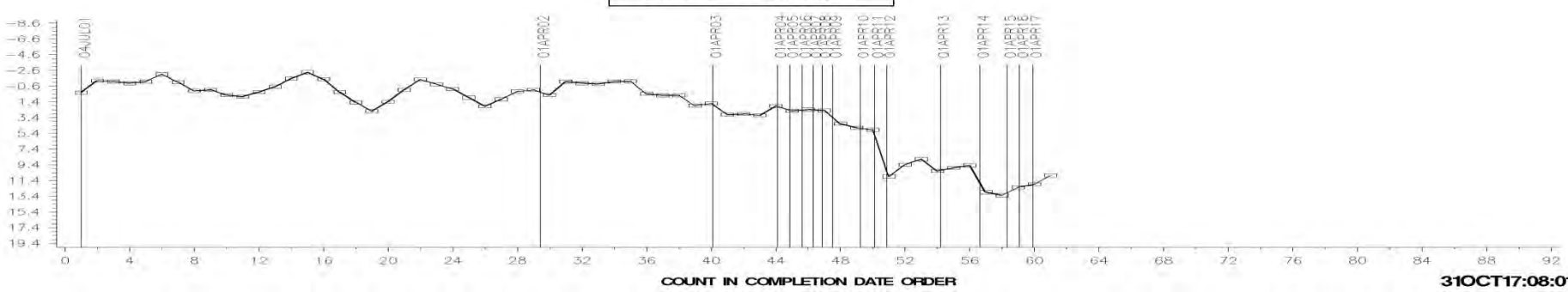
LTMS Severity Analysis



LTMS Precision Analysis



CUSUM Severity Analysis

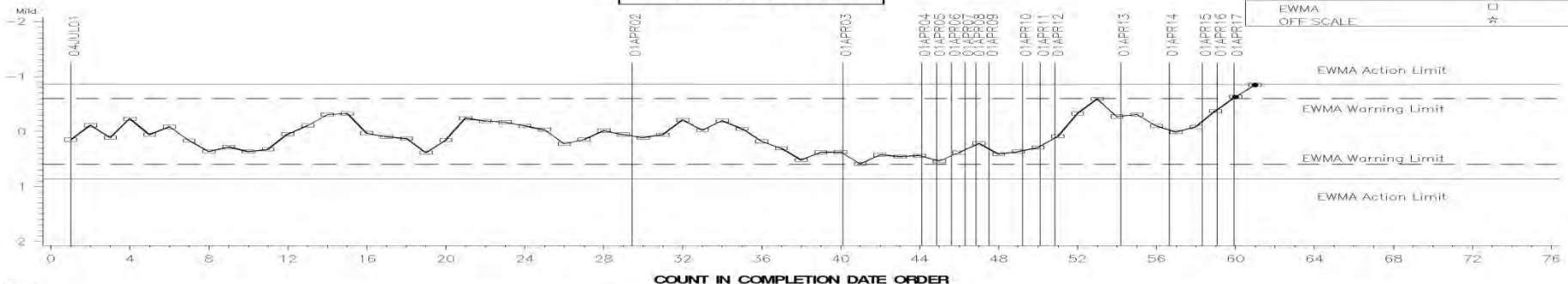


31OCT17:08:01

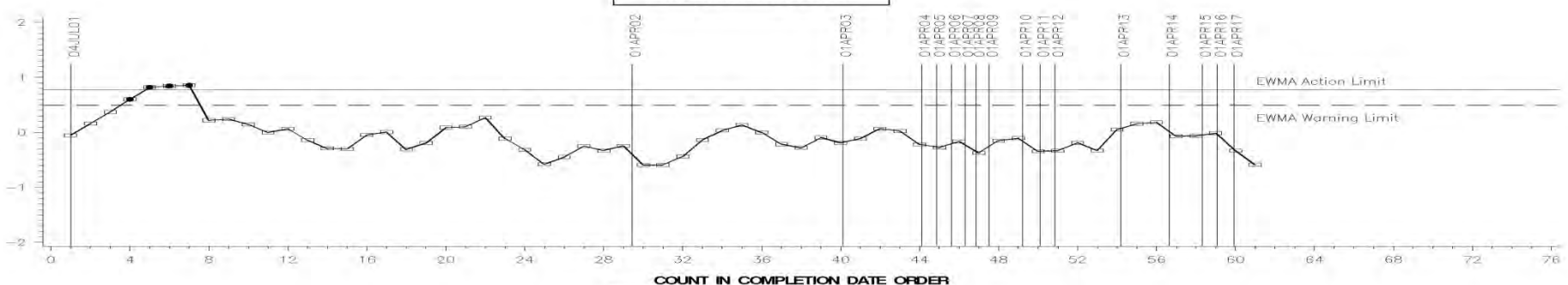


FINAL BOTOC

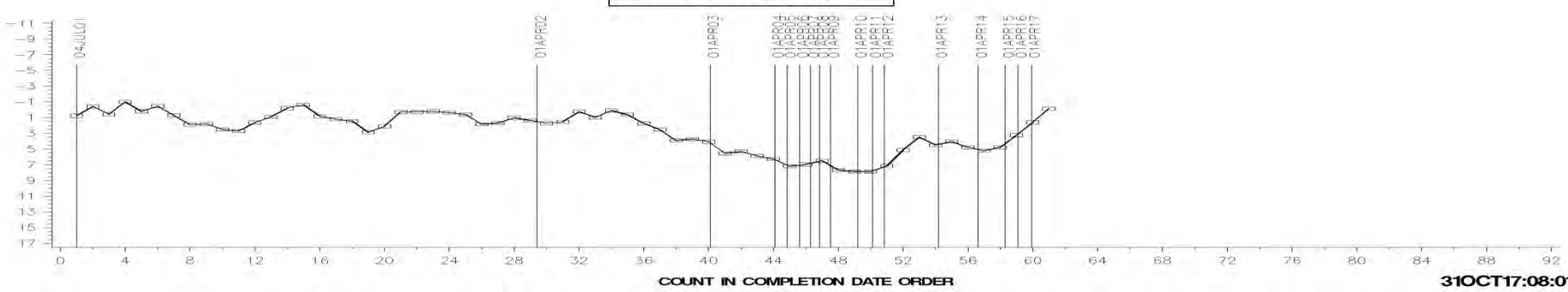
LTMS Severity Analysis



LTMS Precision Analysis

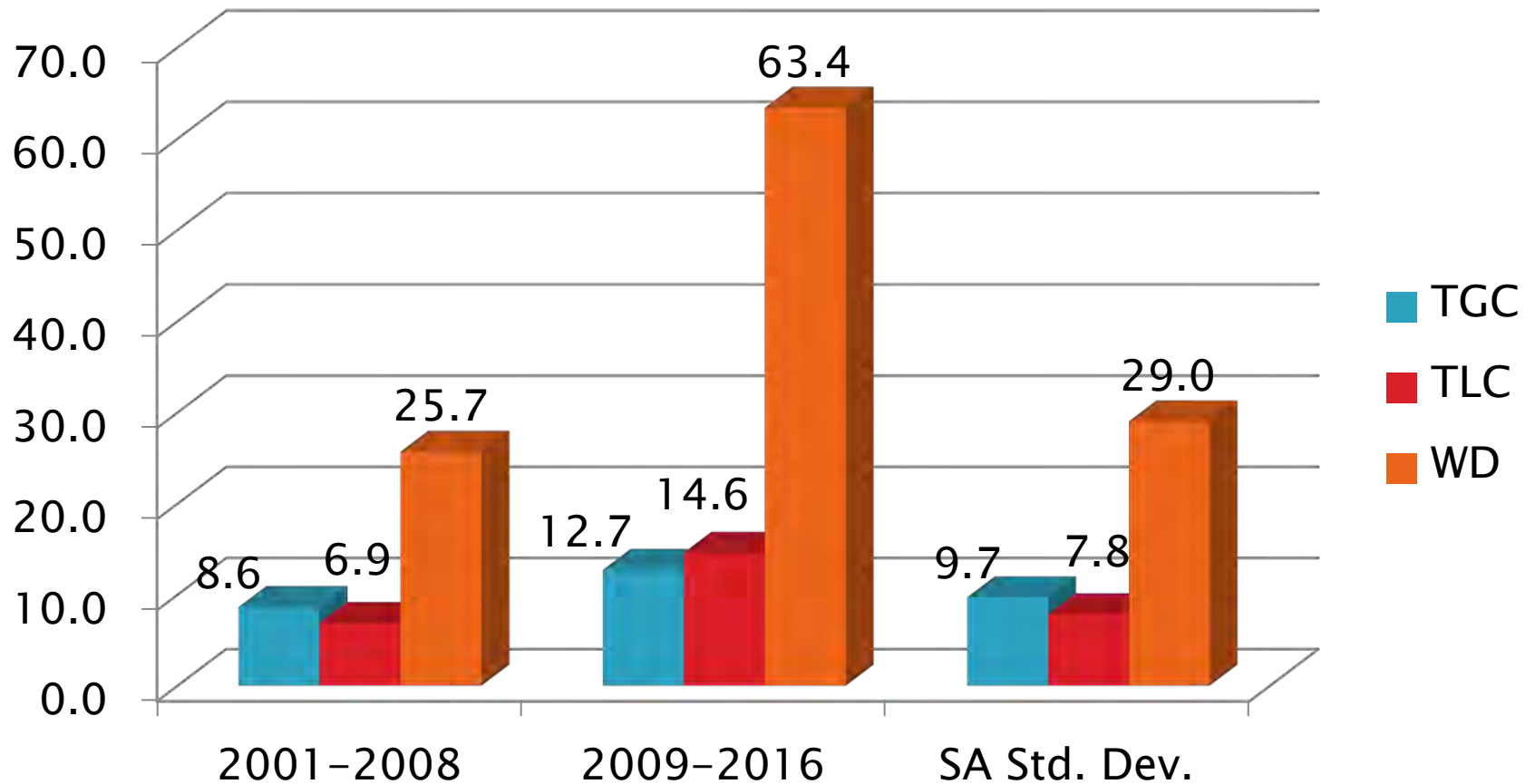


CUSUM Severity Analysis

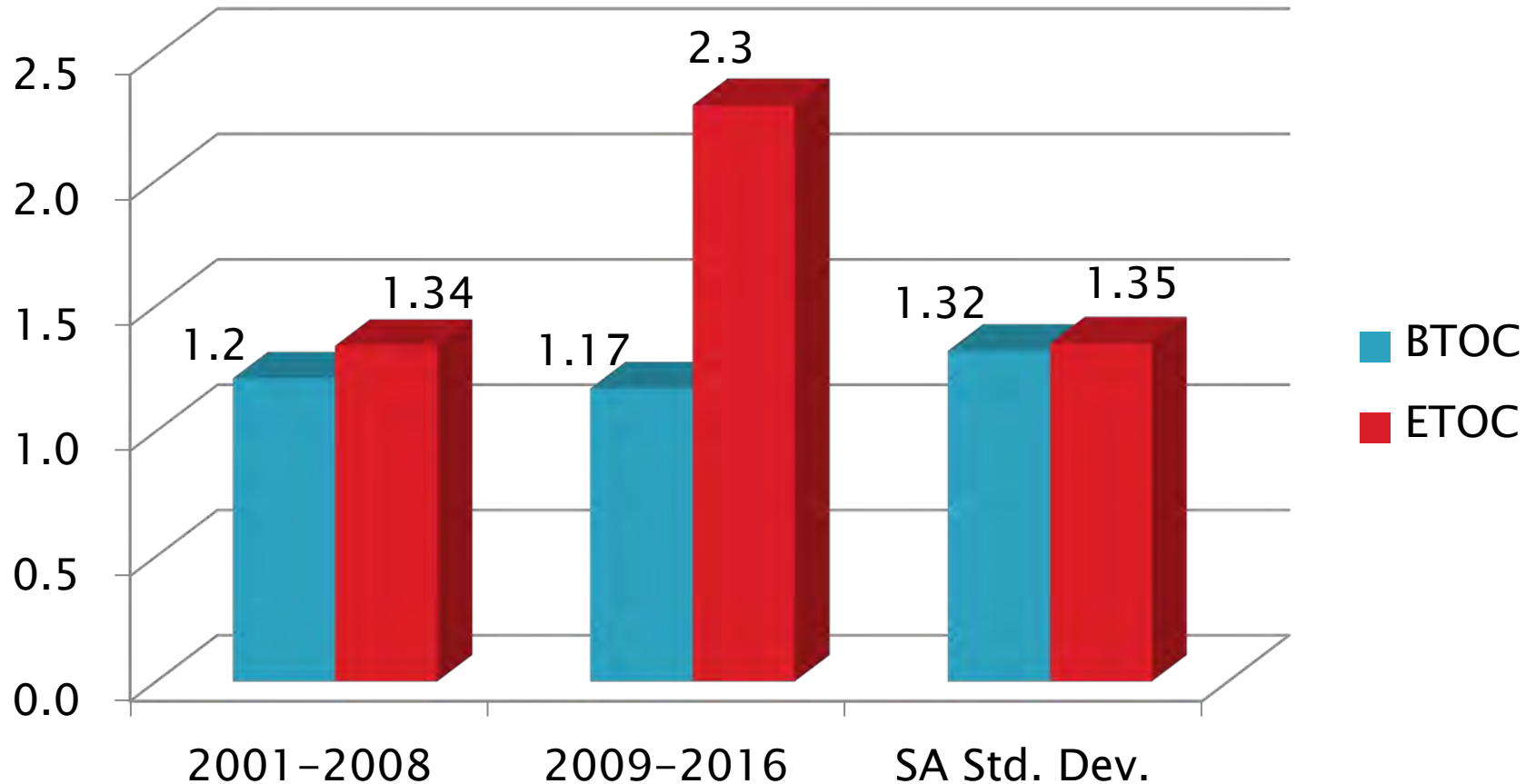


31OCT17:08:01

1R Precision Estimates



1 R Precision Estimates



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Test Monitoring Center
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A Program of ASTM International

CAT C13

»» October 2017

Test Monitoring Center

<http://astmtmc.cmu.edu>



A Program of ASTM International

C13 Test Activity

| Test Status | Validity Code | C13 |
|-----------------------------|---------------|----------|
| Acceptable Calibration Test | AC | 0 |
| Failed Calibration Test | OC | 0 |
| Operationally Invalid | LC | 0 |
| Aborted | XC | 0 |
| Total | | 0 |

C13 Failed Tests

| Failed Parameter | Number of Tests |
|------------------|-----------------|
| No Failed Tests | 0 |
| Total | 0 |

C13 Lost Tests*

| Status | Cause | # |
|--------------|------------------|----------|
| Invalid | No invalid tests | 0 |
| Aborted | No aborted tests | 0 |
| Total | | 0 |

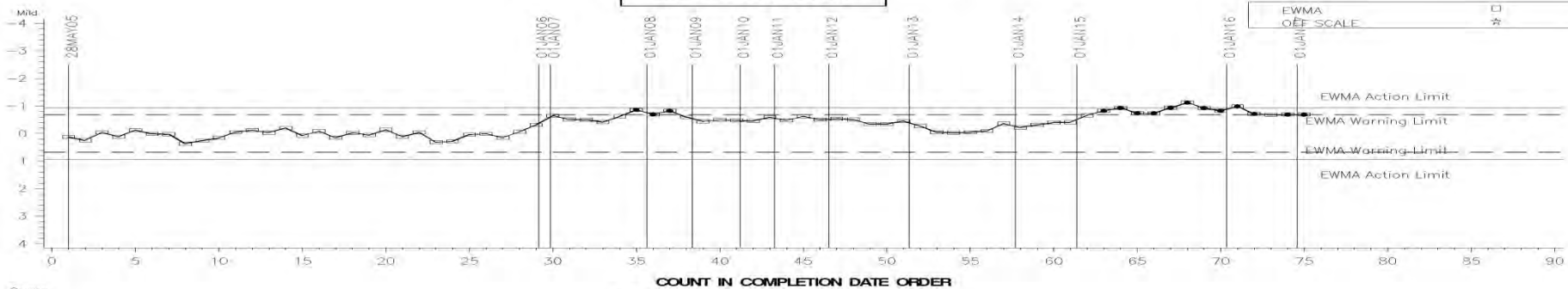
*Invalid and aborted tests

C13 Test Severity

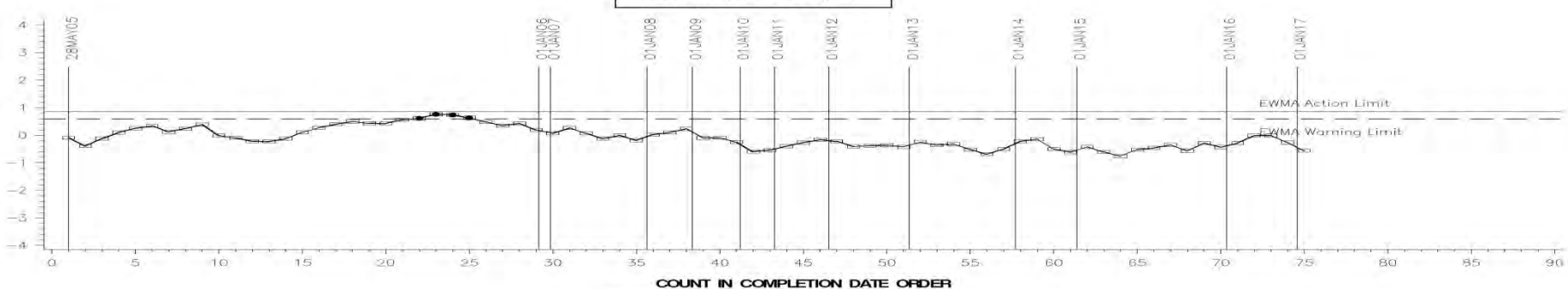
- ▶ As no C13 tests were run during this period no statement about test severity can be made.

TOP LAND CARBON AVG. — FINAL RESULT

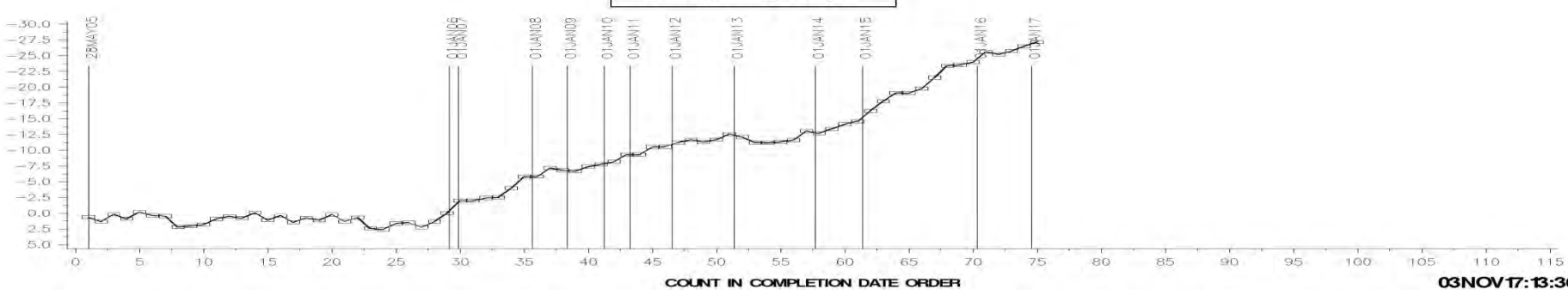
LTMS Severity Analysis



LTMS Precision Analysis



CUSUM Severity Analysis

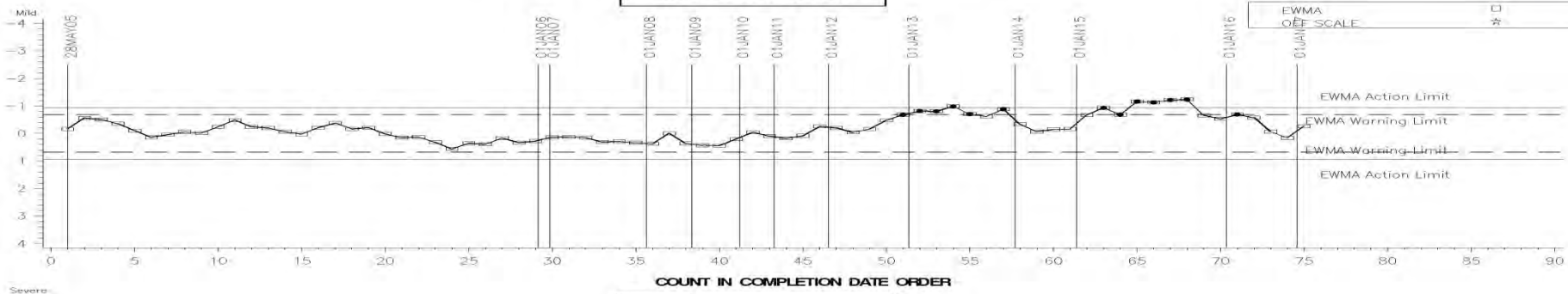


03NOV17:13:36

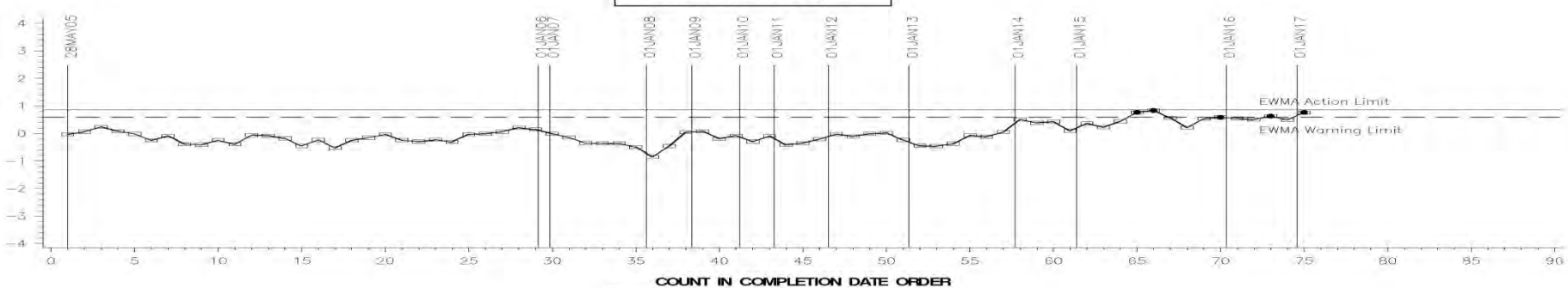
C13 INDUSTRY OPERATIONALLY VALID DATA

TOP GROOVE CARBON AVG — FINAL RESULT

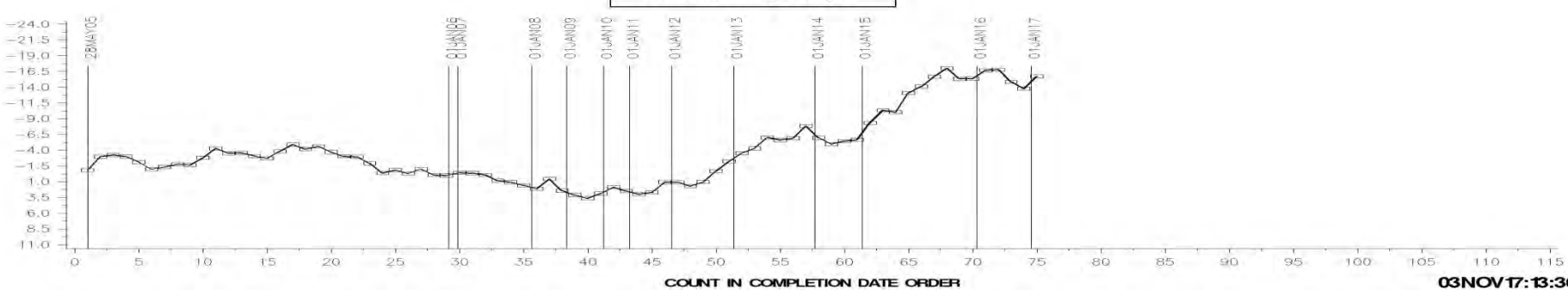
LTMS Severity Analysis



LTMS Precision Analysis



CUSUM Severity Analysis

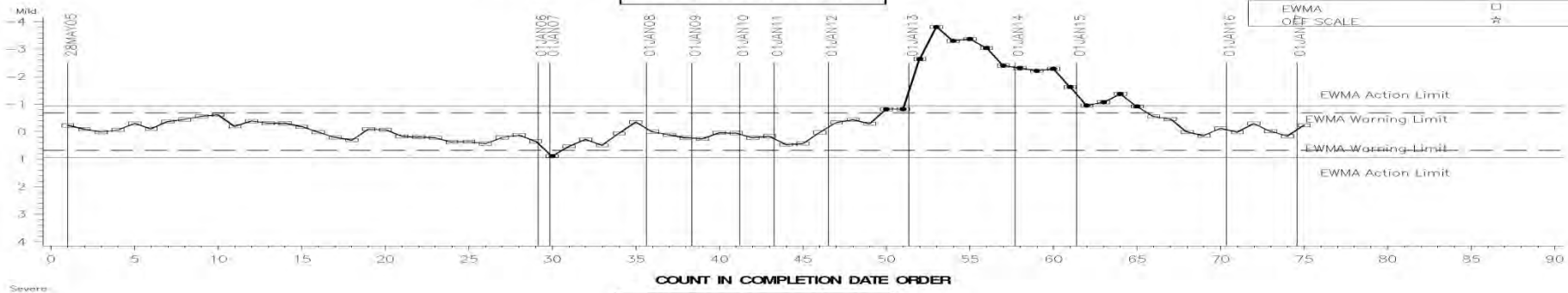


03NOV17:13:36

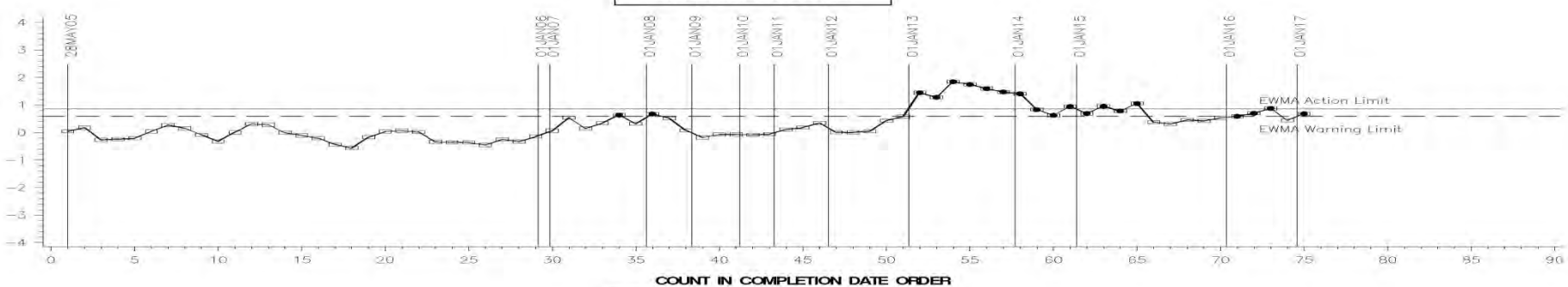
C13 INDUSTRY OPERATIONAL VALID DATA

2ND RING TOP CARBON AVG. — FINAL RESULT

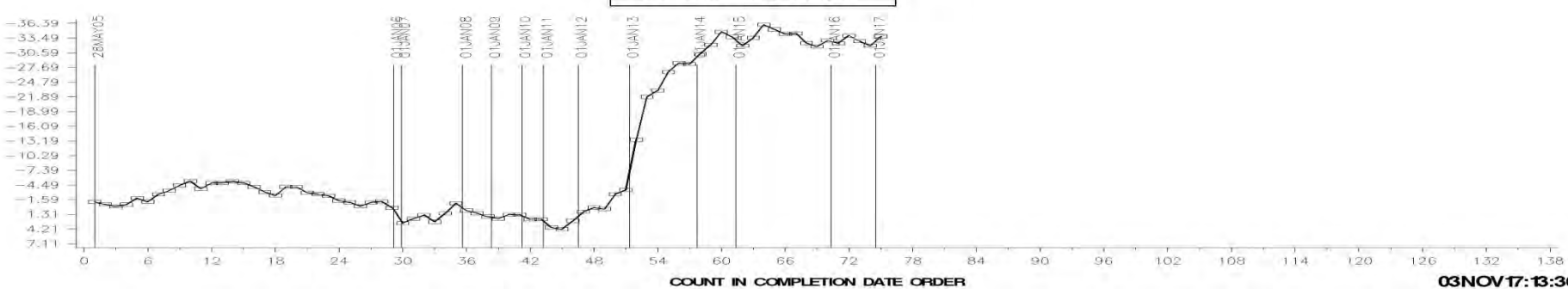
LTMS Severity Analysis



LTMS Precision Analysis



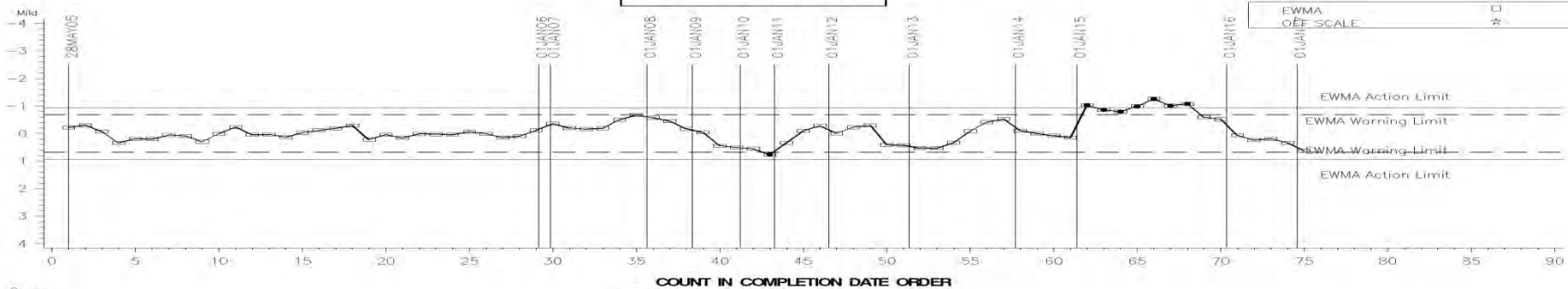
CUSUM Severity Analysis



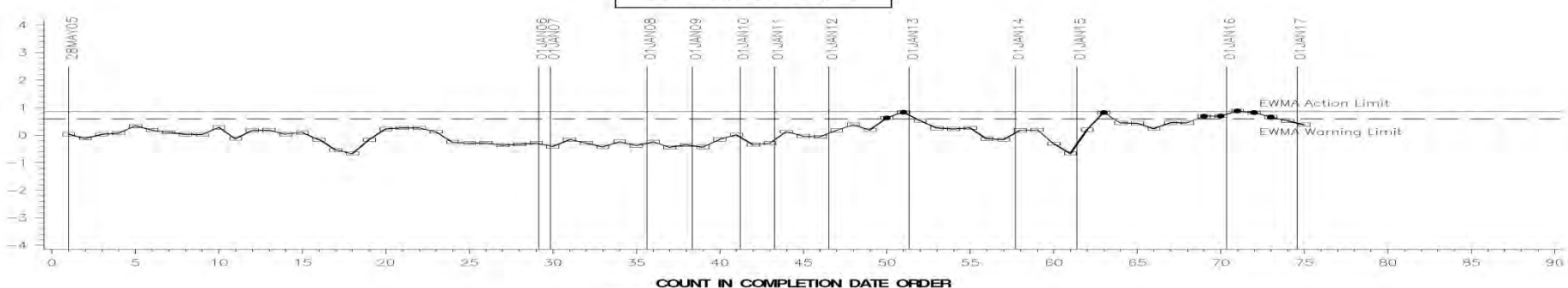
03 NOV 17: 13:36

OIL CONS. DELTA — FINAL RESULT

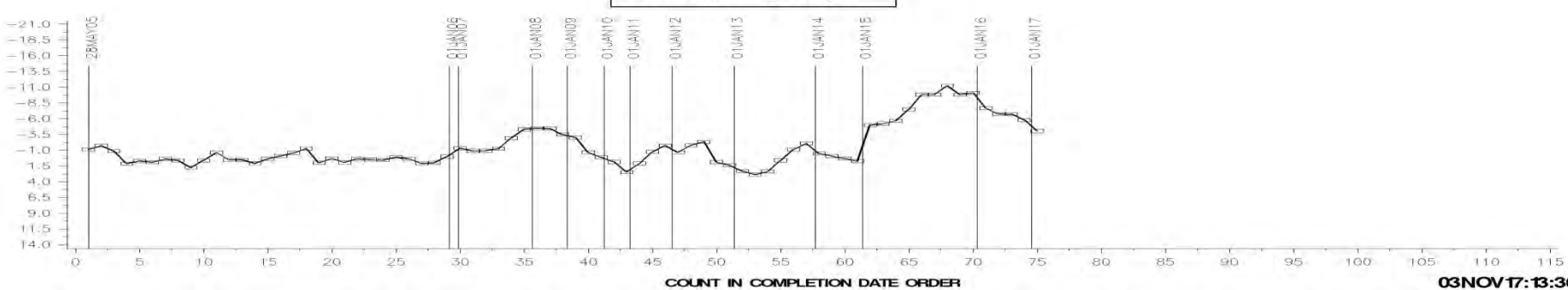
LTMS Severity Analysis



LTMS Precision Analysis

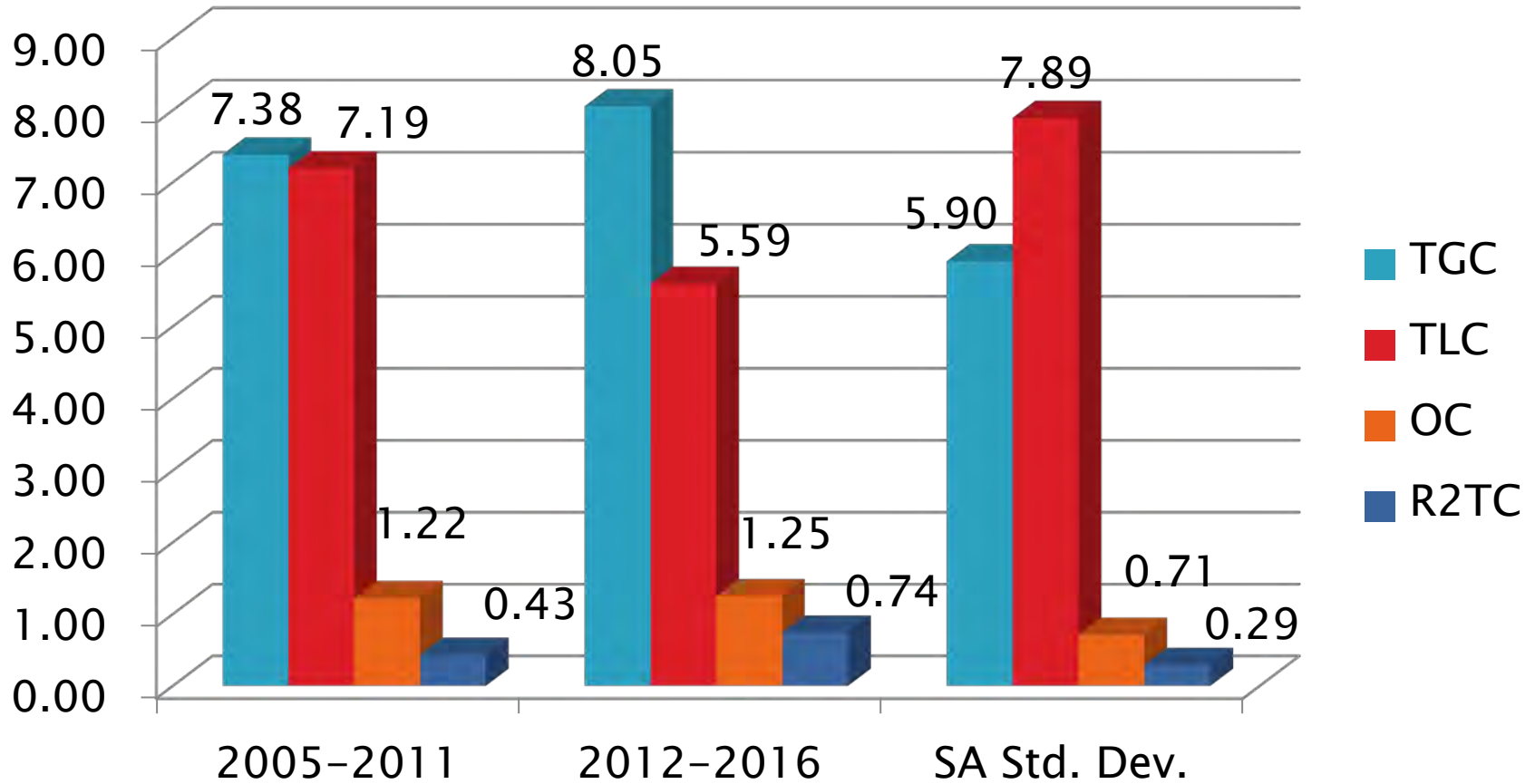


CUSUM Severity Analysis



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C13 Precision Estimates



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Test Monitoring Center

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C13 Oil Aeration (COAT)

»» October 2017

Test Monitoring Center

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COAT Test Activity

| Test Status | Validity Code | COAT |
|-----------------------------|---------------|-----------|
| Acceptable Calibration Test | AC | 8 |
| Failed Calibration Test | OC | 1 |
| Operationally Invalid | LC | 3 |
| Aborted | XC | 3 |
| Industry Donated Test | AG | 1 |
| Non-blind Information | NN | 1 |
| Total | | 17 |

COAT Failed Tests

| Failed Parameter | Number of Tests |
|-----------------------|-----------------|
| Average Aeration Mild | 1 |
| Total | 1 |

COAT Lost Tests*

| Status | Cause | # |
|--------------|-------------------------------------|----------|
| Invalid | Sample line length too short | 2 |
| Invalid | Abnormally low oil gallery pressure | 1 |
| Aborted | Flow meter issue | 1 |
| Aborted | Aeration measurement system leak | 1 |
| Aborted | Abnormally low oil gallery pressure | 1 |
| Total | | 6 |

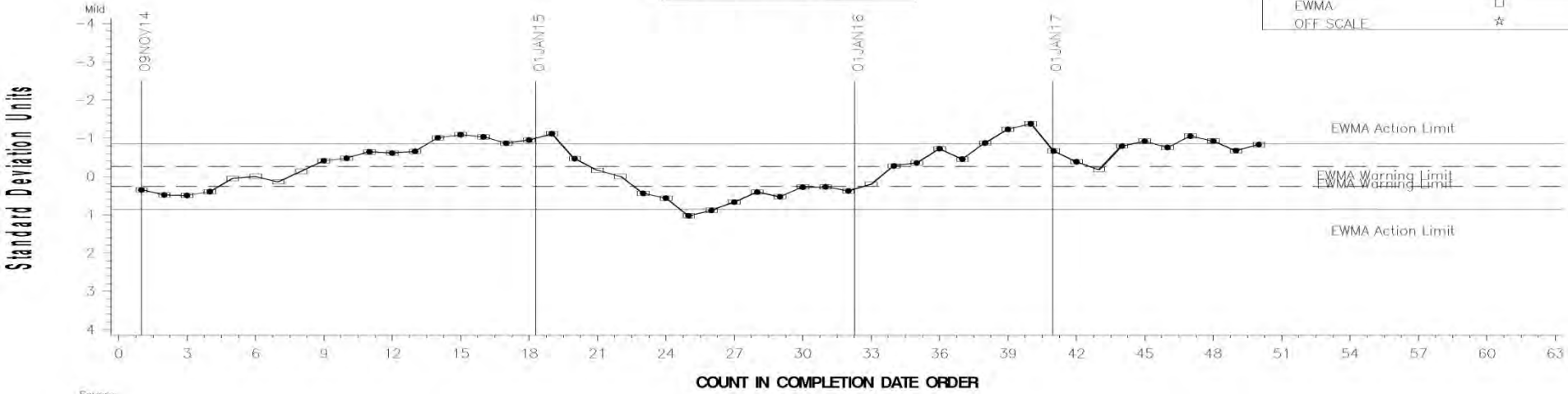
*Invalid and aborted tests

COAT Test Severity

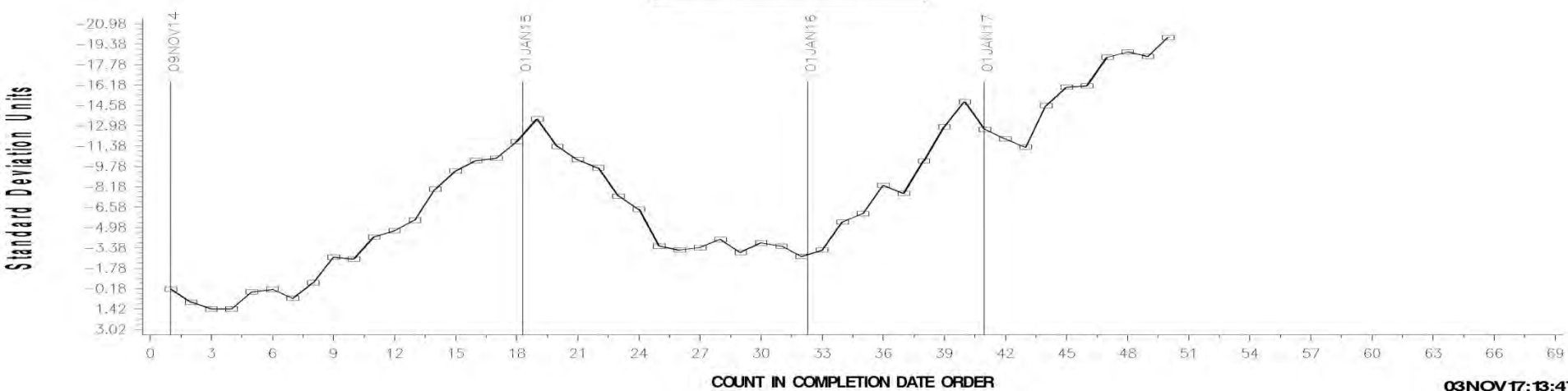
- ▶ AAVE is in Level 1 Zi Alarm in the mild direction.

FINAL AVERAGE OIL AERATION OVER TEST HOURS 40-50

LTMS Severity Analysis



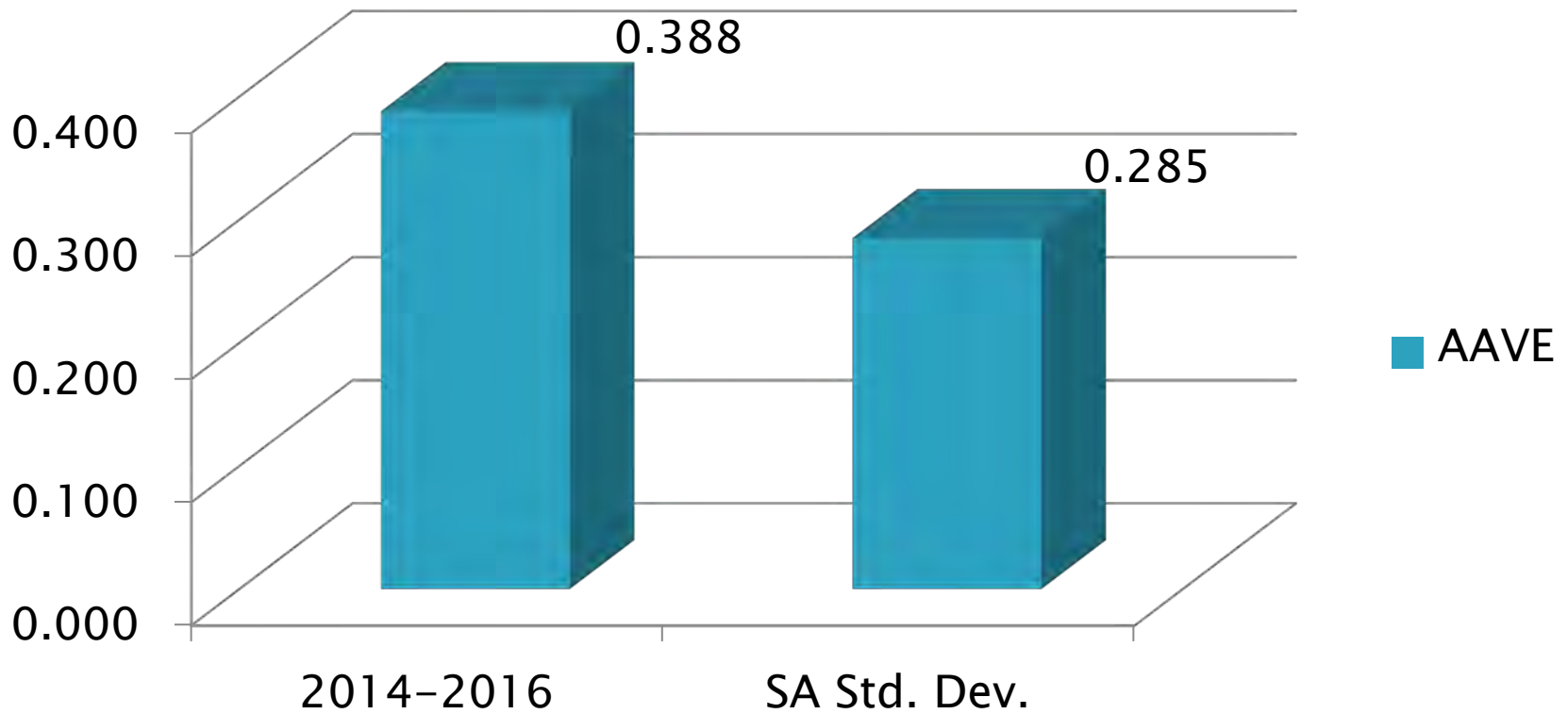
CUSUM Severity Analysis



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COAT Precision Estimates

AAVE



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Daimler DD13 Scuffing Test

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Test Monitoring Center

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DD13 Test Activity*

| Test Status | Validity Code | COAT |
|-----------------------------|---------------|----------|
| Acceptable Calibration Test | AC | 0 |
| Failed Calibration Test | OC | 0 |
| Operationally Invalid | LC | 0 |
| Aborted | XC | 0 |
| Total | | 0 |

DD13 Failed Tests

| Failed Parameter | Number of Tests |
|------------------|-----------------|
| No failed tests | 0 |
| Total | 0 |

DD13 Lost Tests*

| Status | Cause | # |
|--------------|------------------|----------|
| Invalid | No invalid tests | 0 |
| Aborted | No aborted tests | 0 |
| Total | | 0 |

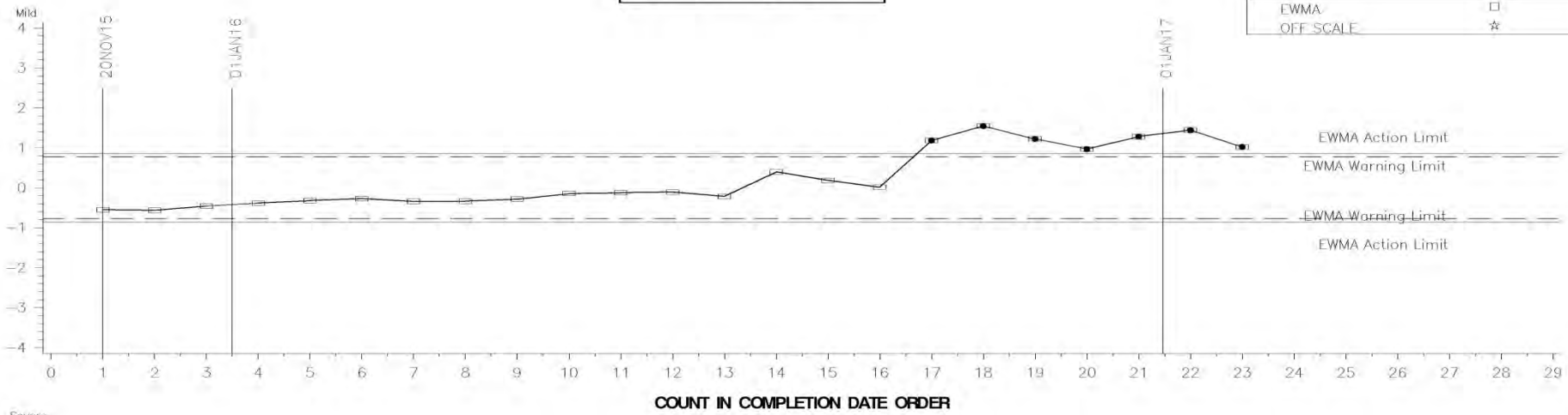
*Invalid and aborted tests

DD13 Test Severity

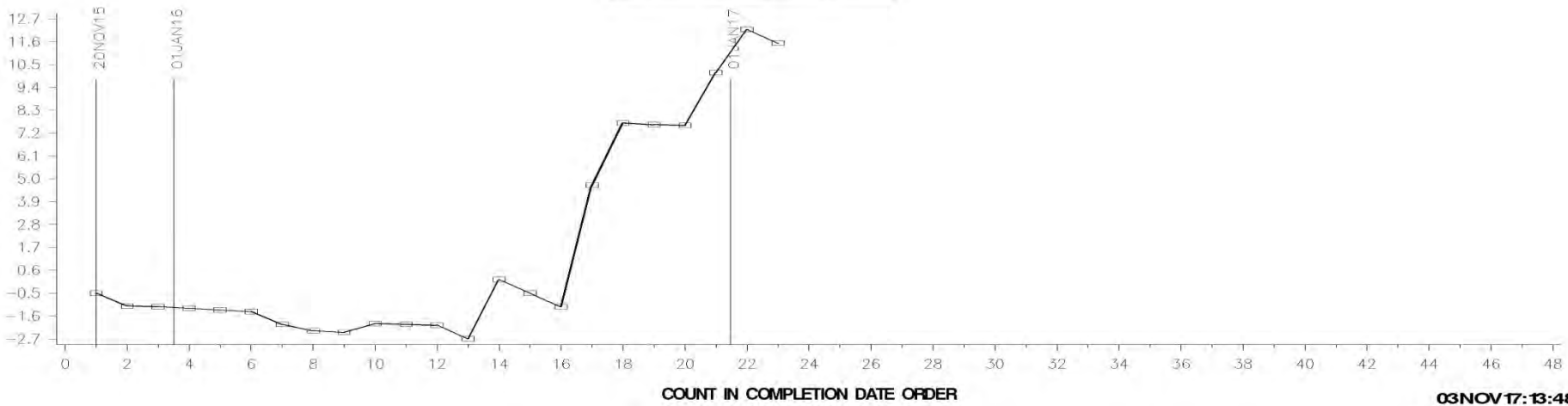
- ▶ As no DD13 tests were run during this period no statement about test severity can be made.

FNL. ORIG. UNIT HOURS TO SCUFF

LTMS Severity Analysis



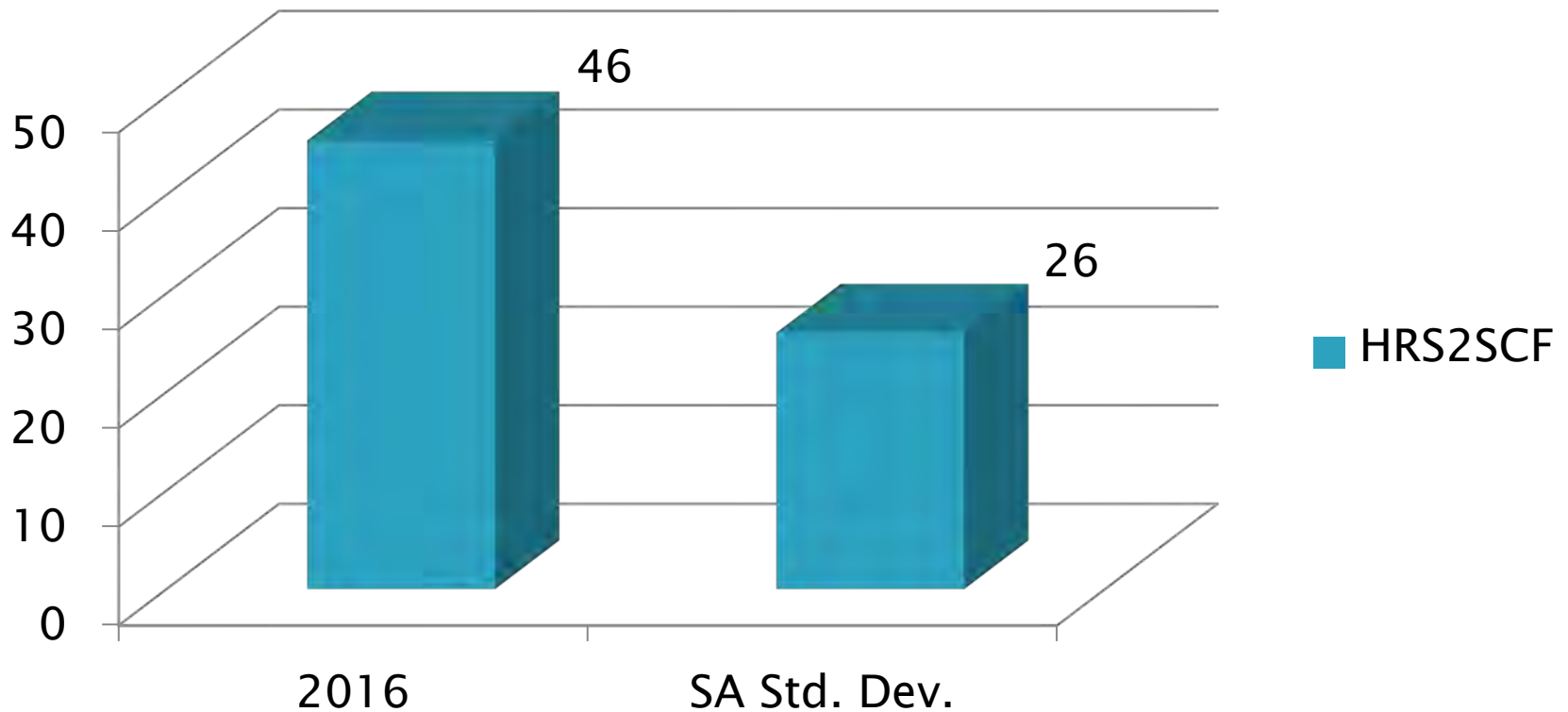
CUSUM Severity Analysis



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DD13 Precision Estimates

HRS2SCF



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Cummins ISB

»» October 2017

Test Monitoring Center

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ISB Test Activity

| Test Status | Validity Code | # |
|-----------------------------|---------------|----------|
| Acceptable Calibration Test | AC | 3 |
| Failed Calibration Test | OC | 4 |
| Operationally Invalid | LC | 0 |
| Aborted | XC | 0 |
| Total | | 7 |

ISB Failed Tests

| Failed Parameter | Number of Tests |
|--|-----------------|
| Severe Average Camshaft Wear (ACSW) | 2 |
| Severe Average Tappet Weight Loss (ATWL) | 1 |
| Severe ACSW and ATWL | 1 |
| Total | 4 |

ISB Lost Tests*

| Status | Cause | # |
|--------------|------------------|----------|
| Invalid | No Invalid Tests | 0 |
| Aborted | No Aborted Tests | 0 |
| Total | | 0 |

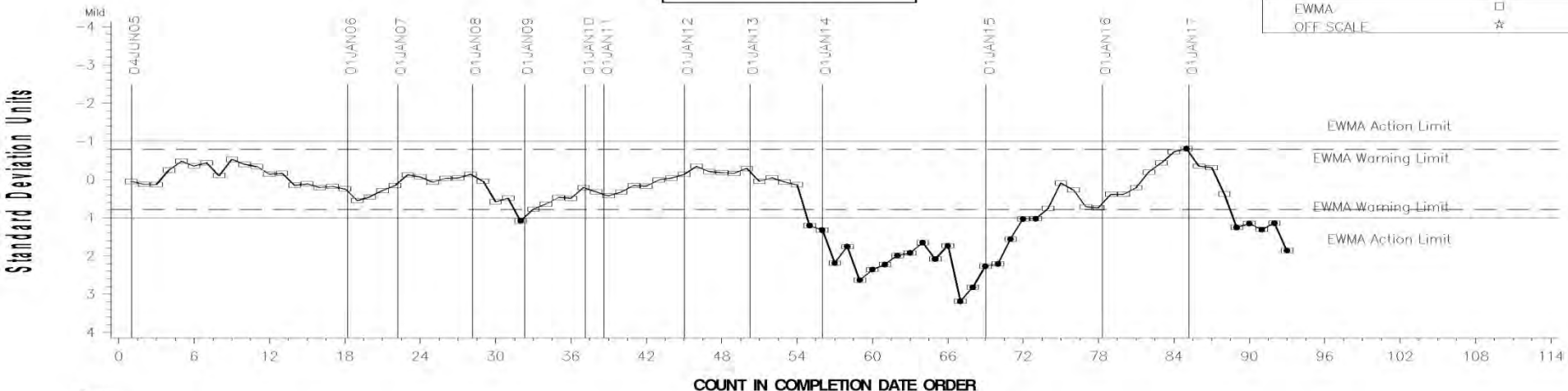
*Invalid and aborted tests

ISB Test Severity

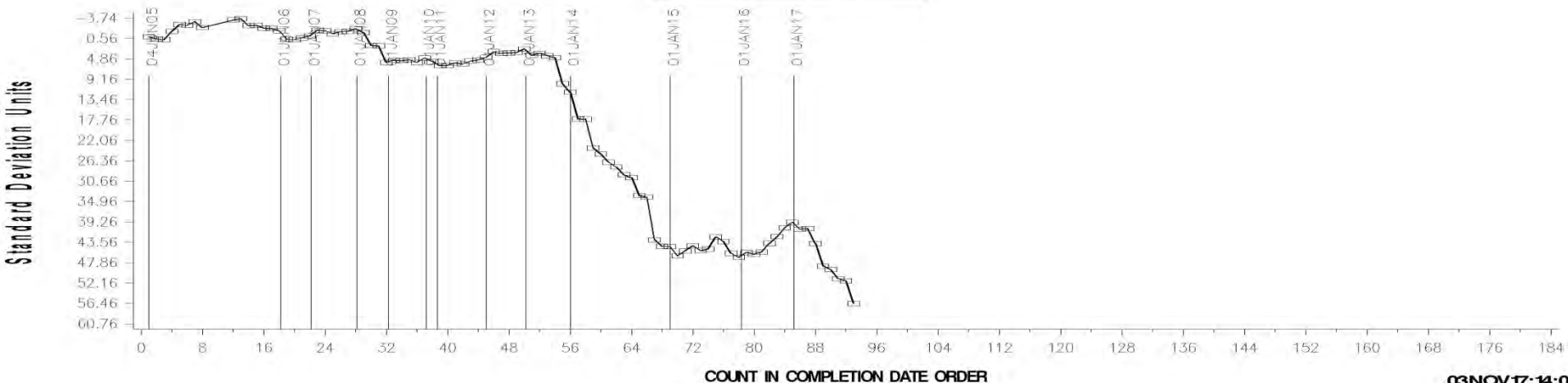
- ▶ ACSW and ATWL are severity action alarm in the severe direction.

AVERAGE CAMSHAFT WEAR

LTMS Severity Analysis



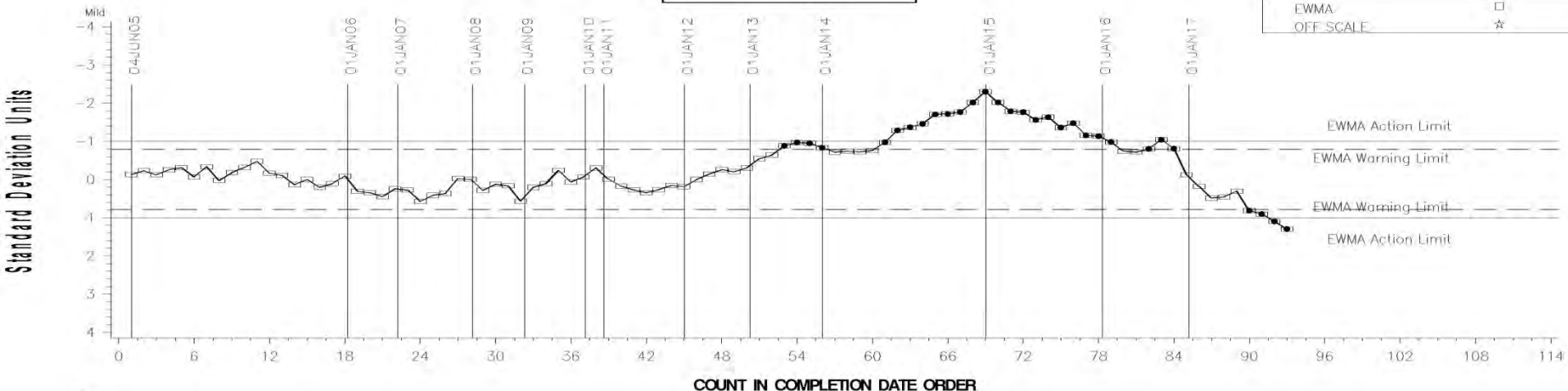
CUSUM Severity Analysis



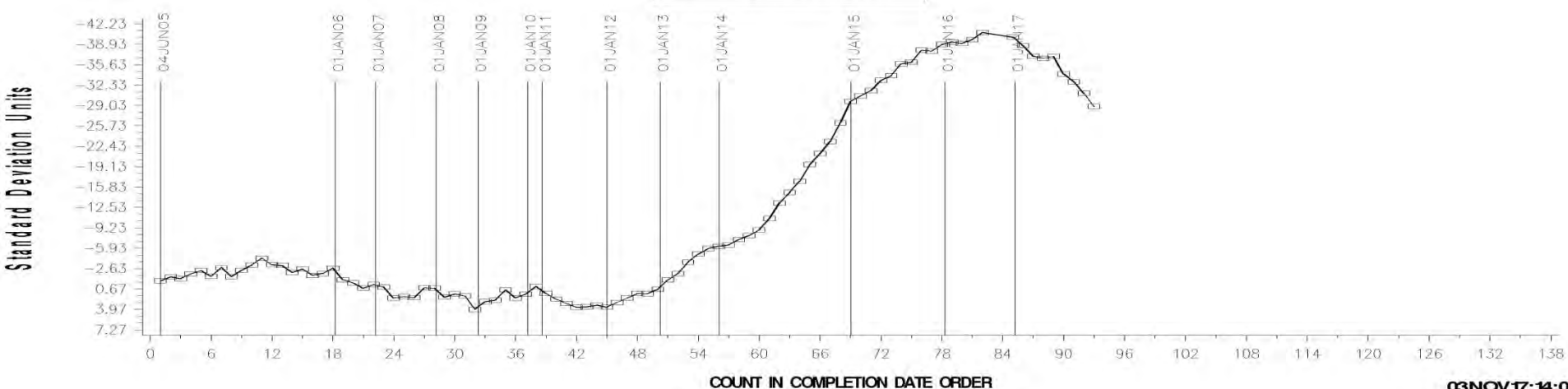
03NOV17:14:01

AVERAGE TAPPET WEIGHT LOSS

LTMS Severity Analysis

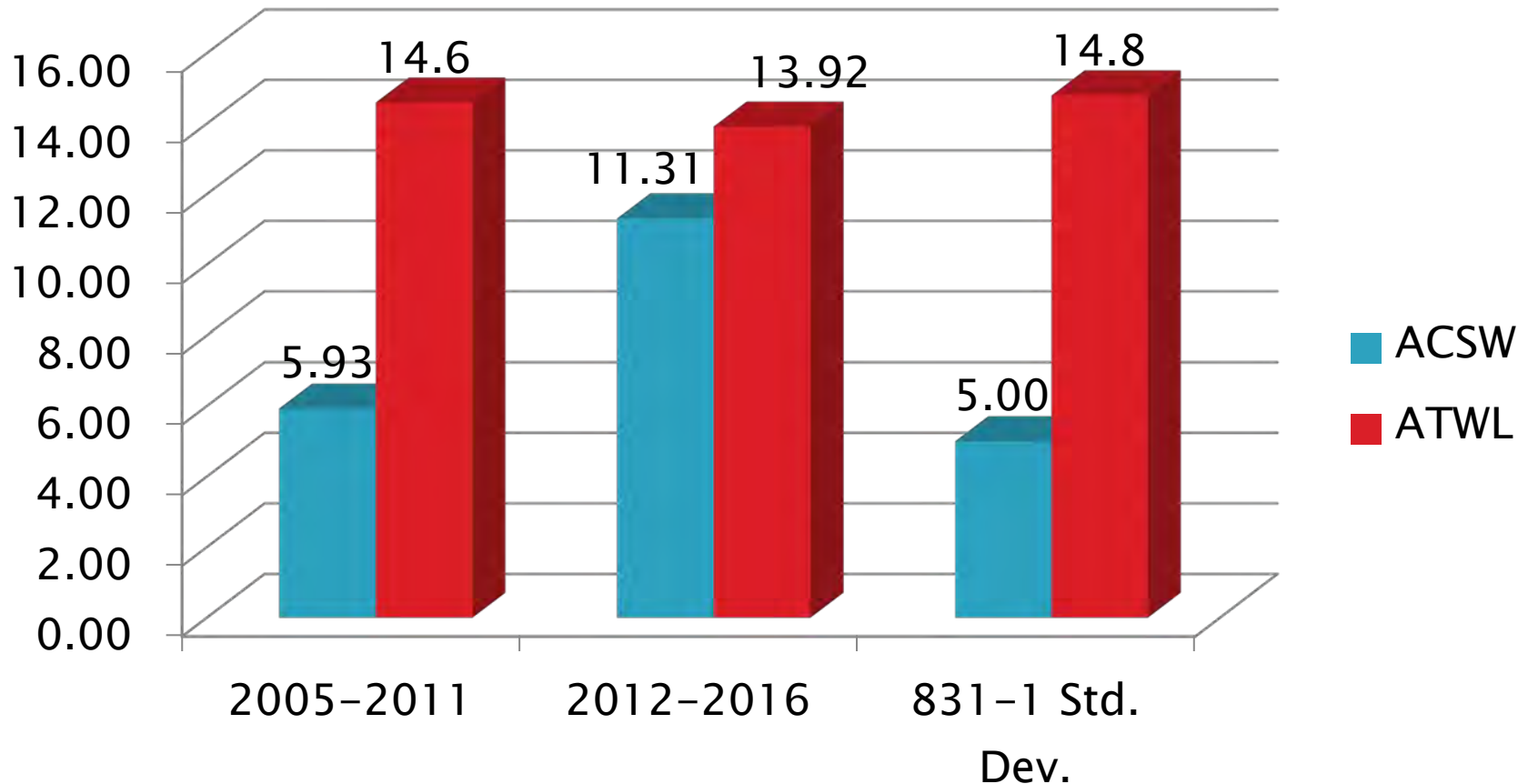


CUSUM Severity Analysis



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ISB Precision Estimates



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Cummins ISM

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Test Monitoring Center

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ISM Test Activity

| Test Status | Validity Code | # |
|-----------------------------|---------------|----------|
| Acceptable Calibration Test | AC | 0 |
| Failed Calibration Test | OC | 0 |
| Operationally Invalid | LC | 0 |
| Aborted | XC | 0 |
| Total | | 0 |

ISM Failed Tests

| Failed Parameter | Number of Tests |
|------------------|-----------------|
| No failed tests | 0 |
| Total | 0 |

ISM Lost Tests*

| Status | Cause | # |
|--------------|------------------|----------|
| Invalid | No Invalid Tests | 0 |
| Aborted | No Aborted Tests | 0 |
| Total | | 0 |

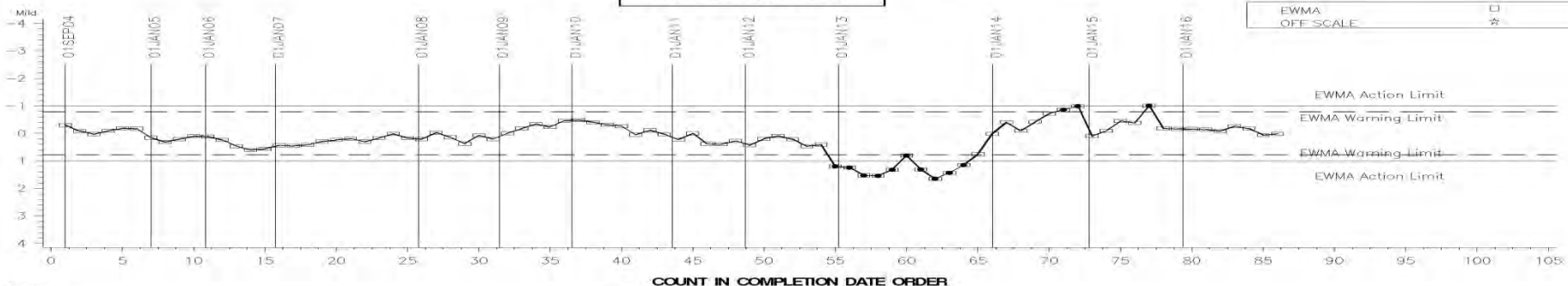
*Invalid and aborted tests

ISM Test Severity

- ▶ As no ISM tests were run during this period no statement about test severity can be made.

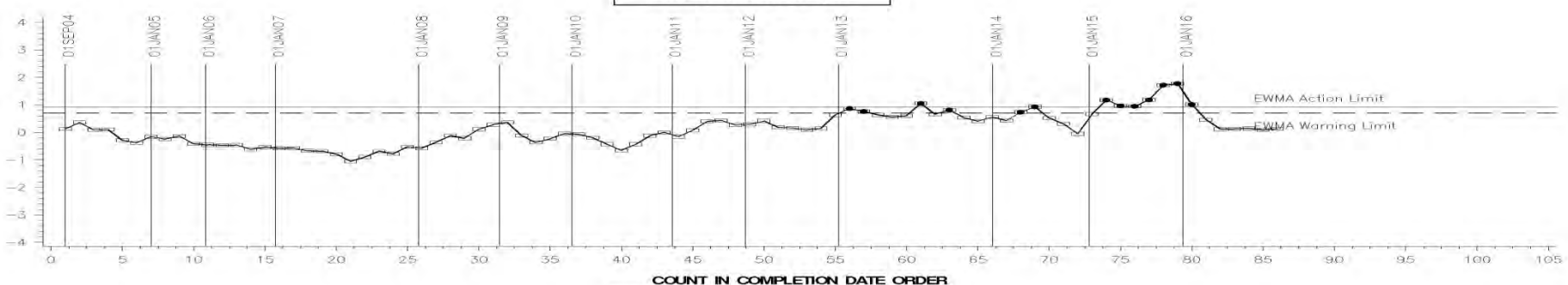
INJECTOR SCREW WEIGHT LOSS ADJUSTED TO 3.9% SOOT

LTMS Severity Analysis



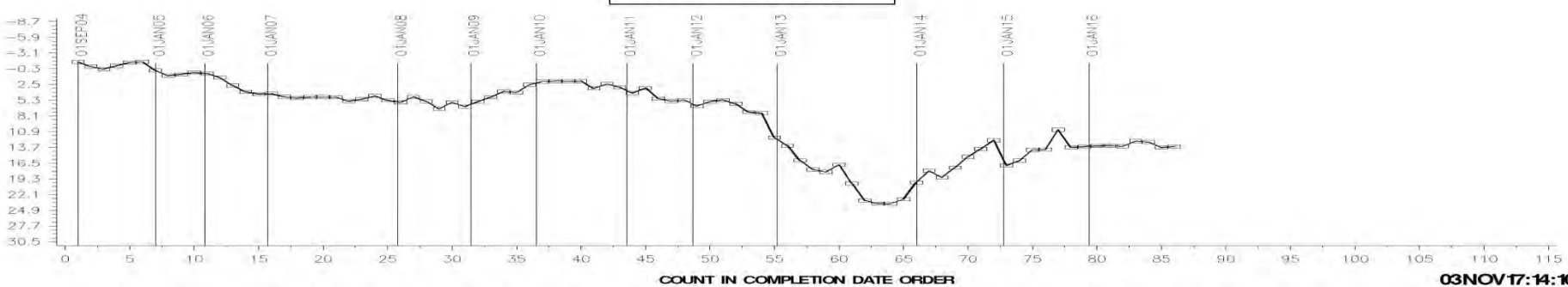
COUNT IN COMPLETION DATE ORDER

LTMS Precision Analysis



COUNT IN COMPLETION DATE ORDER

CUSUM Severity Analysis

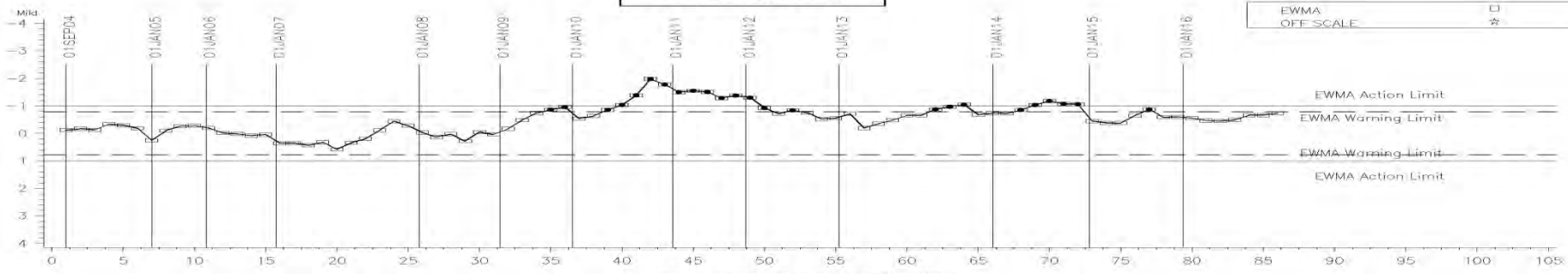


COUNT IN COMPLETION DATE ORDER

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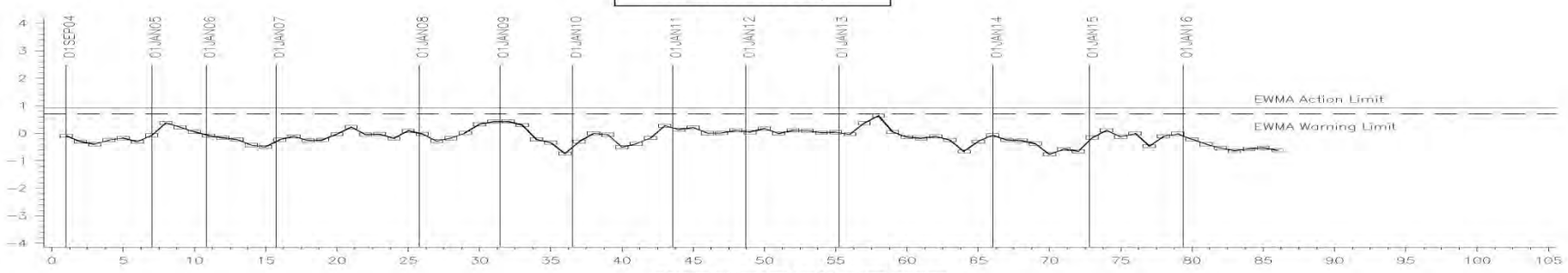
FILTER PLUGGING DELTA P

LTMS Severity Analysis



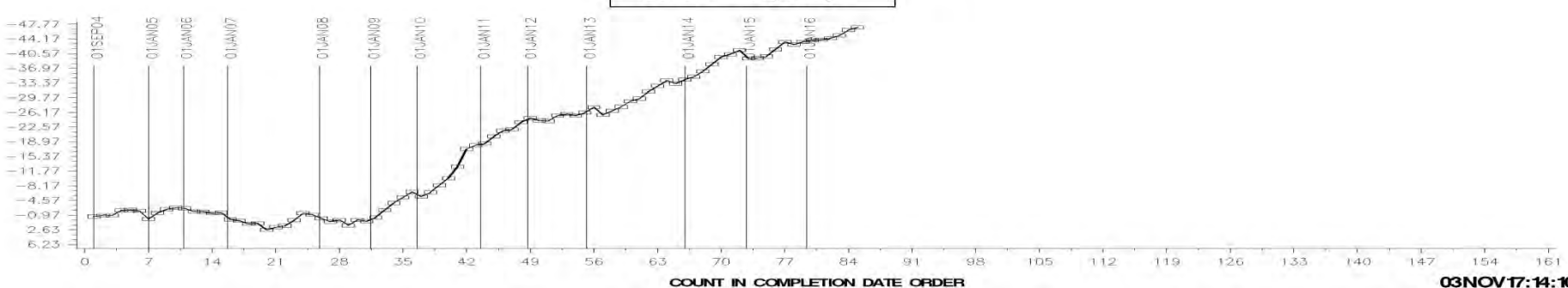
COUNT IN COMPLETION DATE ORDER

LTMS Precision Analysis



COUNT IN COMPLETION DATE ORDER

CUSUM Severity Analysis



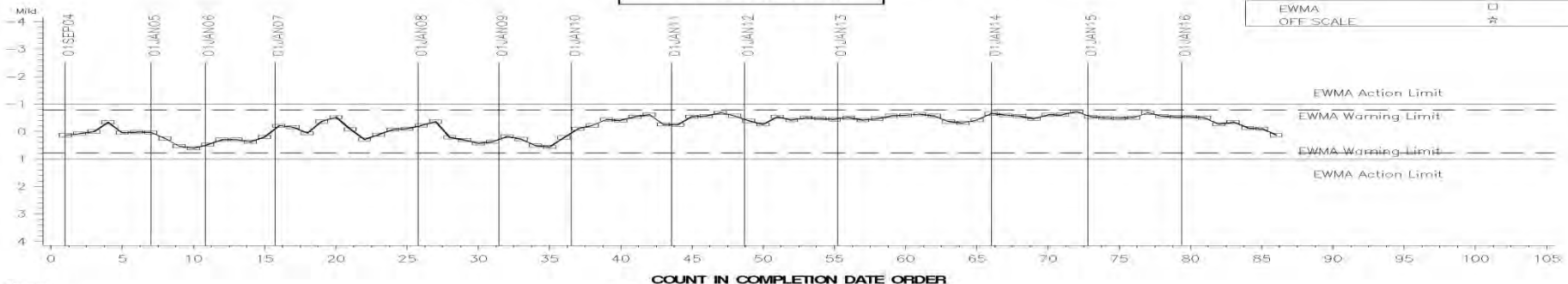
03NOV17:14:10

ISM INDUSTRY OPERATIONALLY VALID DATA

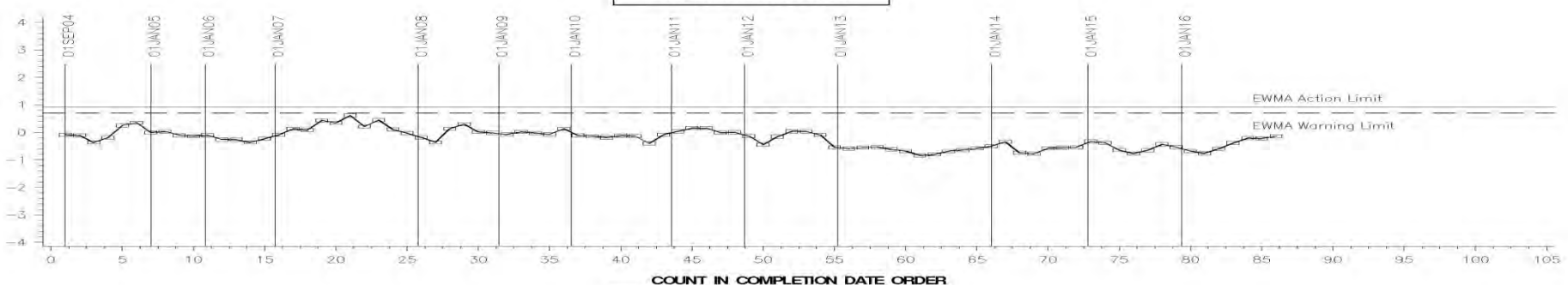


CROSSHEAD WEIGHT LOSS ADJUSTED TO 3.9 % SOOT

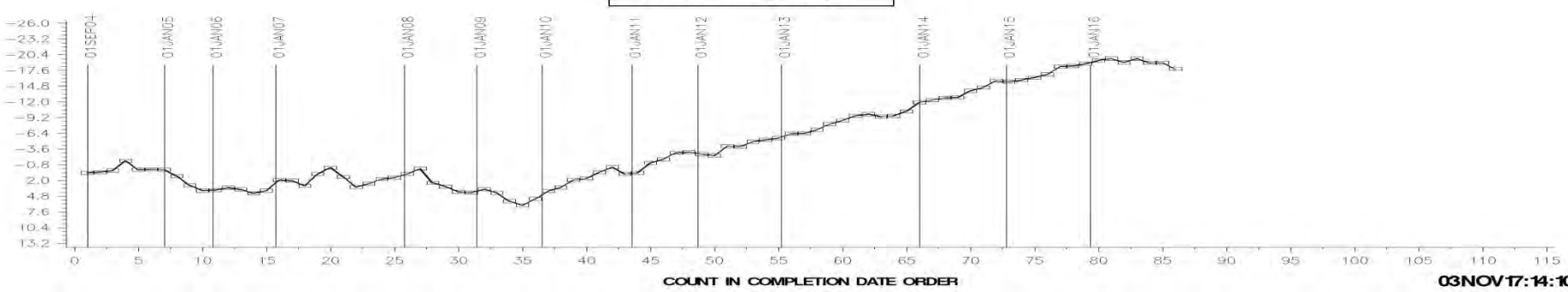
LTMS Severity Analysis



LTMS Precision Analysis



CUSUM Severity Analysis



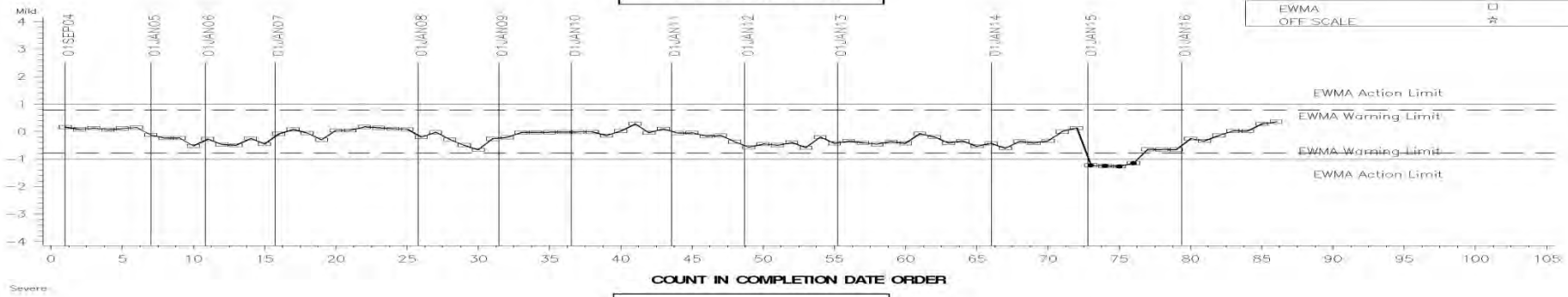
03NOV17:14:10



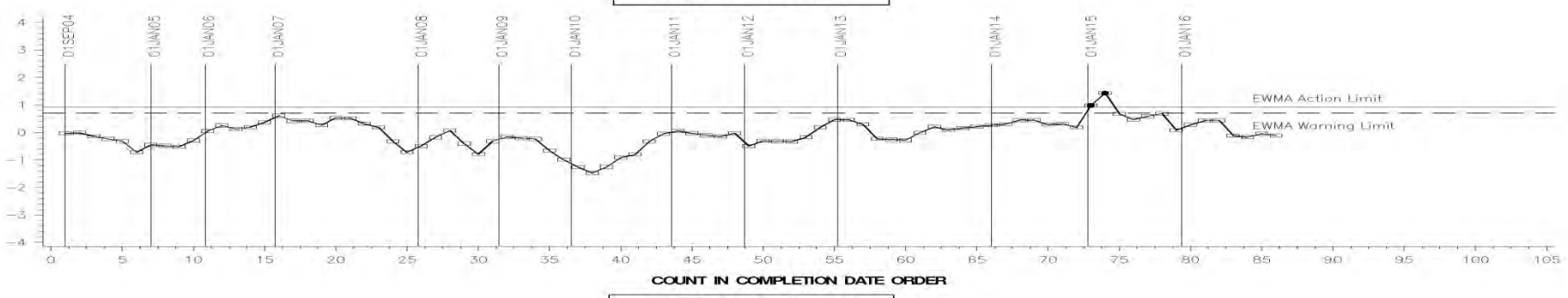
ISM INDUSTRY OPERATIONALLY VALID DATA

AVERAGE SLUDGE RATING

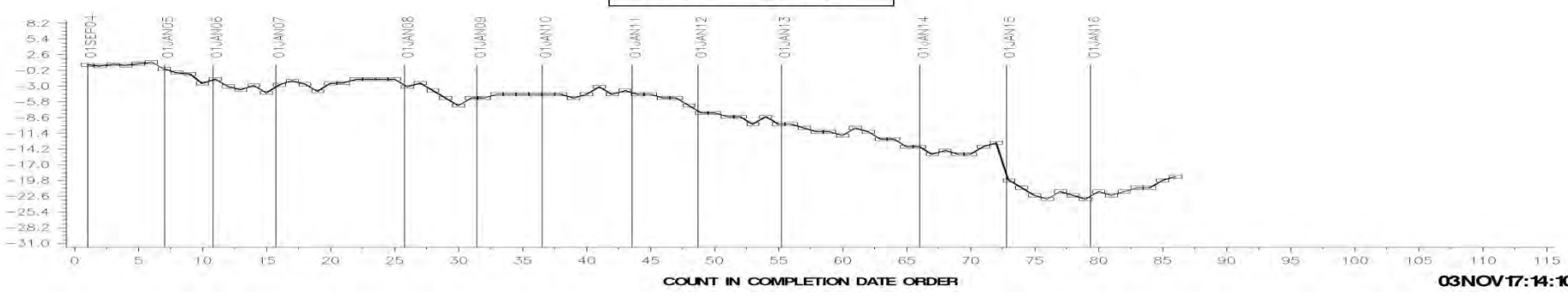
LTMS Severity Analysis



LTMS Precision Analysis

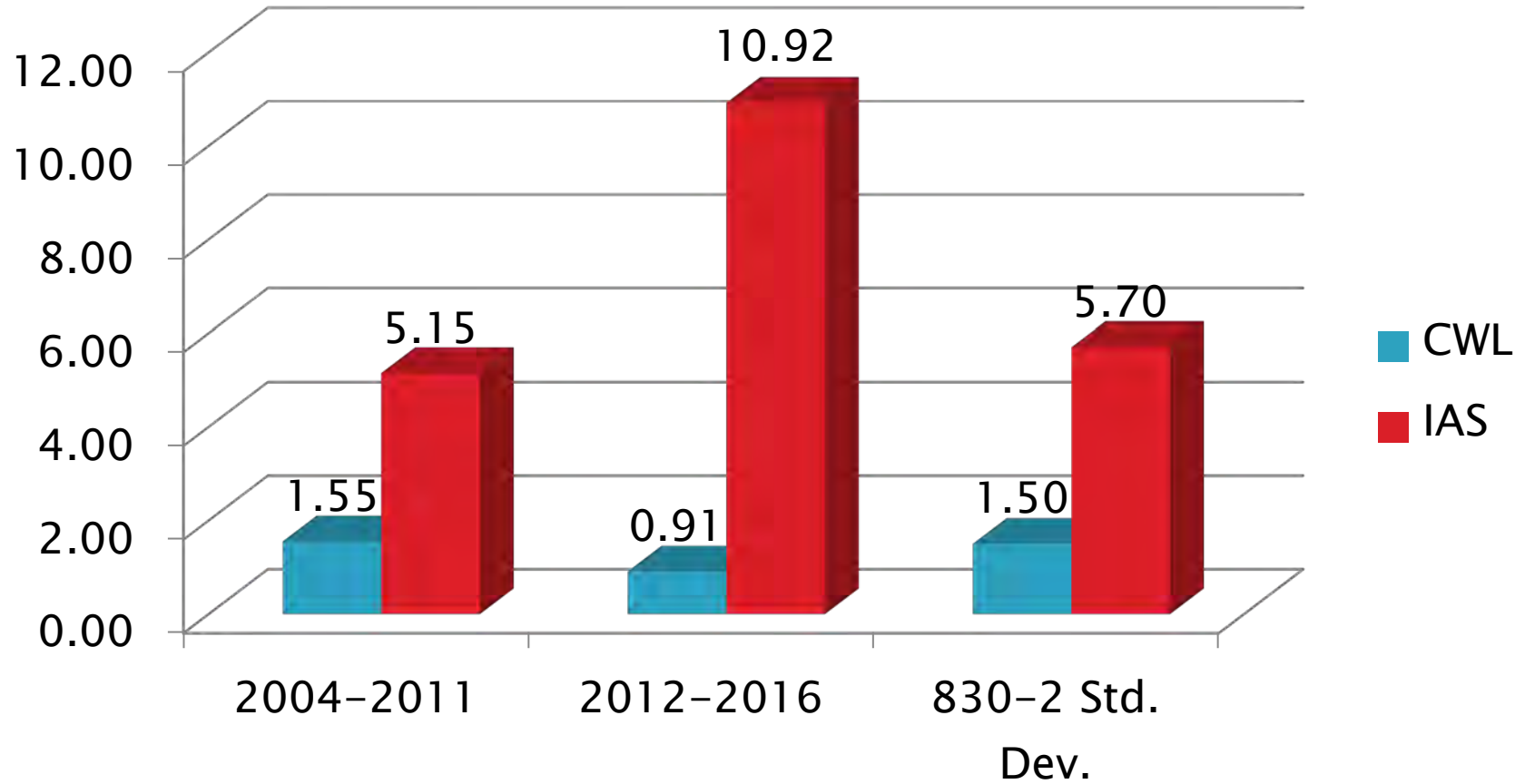


CUSUM Severity Analysis

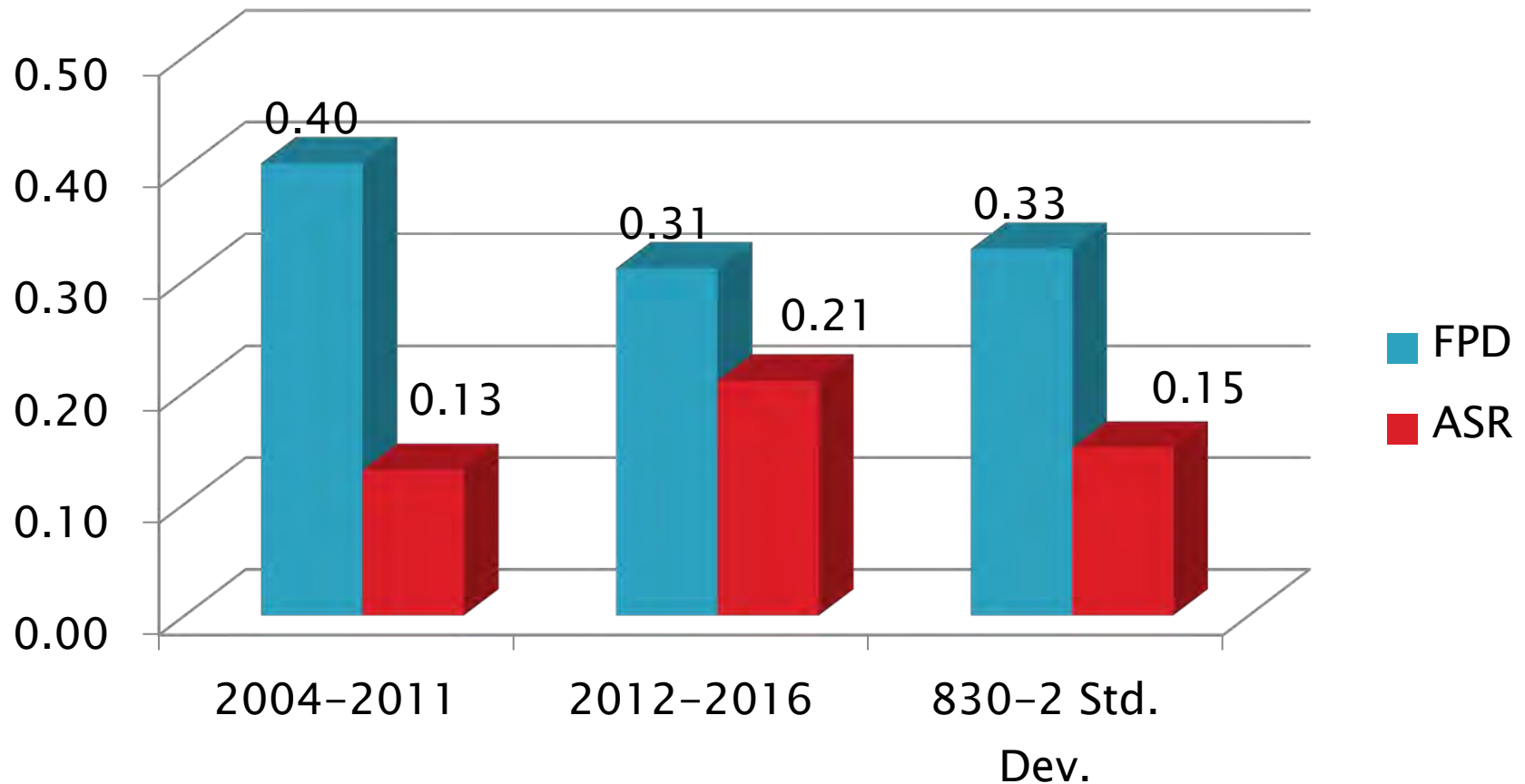


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ISM Precision Estimates



ISM Precision Estimates



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EOAT

»» October 2017

EOAT Test Activity

| Test Status | Validity Code | # |
|-----------------------------|---------------|----------|
| Acceptable Calibration Test | AC | 0 |
| Failed Calibration Test | OC | 0 |
| Operationally Invalid | LC | 0 |
| Aborted | XC | 0 |
| Total | | 0 |

EOAT Failed Tests

| Failed Parameter | Number of Tests |
|------------------|-----------------|
| No failed tests | 0 |
| Total | 0 |

EOAT Lost Tests*

| Status | Cause | # |
|--------------|------------------|----------|
| Invalid | No invalid tests | 0 |
| Aborted | No aborted tests | 0 |
| Total | | 0 |

*Invalid and aborted tests

EOAT Test Severity

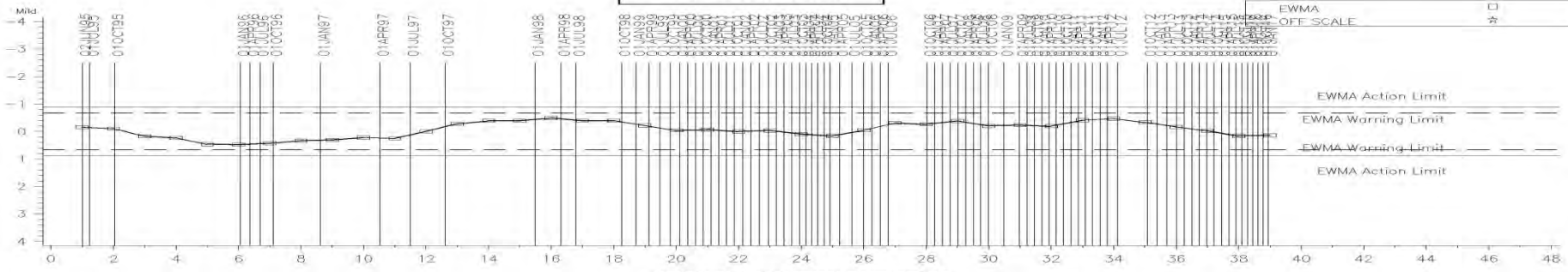
- ▶ As no EOAT tests were run during this period no statement about test severity can be made.

EOAT INDUSTRY OPERATIONAL VALID DATA

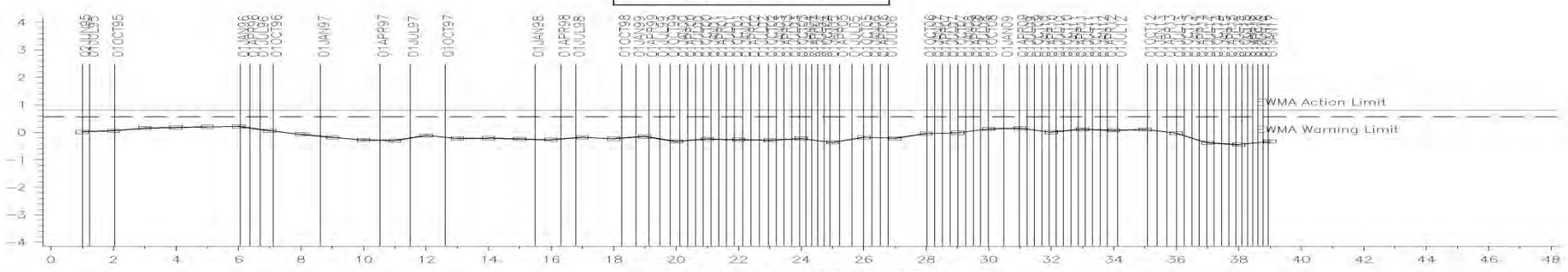


ENGINE OIL AERATION

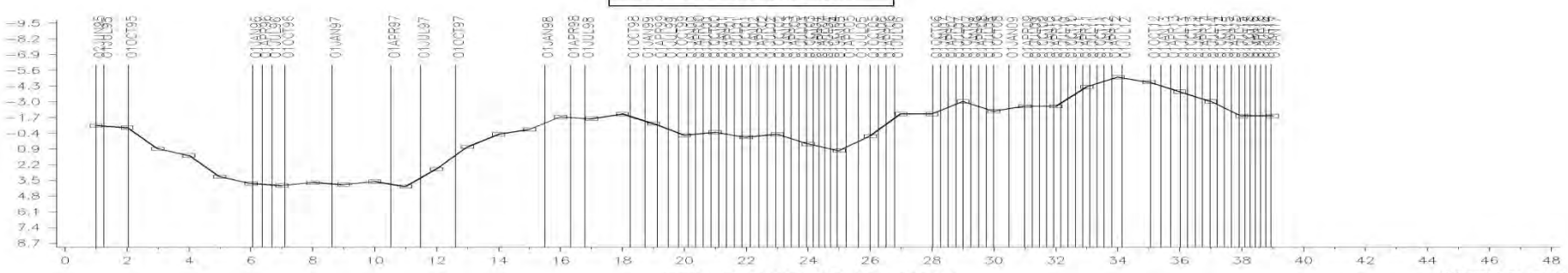
LTMS Severity Analysis



LTMS Precision Analysis



CUSUM Severity Analysis



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Test Monitoring Center

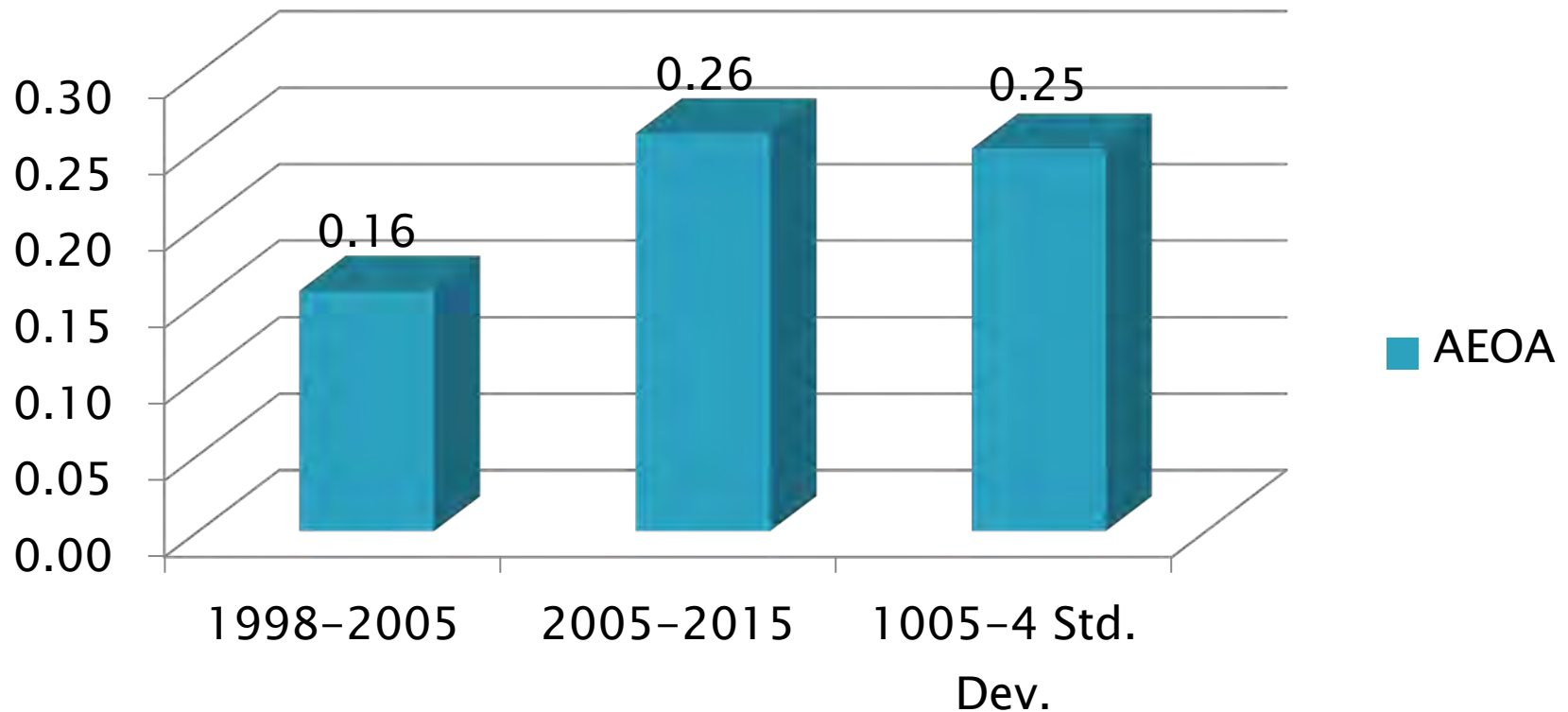
<http://astmtmc.cmu.edu>



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EOAT Precision Estimates

AEOA



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RFWT

»» October 2017

Test Monitoring Center

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RFWT Test Activity

| Test Status | Validity Code | # |
|-----------------------------|---------------|----------|
| Acceptable Calibration Test | AC | 1 |
| Failed Calibration Test | OC | 0 |
| Operationally Invalid | LC | 0 |
| Aborted | XC | 0 |
| Total | | 1 |

RFWT Failed Tests

| Failed Parameter | Number of Tests |
|------------------|-----------------|
| No failed tests | 0 |
| Total | 0 |

RFWT Lost Tests*

| Status | Cause | # |
|--------------|------------------|----------|
| Invalid | No invalid tests | 0 |
| Aborted | No aborted tests | 0 |
| Total | | 0 |

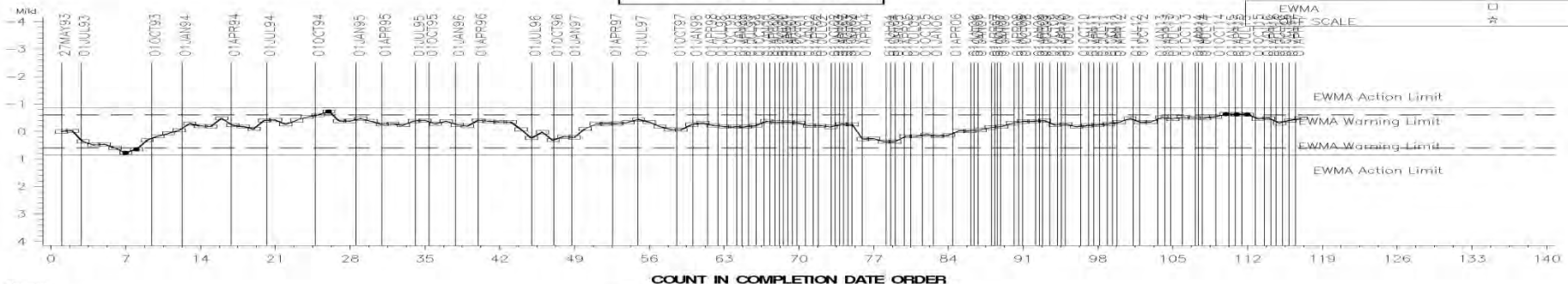
*Invalid and aborted tests

RFWT Test Severity

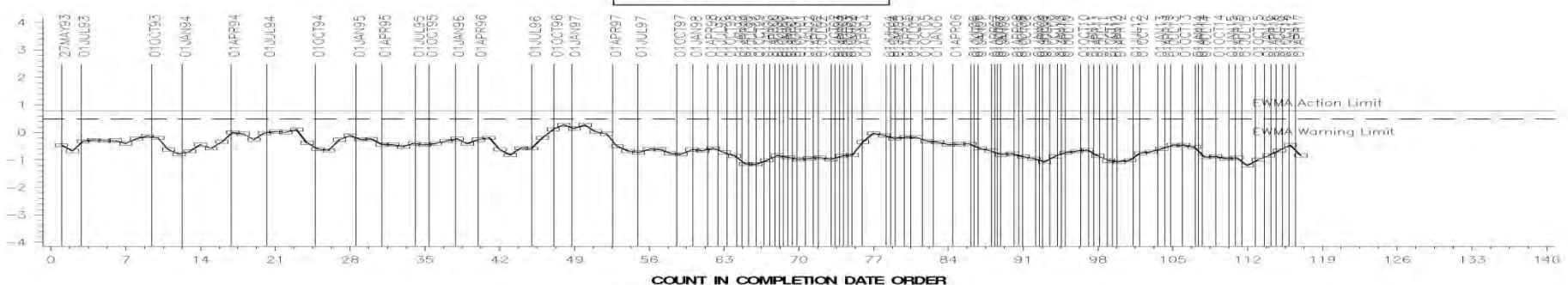
- ▶ AFW is in control.

Average Follower Wear

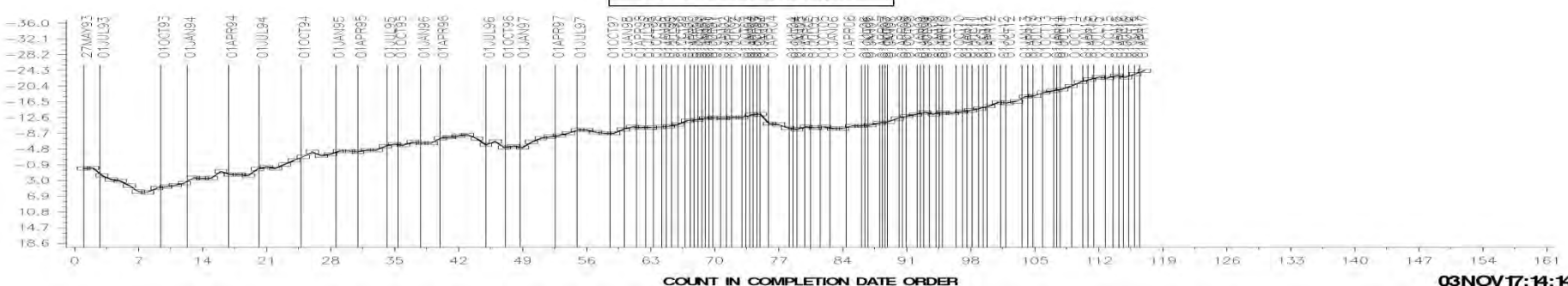
LTMS Severity Analysis



LTMS Precision Analysis



CUSUM Severity Analysis



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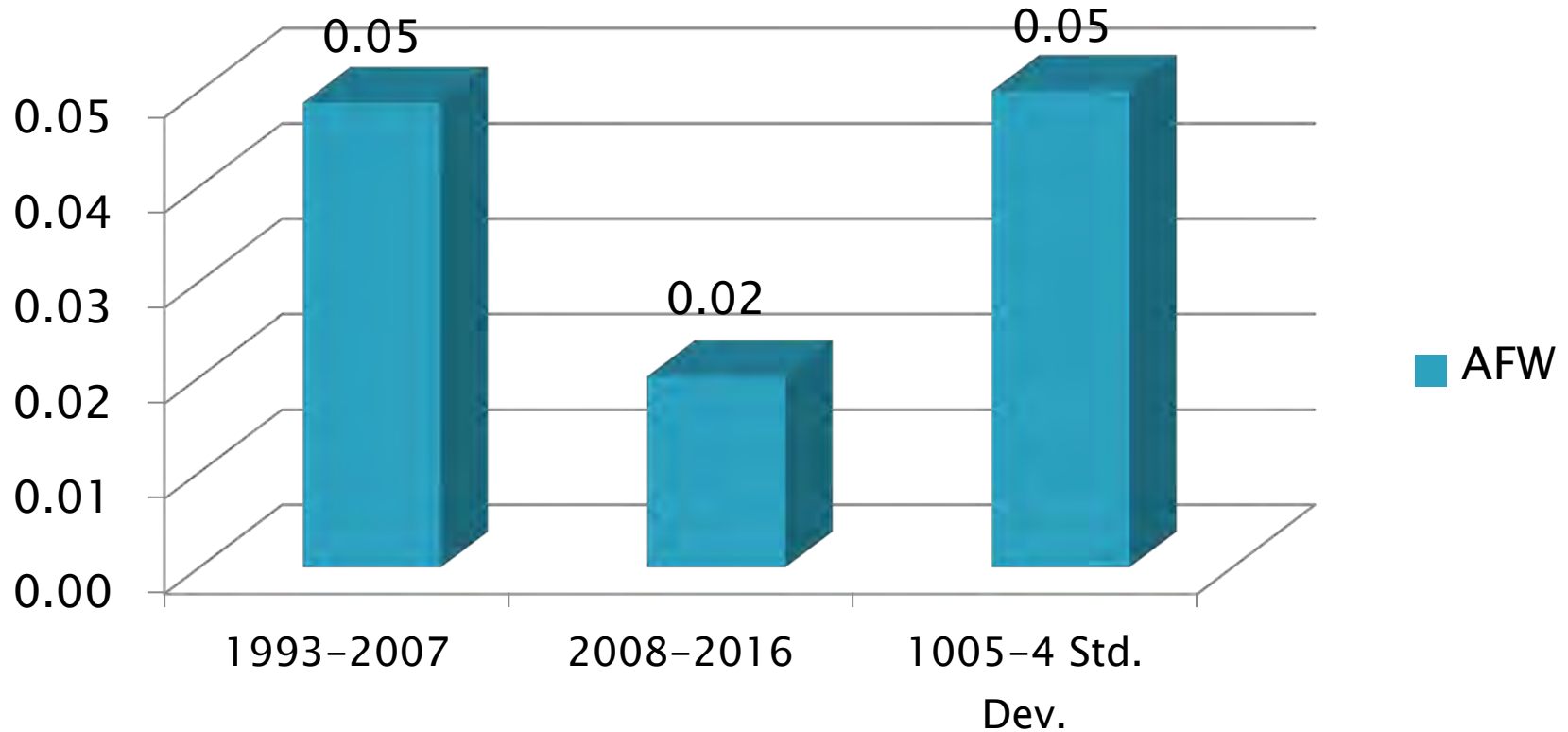
Standard Deviation Units

Standard Deviation Units

Standard Deviation Units

RFWT Precision Estimates

AFW



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Mack T-8/T-8E

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Test Monitoring Center

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T-8/T-8E Test Activity

| Test Status | Validity Code | # |
|-----------------------------|---------------|----------|
| Acceptable Calibration Test | AC | 3 |
| Failed Calibration Test | OC | 1 |
| Operationally Invalid | LC | 0 |
| Aborted | XC | 2 |
| Total | | 6 |

T-8/T8-E Failed Tests

| Failed Parameter | Number of Tests |
|-------------------------------------|-----------------|
| Viscosity increase @ 3.8% soot mild | 1 |
| Total | 1 |

T-8/T8-E Lost Tests*

| Status | Cause | # |
|--------------|---|----------|
| Invalid | No invalid tests | 0 |
| Aborted | High oil consumption due to stuck rings | 1 |
| Aborted | Missed soot window | 1 |
| Total | | 2 |

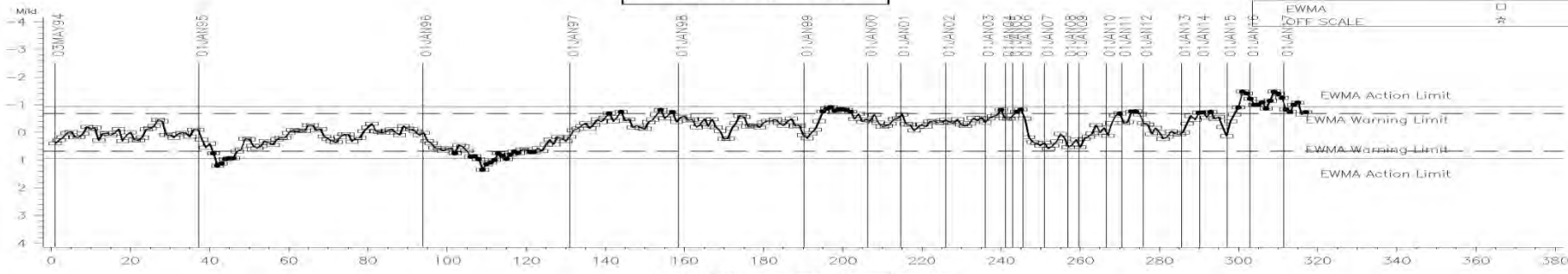
*Invalid and aborted tests

T-8/T-8E Test Severity

- ▶ VI38, RV48 and RV2 are in control.

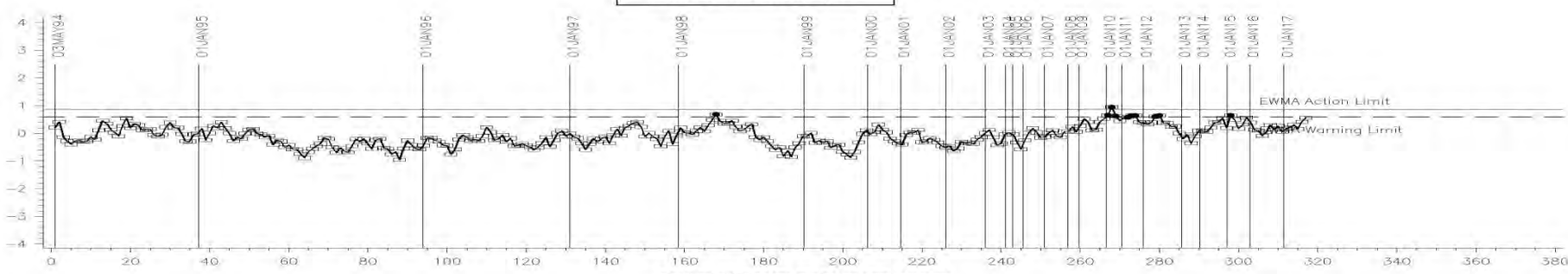
VISCOSITY INCR @ 3.8% SOOT

LTMS Severity Analysis



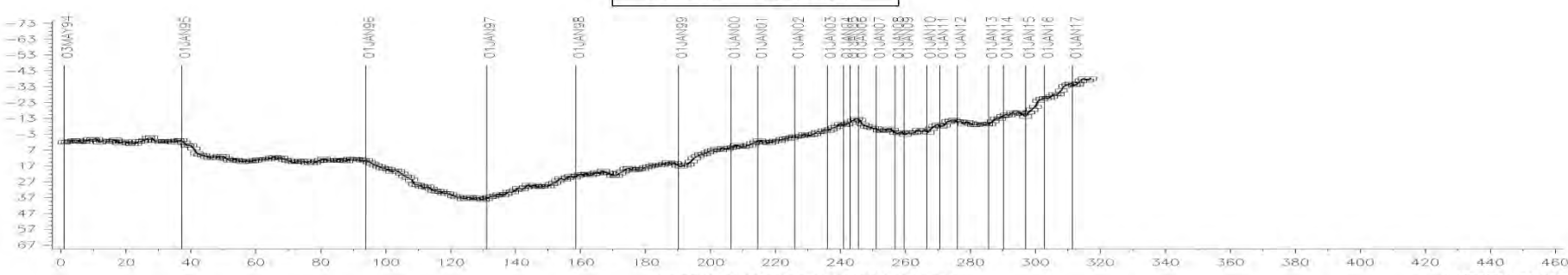
COUNT IN COMPLETION DATE ORDER

LTMS Precision Analysis



COUNT IN COMPLETION DATE ORDER

CUSUM Severity Analysis

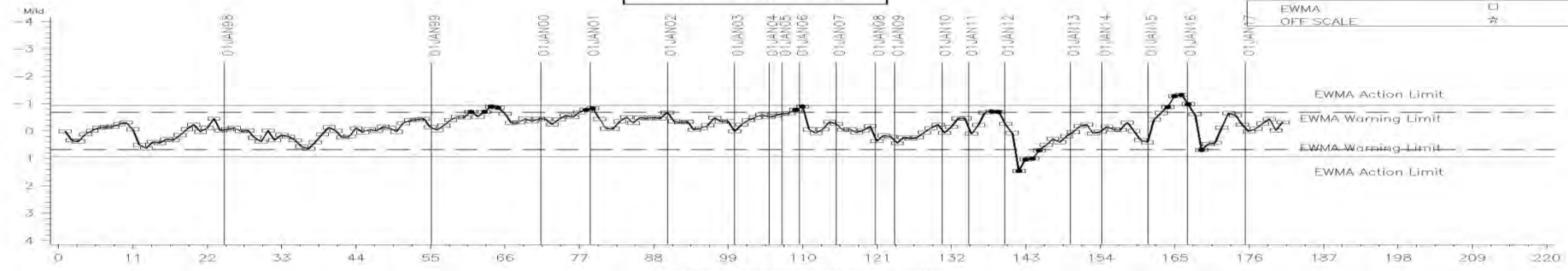


COUNT IN COMPLETION DATE ORDER

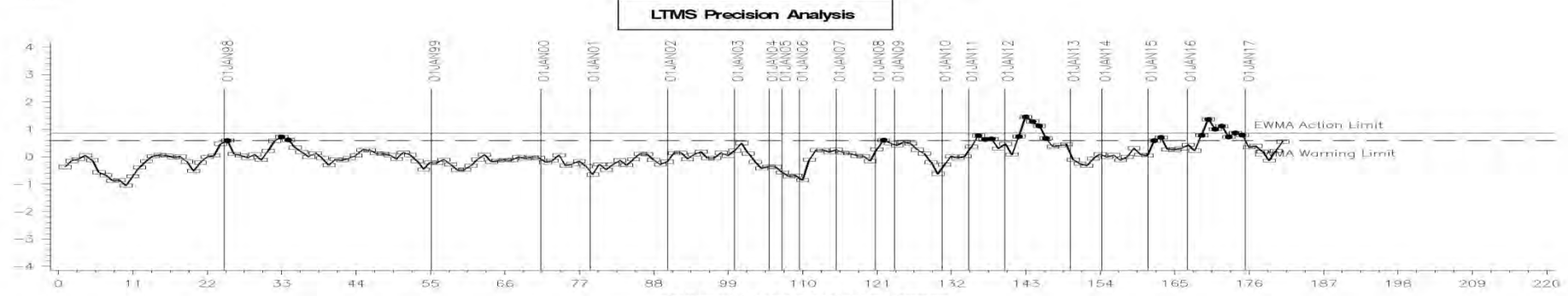
03NOV17:14:19

RELATIVE VISCOSITY @ 4.8% (50% LOSS)

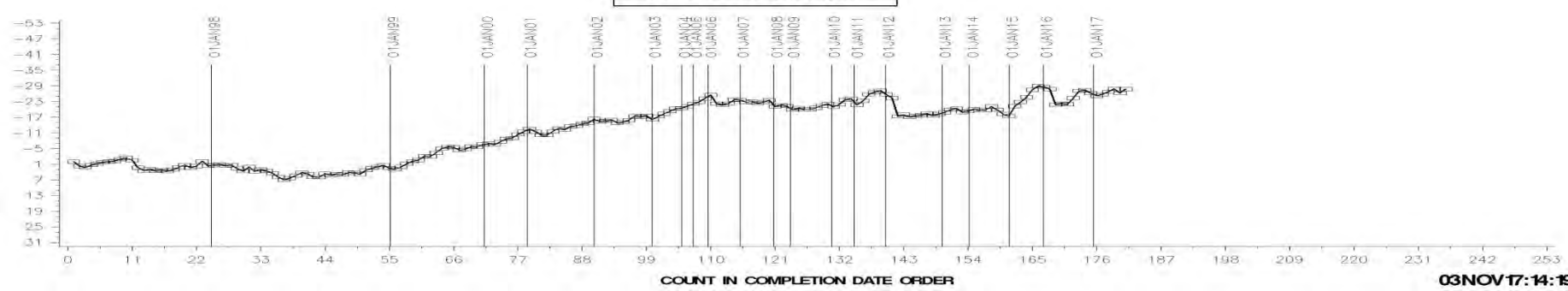
LTMS Severity Analysis



LTMS Precision Analysis



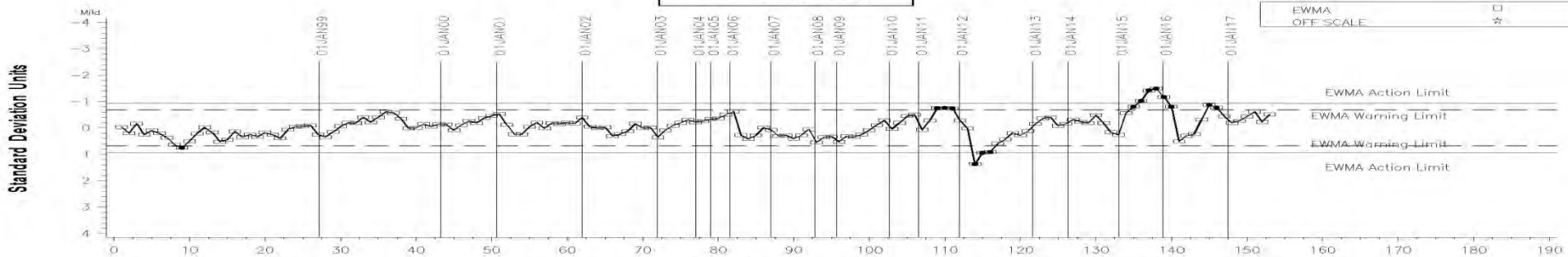
CUSUM Severity Analysis



03NOV17:14:19

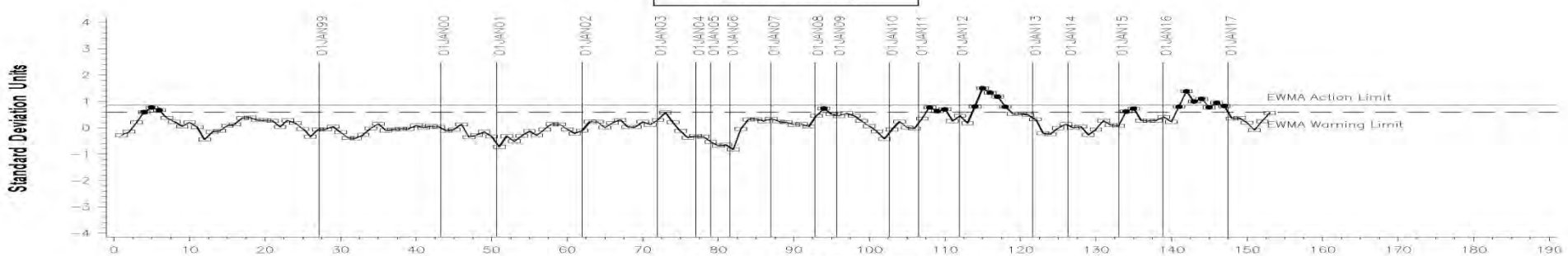
RELATIVE VISCOSITY @ 4.8% (100% LOSS)

LTMS Severity Analysis



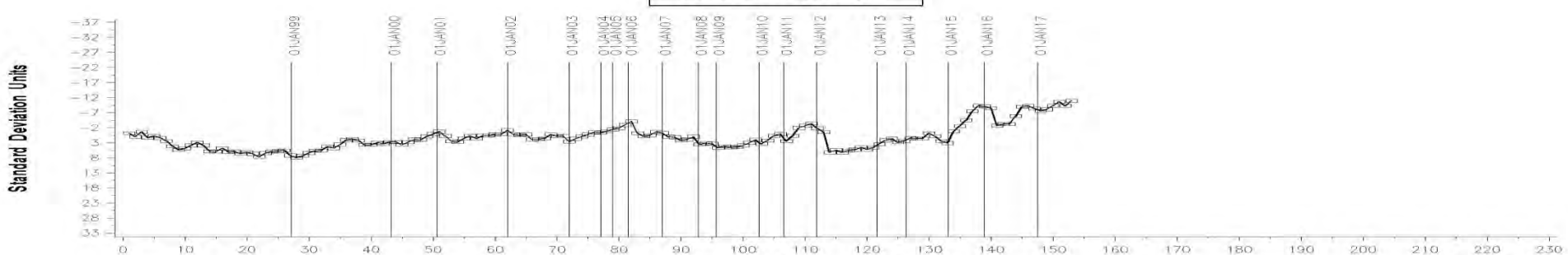
COUNT IN COMPLETION DATE ORDER

LTMS Precision Analysis



COUNT IN COMPLETION DATE ORDER

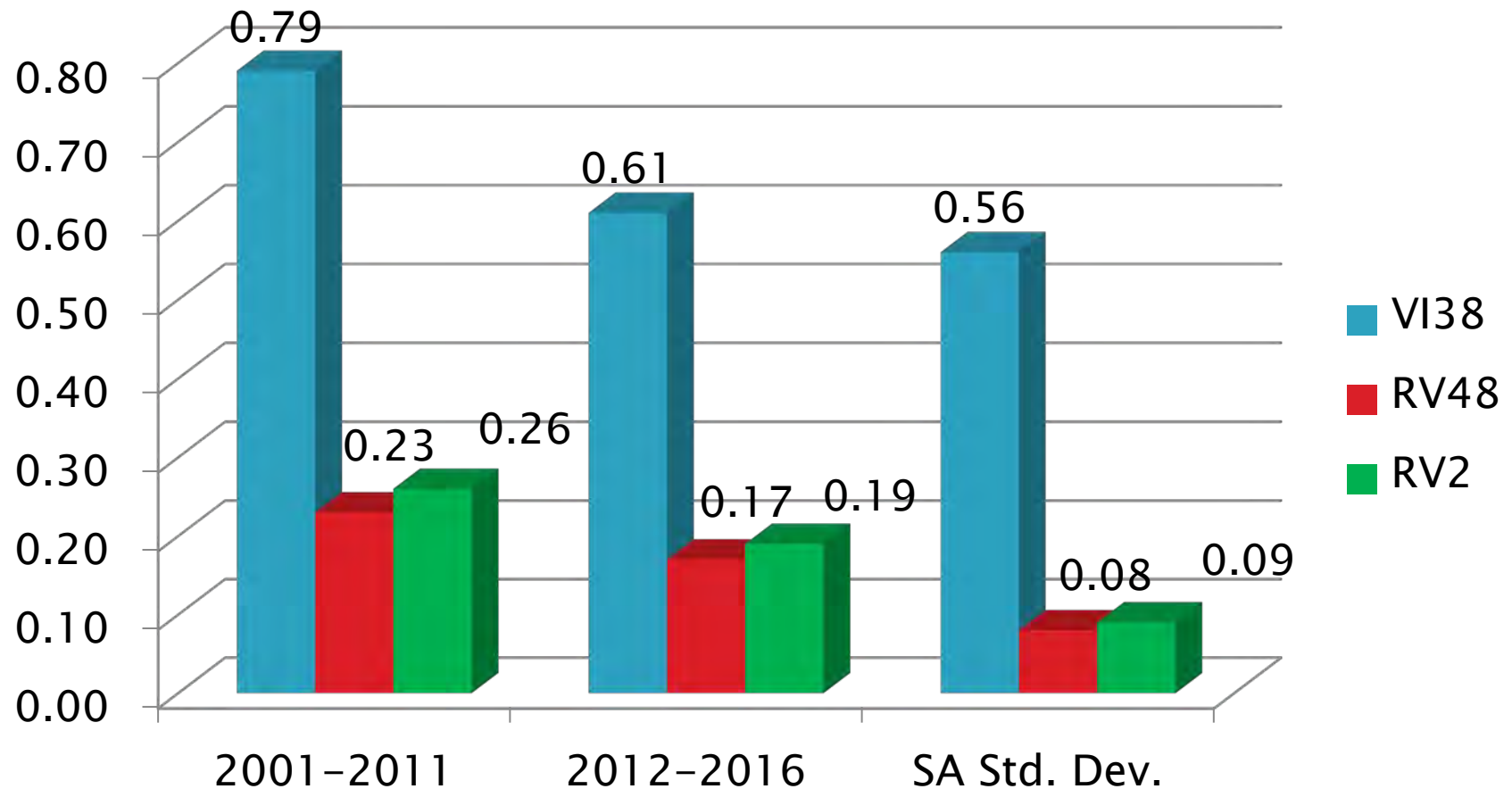
CUSUM Severity Analysis



COUNT IN COMPLETION DATE ORDER

03NOV17:14:19

T-8/E Precision Estimates



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Mack T-11

»» October 2017

Test Monitoring Center

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T-11 Test Activity

| Test Status | Validity Code | # |
|-----------------------------|---------------|----------|
| Acceptable Calibration Test | AC | 1 |
| Failed Calibration Test | OC | 2 |
| Operationally Invalid | LC | 0 |
| Aborted | XC | 0 |
| Total | | 3 |

T-11 Failed Tests

| Failed Parameter | Number of Tests |
|--|-----------------|
| Soot at 12 cSt viscosity increase severe | 2 |
| Total | 2 |

T-11 Lost Tests*

| Status | Cause | # |
|--------------|------------------|----------|
| Invalid | No invalid tests | 0 |
| Aborted | No aborted tests | 0 |
| Total | | 0 |

*Invalid and aborted tests

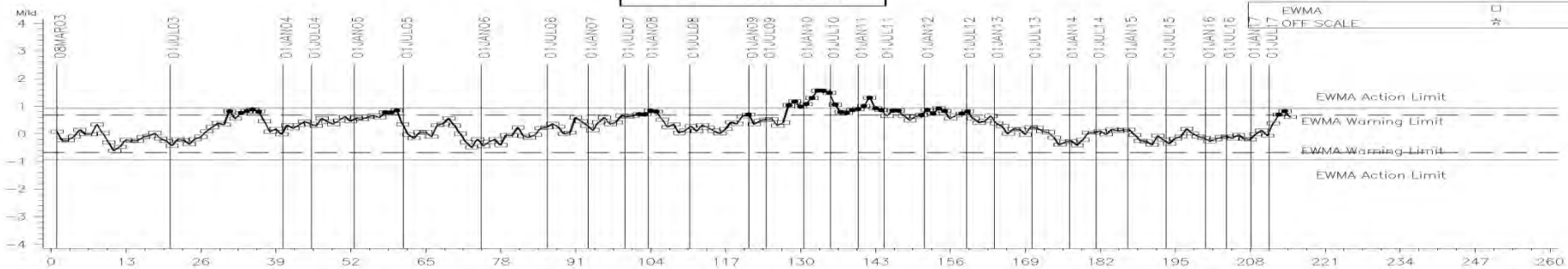
T-11 Test Severity

- ▶ SOOT and SOOT5 are in severity warning alarm in the mild direction.
- ▶ SOOT4 and MRV are in severity action alarm in the severe direction.
- ▶ MRV in precision warning alarm.

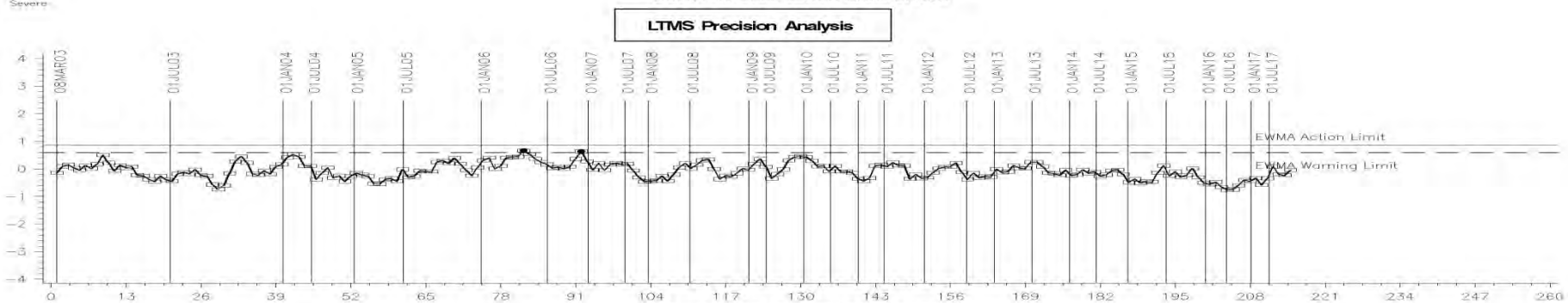
T-11 INDUSTRY OPERATIONAL VALID DATA

SOOT AT 12 cSt

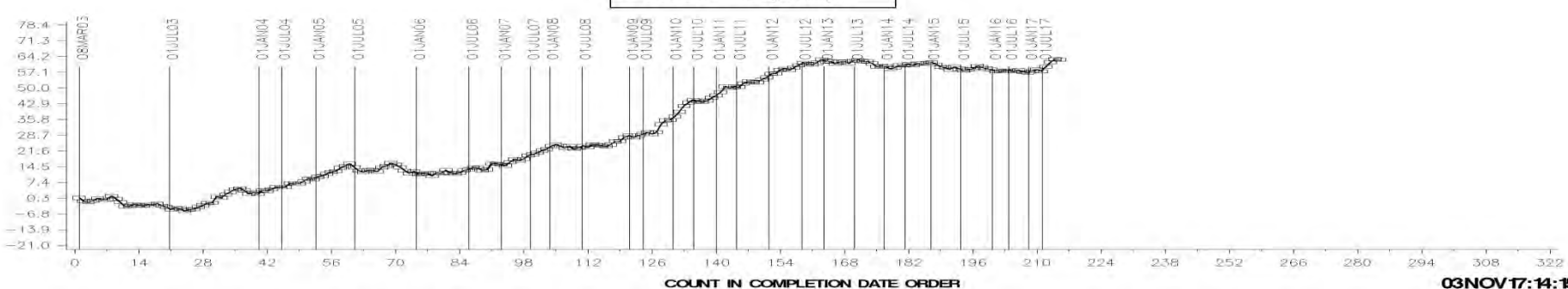
LTMS Severity Analysis



LTMS Precision Analysis



CUSUM Severity Analysis

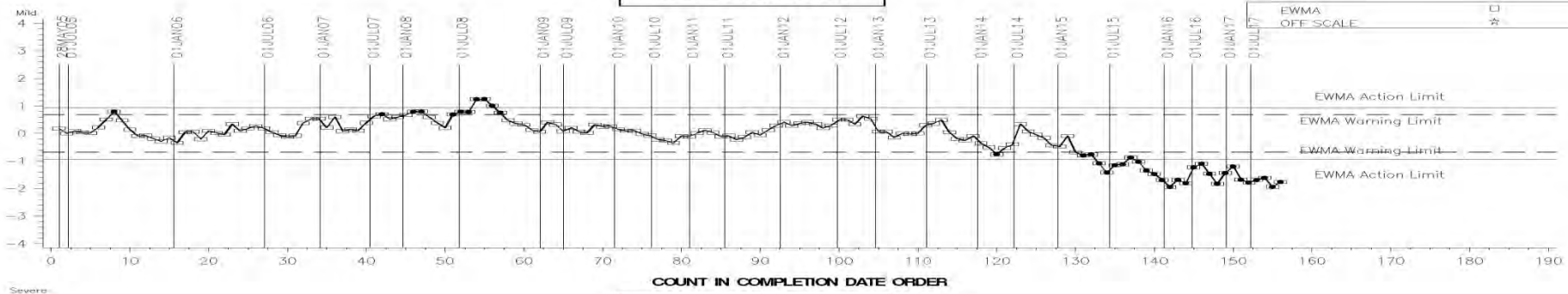


03NOV17:14:15

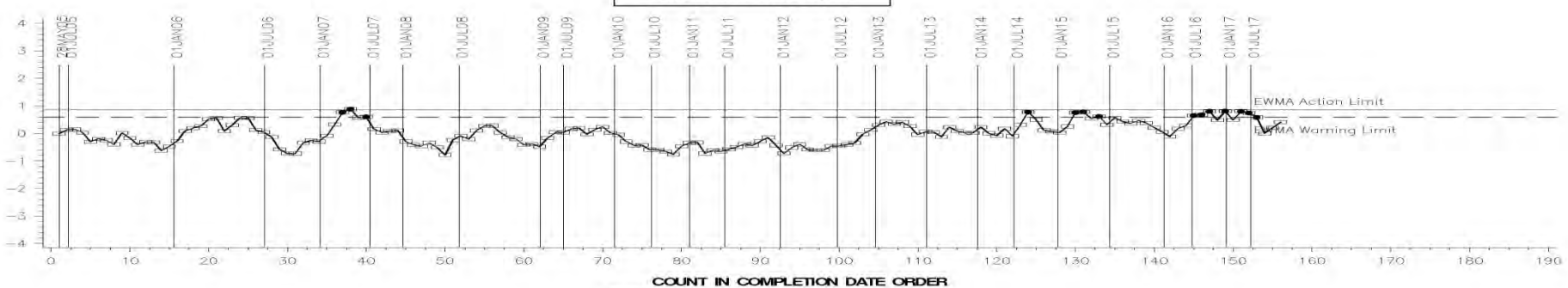
T-11 INDUSTRY OPERATIONALLY VALID DATA

SOOT @ 4 cSt - FINAL RESULT

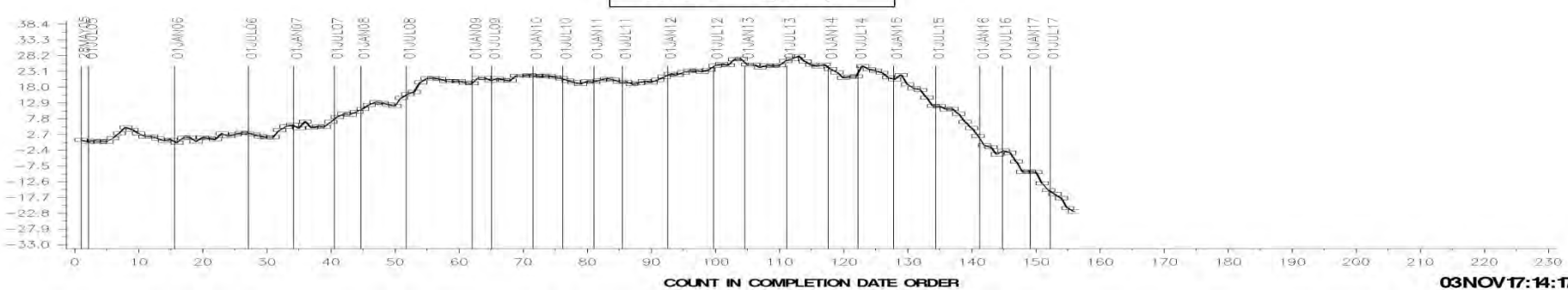
LTMS Severity Analysis



LTMS Precision Analysis



CUSUM Severity Analysis

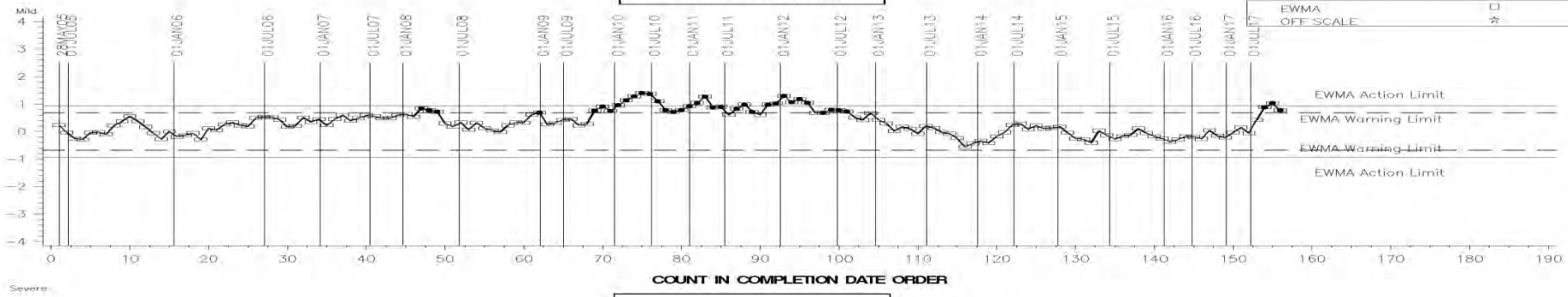


03NOV17:14:17

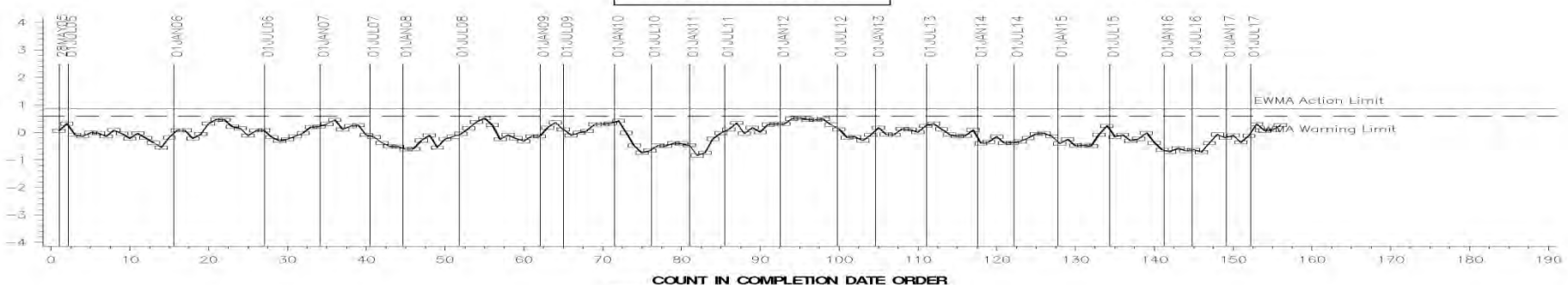
T-11 INDUSTRY OPERATIONALLY VALID DATA

SOOT @ 15 cSt — FINAL RESULT

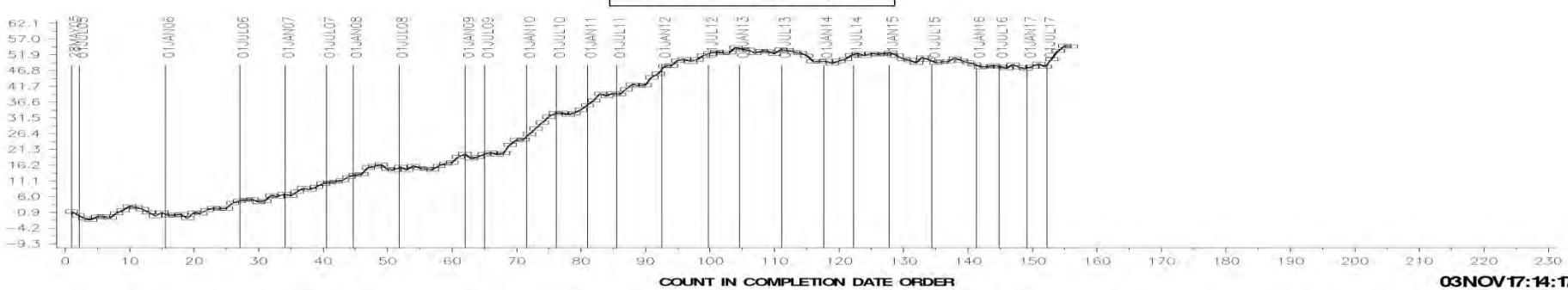
LTMS Severity Analysis



LTMS Precision Analysis



CUSUM Severity Analysis

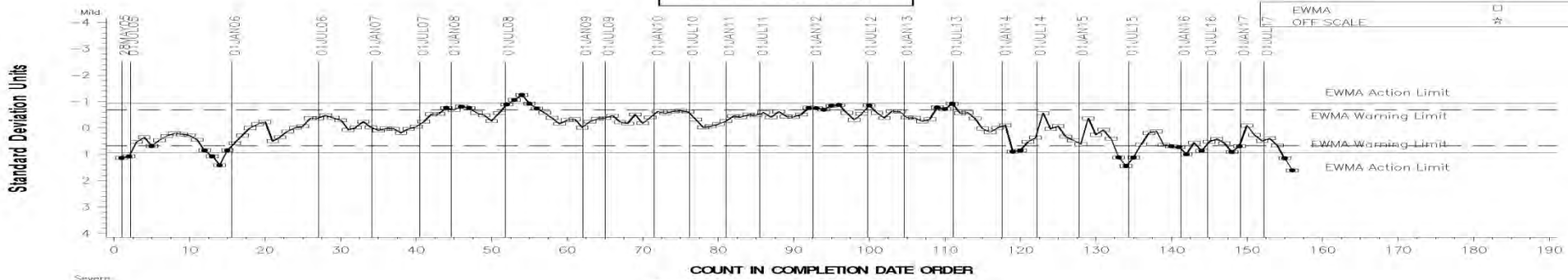


03NOV17:14:17

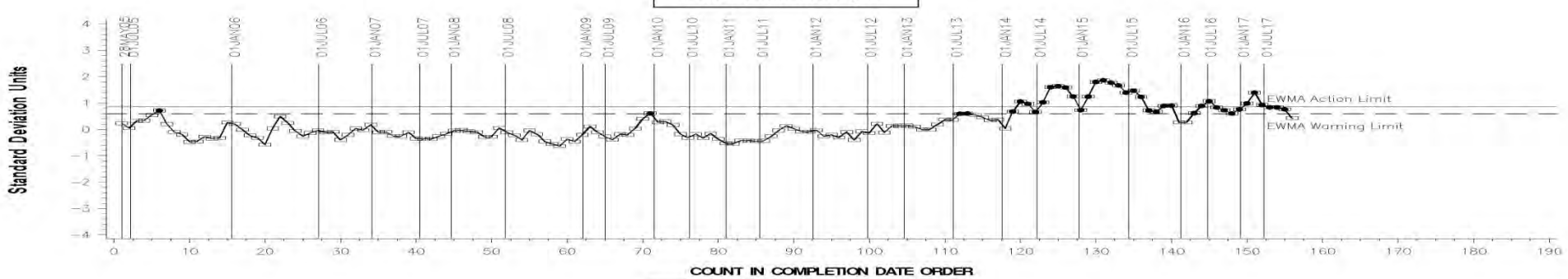
T-11 INDUSTRY OPERATIONALLY VALID DATA

MRV VISCOSITY

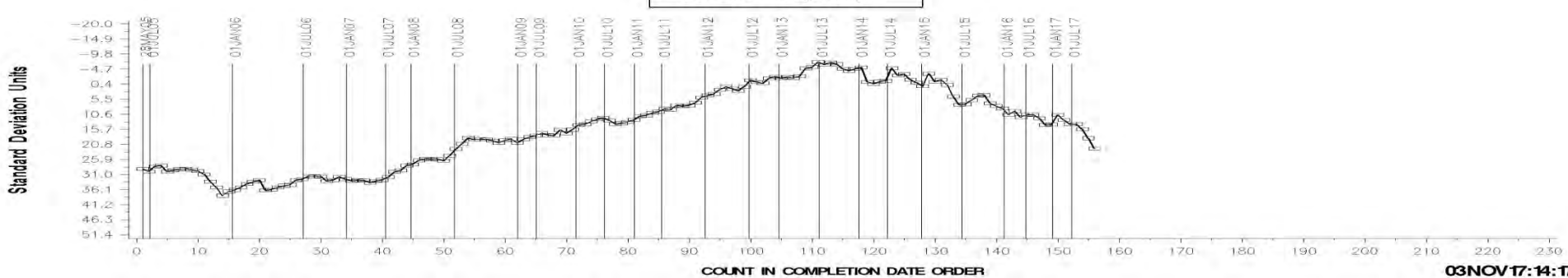
LTMS Severity Analysis



LTMS Precision Analysis

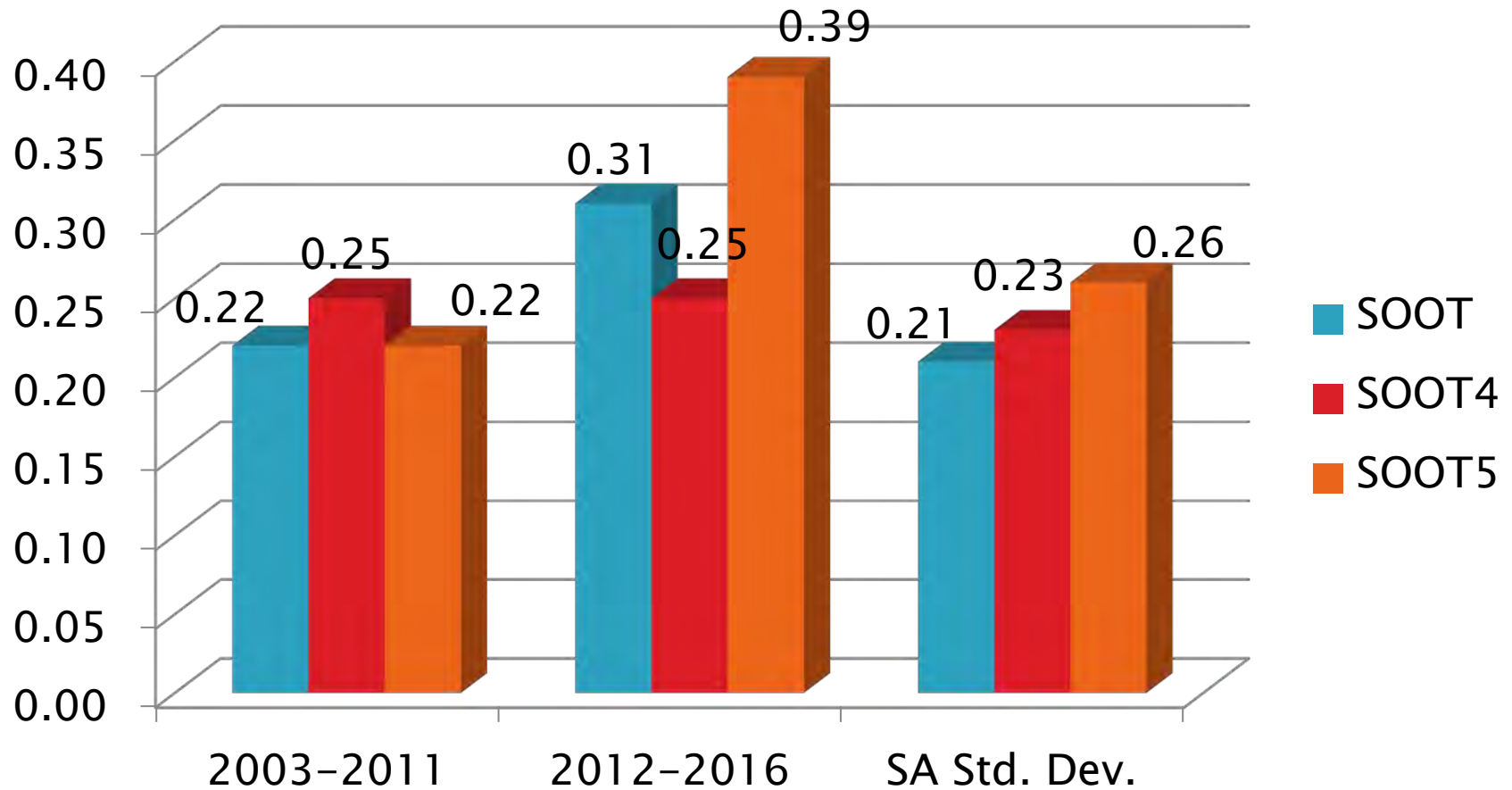


CUSUM Severity Analysis



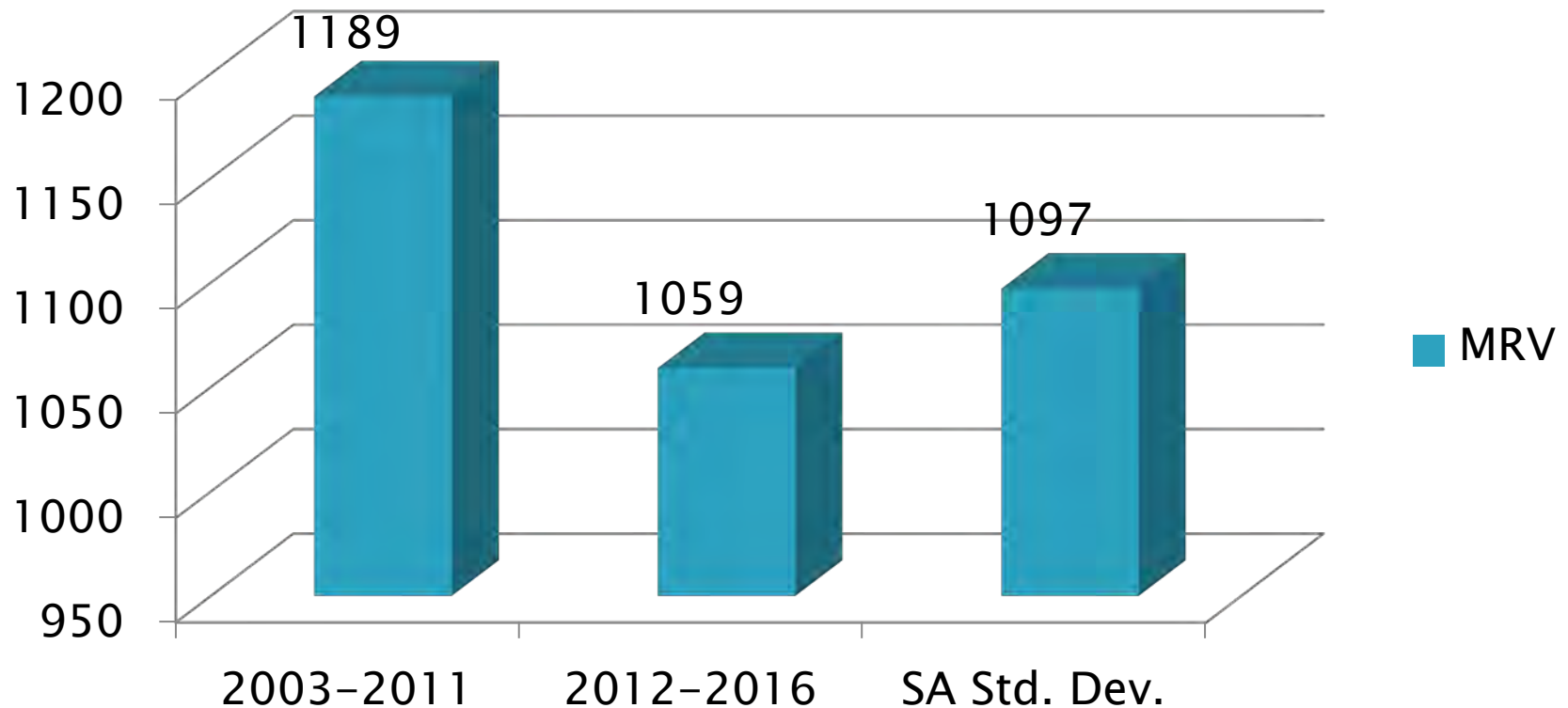
03NOV17:14:17

T-11 Precision Estimates



T-11 Precision Estimates

MRV



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T-12 Test Activity

| Test Status | Validity Code | # |
|-----------------------------|---------------|----------|
| Acceptable Calibration Test | AC | 2 |
| Failed Calibration Test | OC | 1 |
| Operationally Invalid | LC | 0 |
| Aborted | XC | 3 |
| Total | | 6 |

T-12 Failed Tests

| Failed Parameter | Number of Tests |
|-------------------|-----------------|
| Pb and Pb2 severe | 1 |
| Total | 1 |

T-12 Lost Tests*

| Status | Cause | # |
|--------------|---|----------|
| Invalid | No invalid tests | 0 |
| Aborted | Terminated at 126 hours due to excess iron in oil | 1 |
| Aborted | Terminated at 53 hours due to loss of oil charge | 1 |
| Aborted | Rod failure during break-in | 1 |
| Total | | 3 |

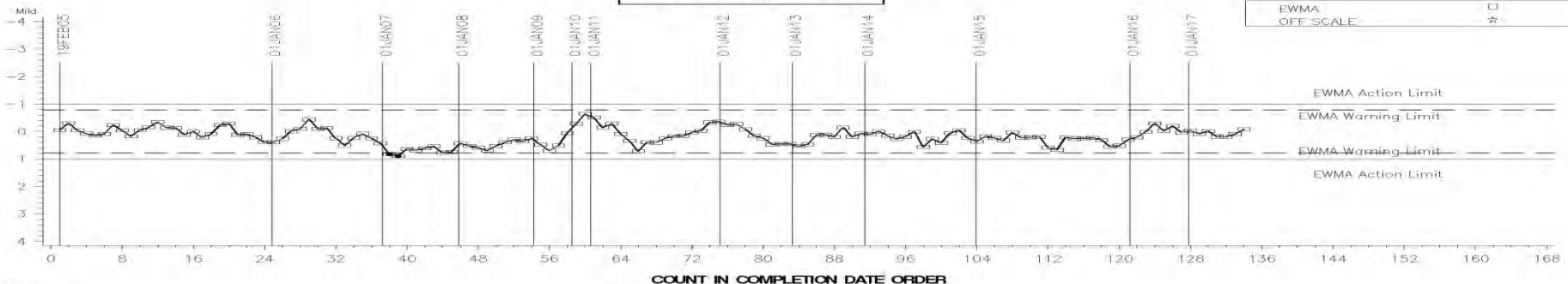
*Invalid and aborted tests

T-12 Test Severity

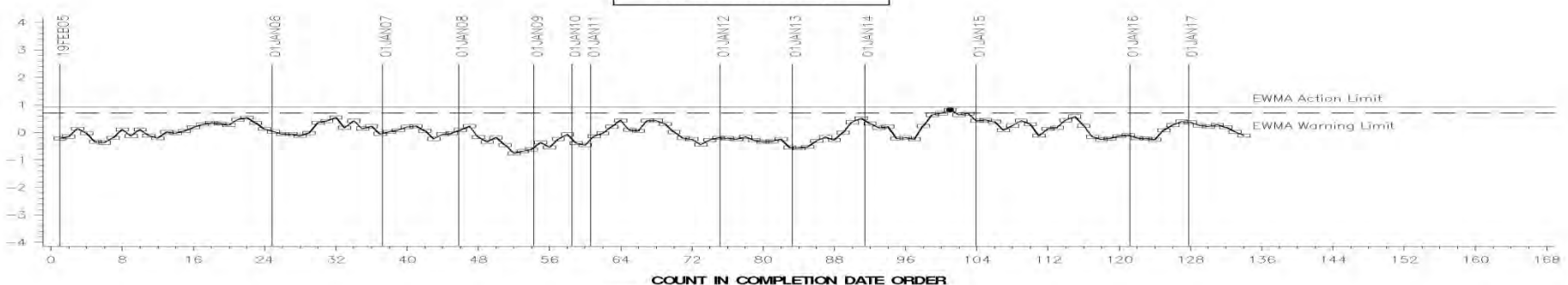
- ▶ All parameters are in control

AVG. CYLINDER LINER WEAR (CLW)

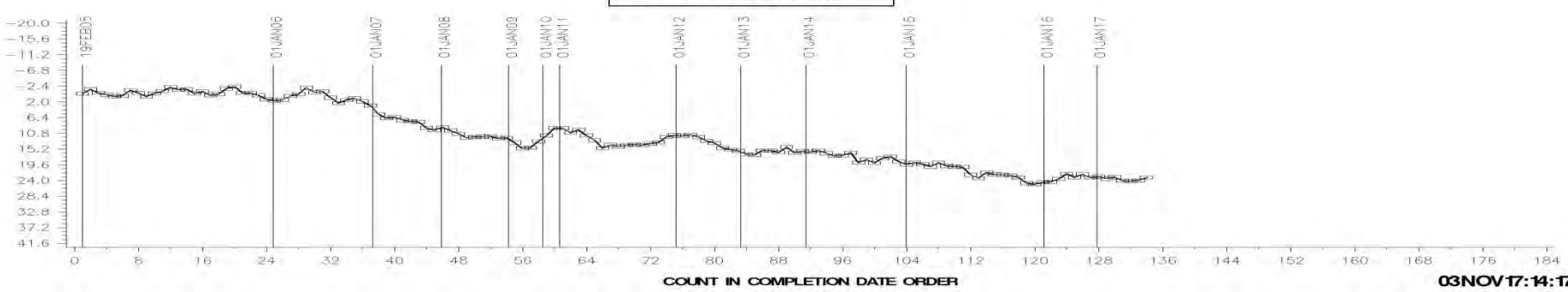
LTMS Severity Analysis



LTMS Precision Analysis



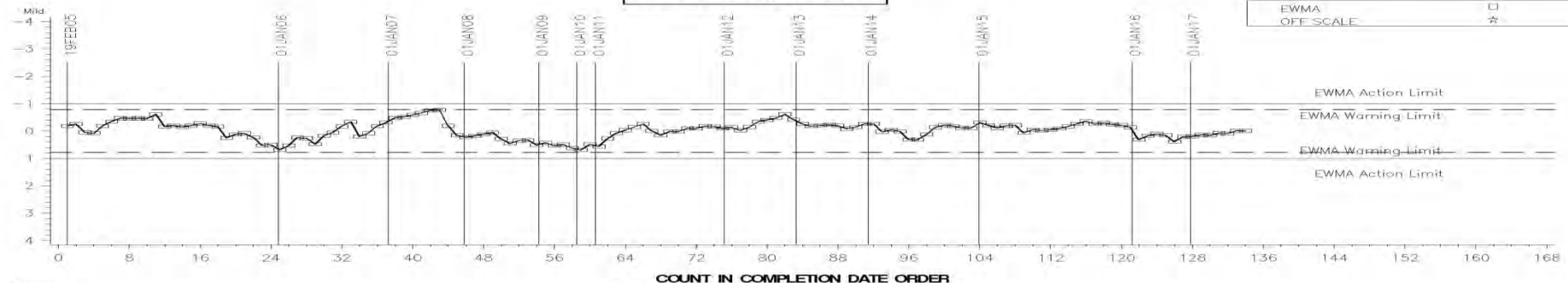
CUSUM Severity Analysis



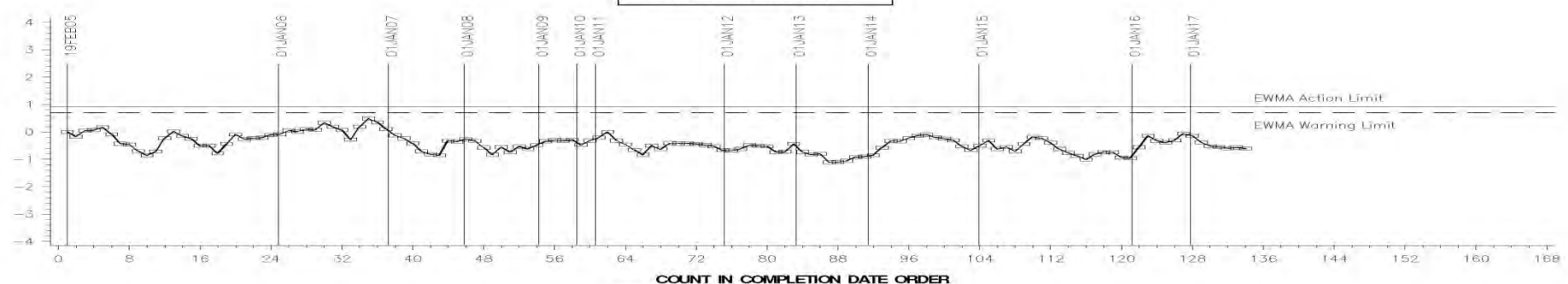
03NOV17:14:17

AVG. TOP RING WEIGHT LOSS (TRWL)

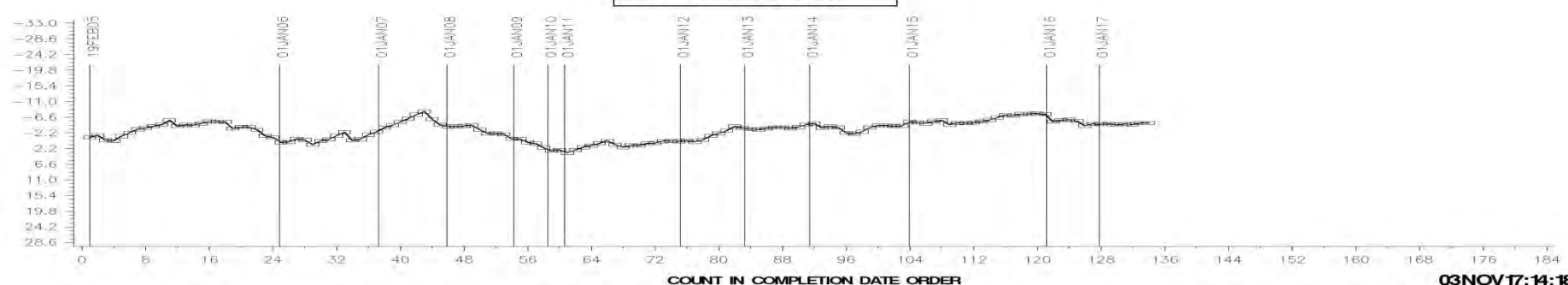
LTMS Severity Analysis



LTMS Precision Analysis



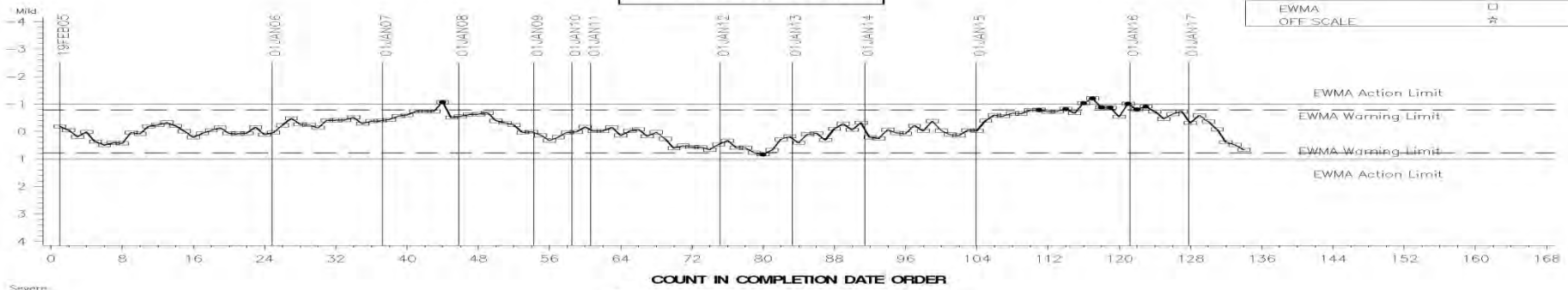
CUSUM Severity Analysis



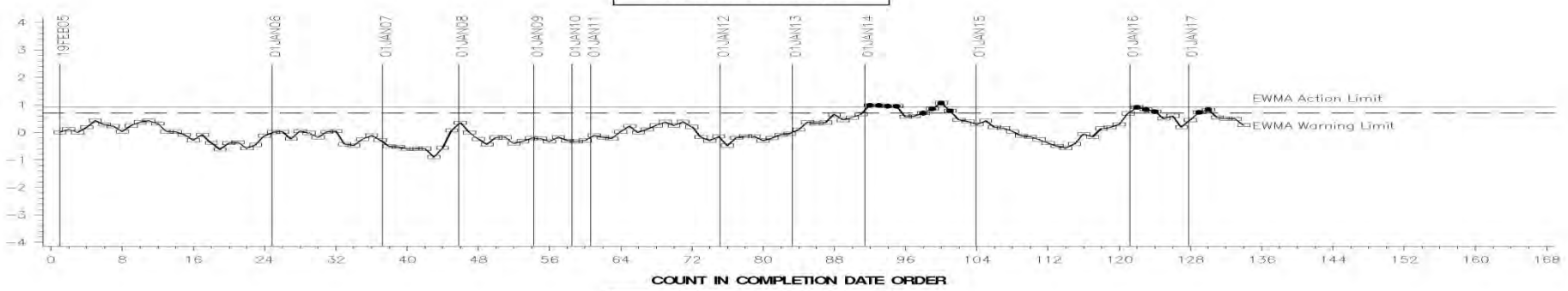
03NOV17:14:18

FINAL TRANS. RES. DELTA PB @ EOT

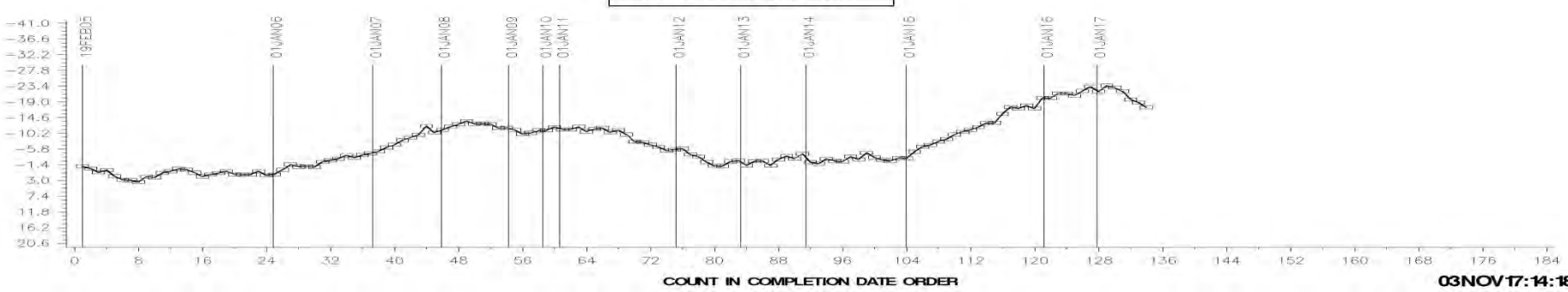
LTMS Severity Analysis



LTMS Precision Analysis



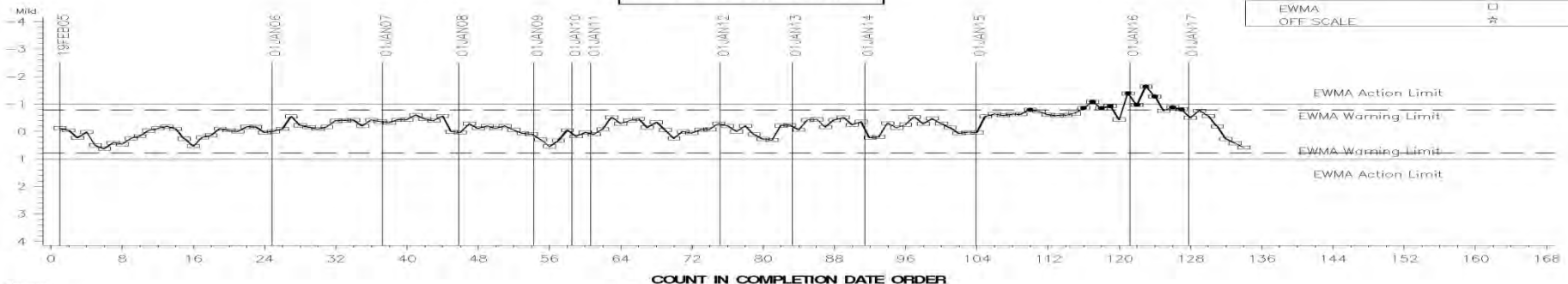
CUSUM Severity Analysis



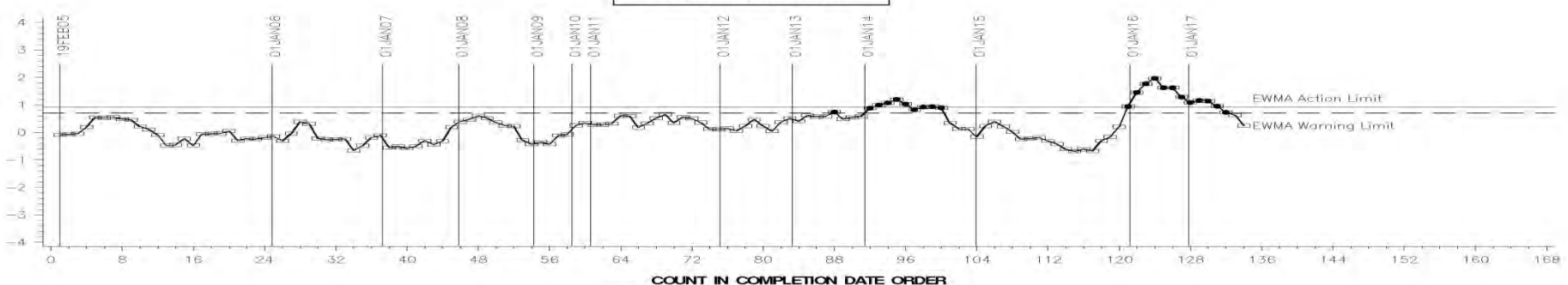
03NOV17:14:18

FINAL TRANS. RES. DELTA PB 250-300H

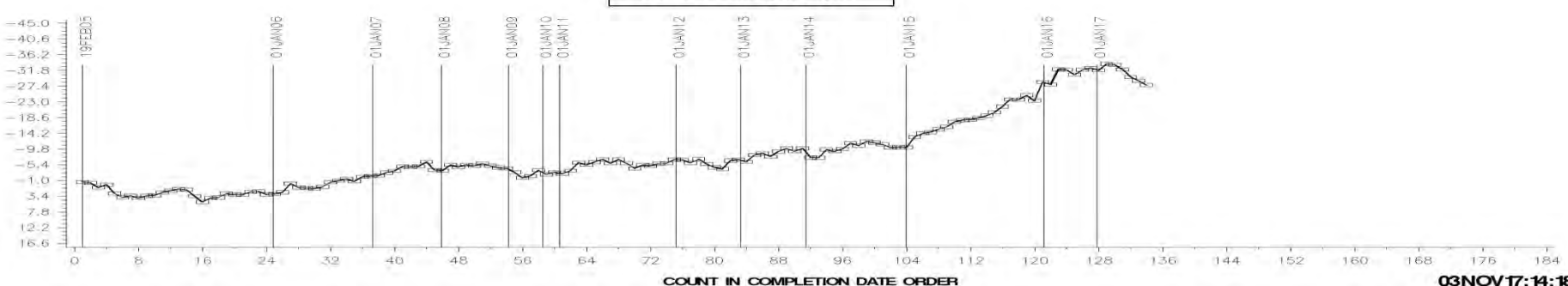
LTMS Severity Analysis



LTMS Precision Analysis



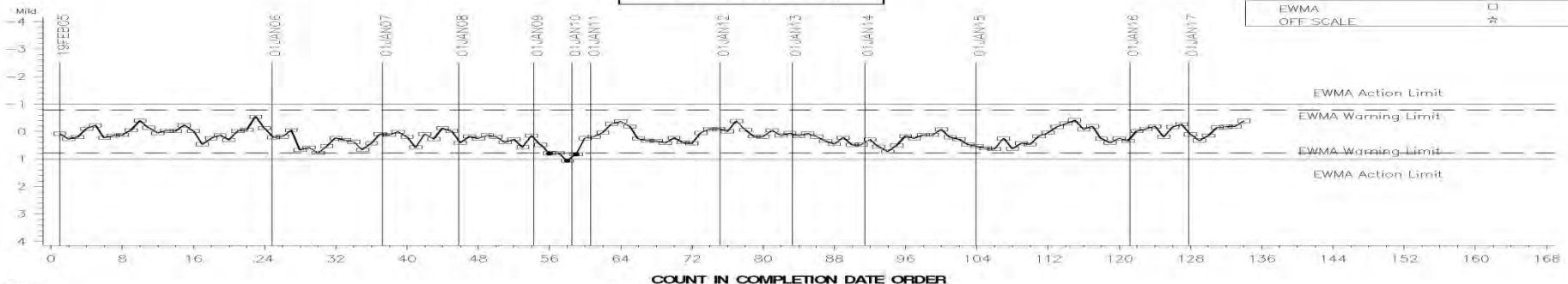
CUSUM Severity Analysis



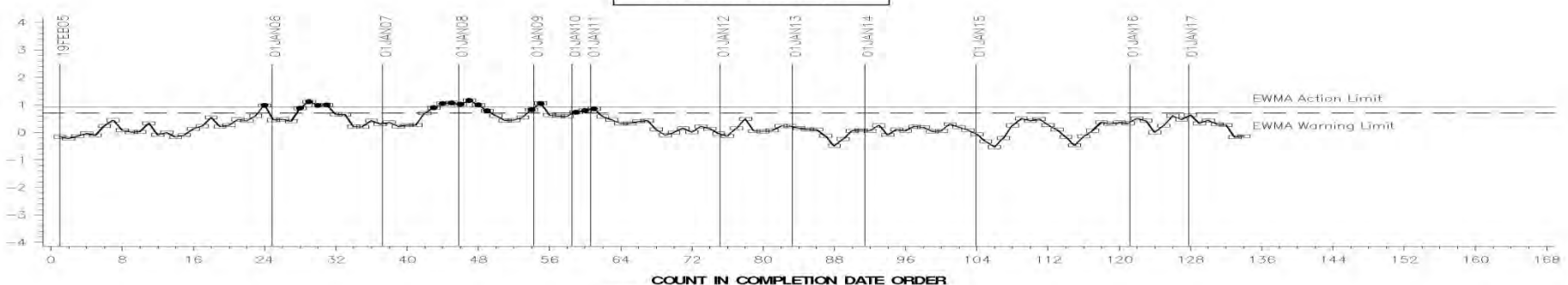
03NOV17:14:18

FINAL TRANS. RES. OIL CONSUMPTION

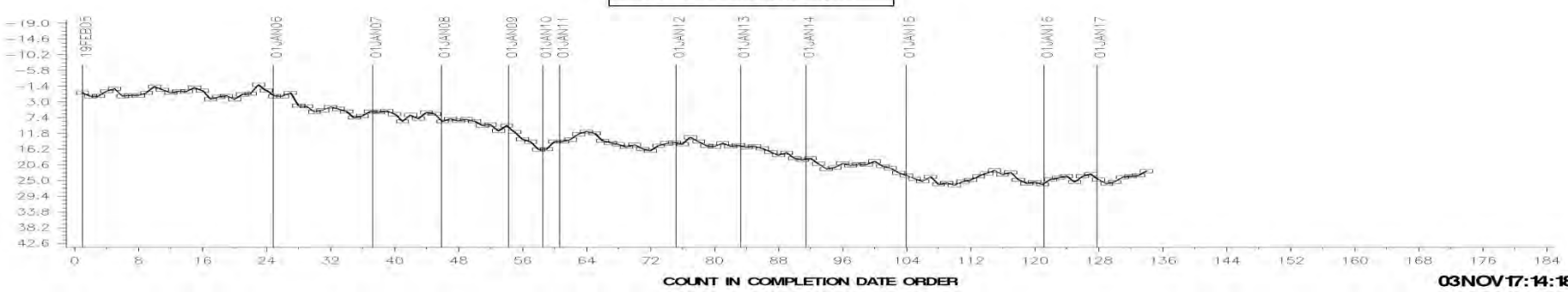
LTMS Severity Analysis



LTMS Precision Analysis

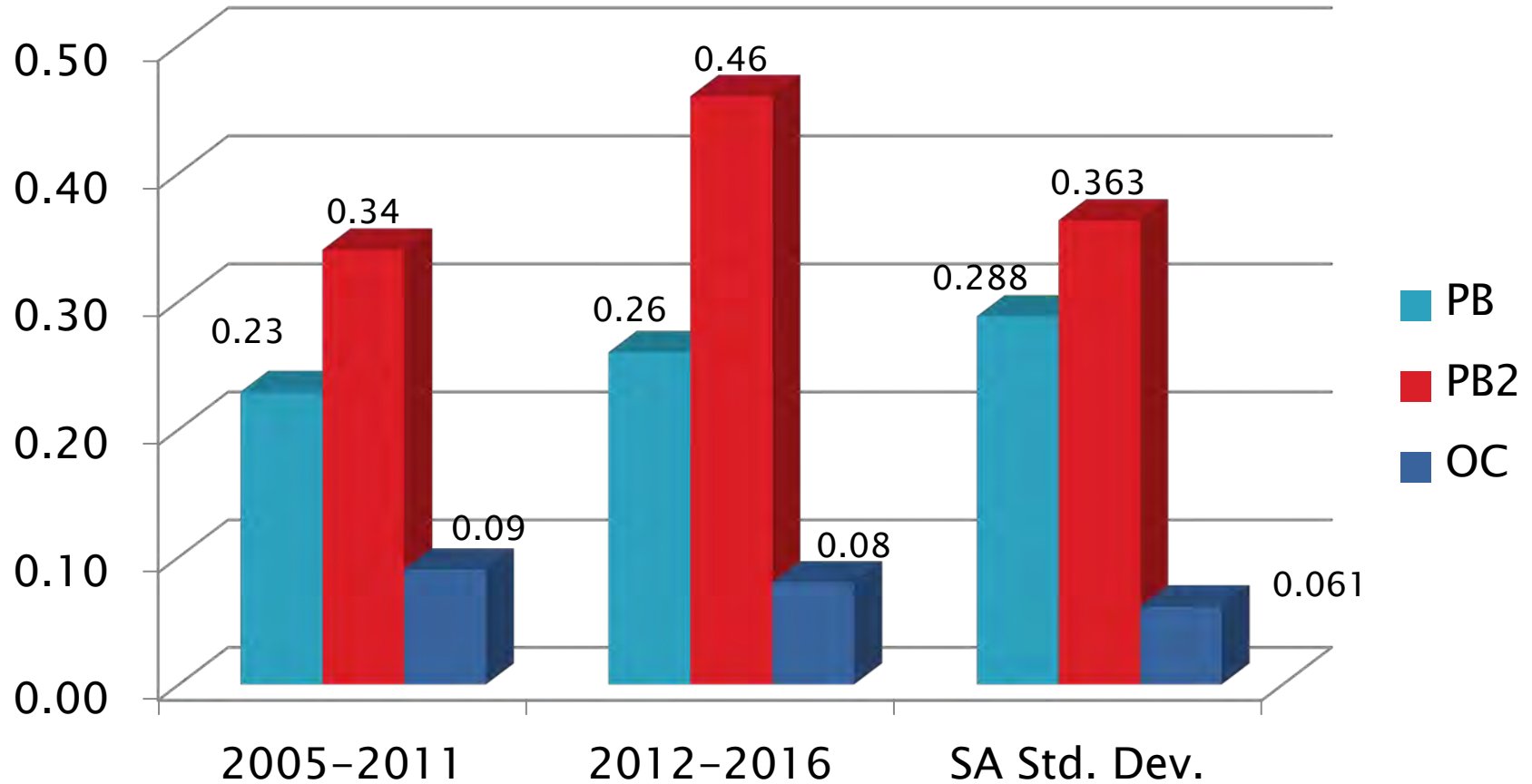


CUSUM Severity Analysis

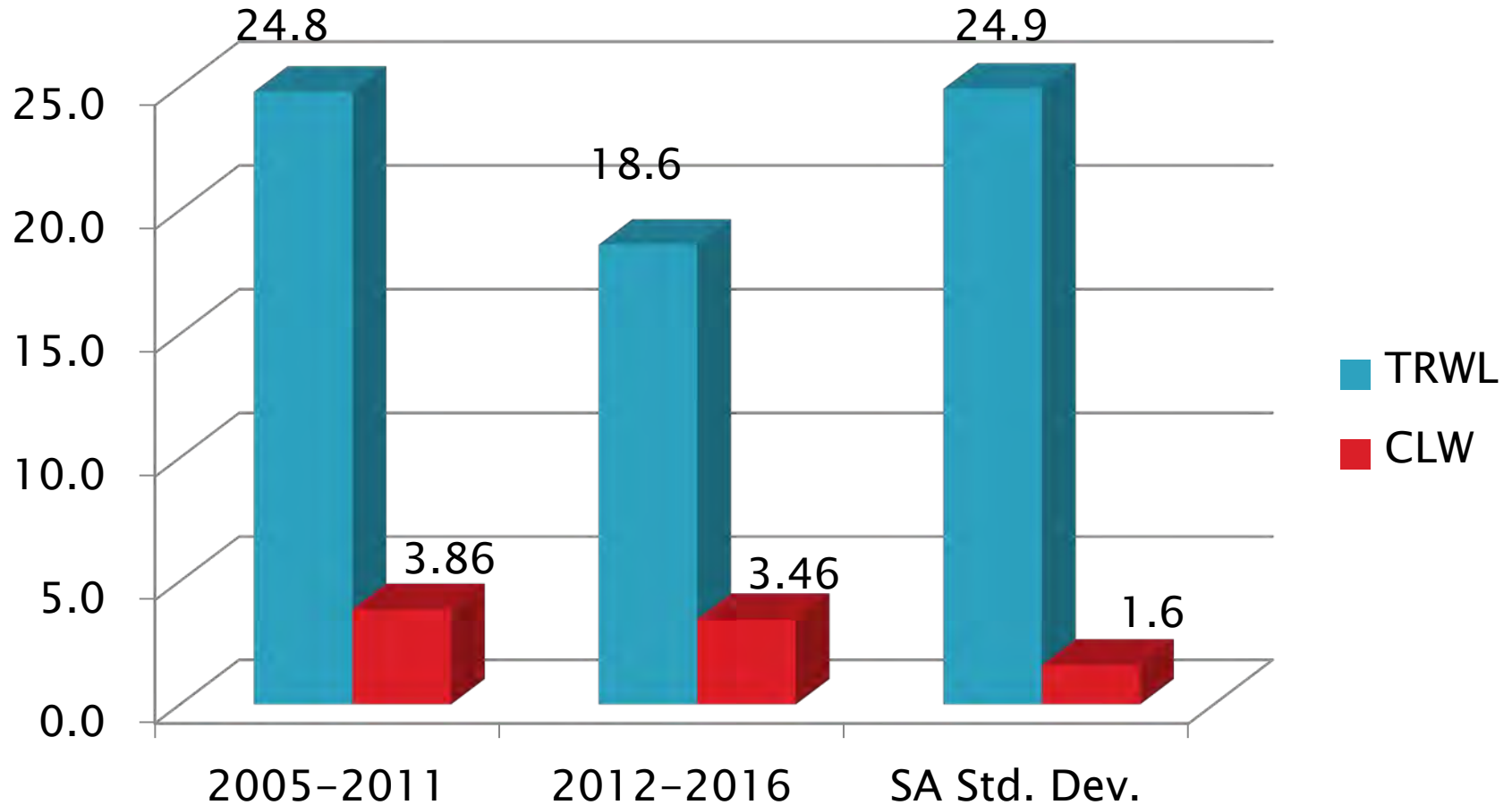


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T-12 Precision Estimates



T-12 Precision Estimates



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Mack T-12A

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T-12A Test Activity

| Test Status | Validity Code | # |
|-----------------------------|---------------|----------|
| Acceptable Calibration Test | AC | 3 |
| Failed Calibration Test | OC | 0 |
| Operationally Invalid | LC | 0 |
| Aborted | XC | 3 |
| Total | | 3 |

T-12A Failed Tests

| Failed Parameter | Number of Tests |
|------------------|-----------------|
| No failed tests | 0 |
| Total | 0 |

T-12A Lost Tests*

| Status | Cause | # |
|--------------|---|----------|
| Invalid | No invalid tests | 0 |
| Aborted | Terminated at 126 hours due to excess iron in oil | 1 |
| Aborted | Terminated at 53 hours due to loss of oil charge | 1 |
| Aborted | Rod failure during break-in | 1 |
| Total | | 3 |

*Invalid and aborted tests

T-12A Test Severity

- ▶ MRV is severity action alarm in the severe direction.
- ▶ MRV is in precision action alarm.

MACK T-12A INDUSTRY OPERATIONAL VALID DATA



FINAL ORIGINAL UNIT MRV VISCOSITY [NM, SOLID, FROZEN, <, >]

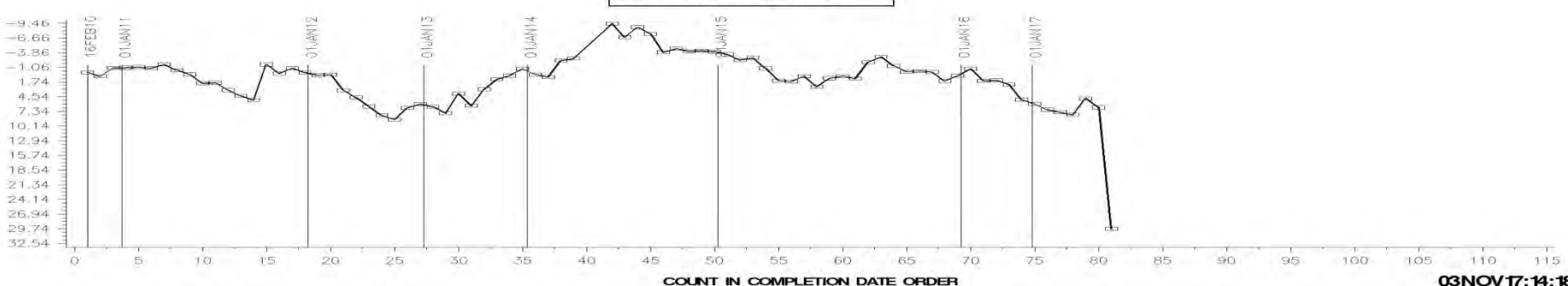
LTMS Severity Analysis



LTMS Precision Analysis



CUSUM Severity Analysis

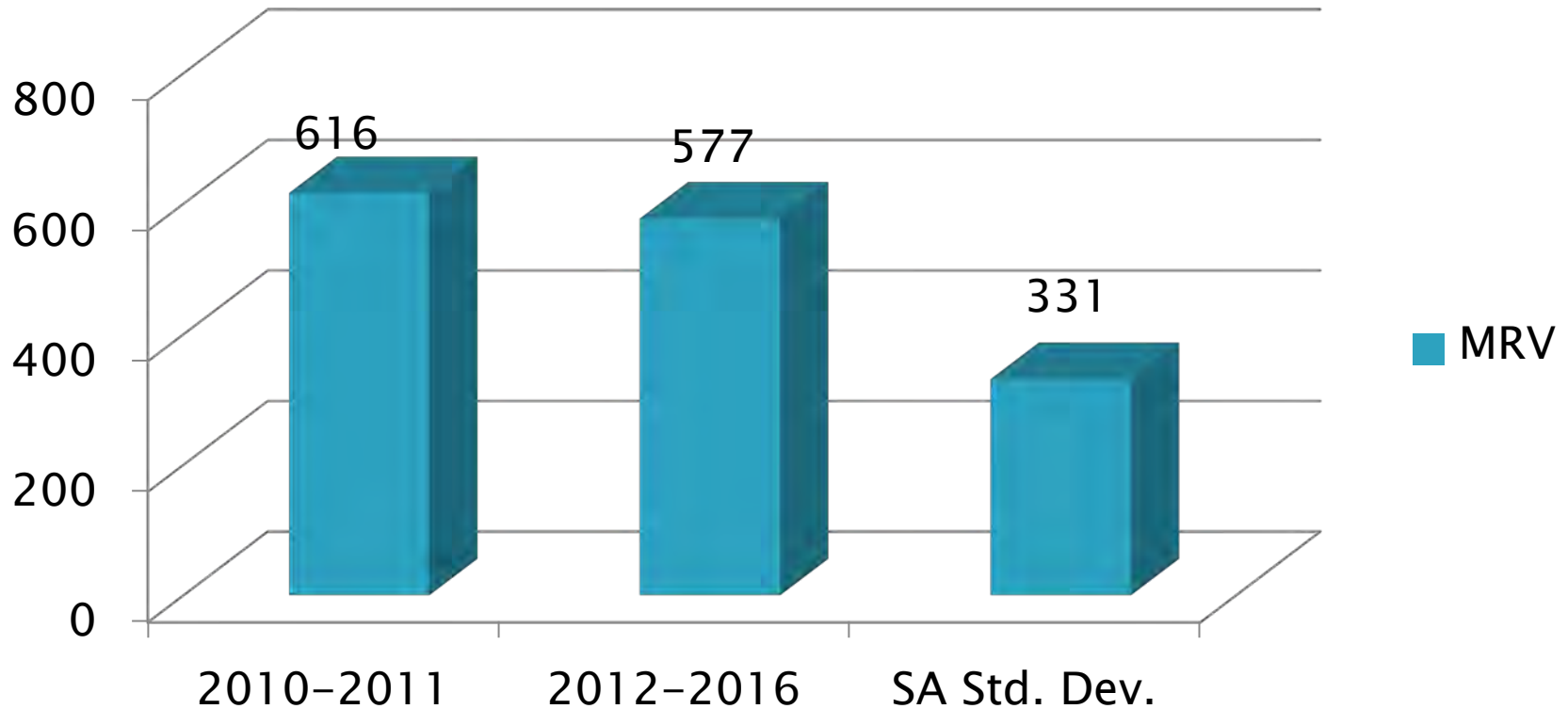


03NOV17:14:18



T-12A Precision Estimates

MRV



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Mack T-13

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T-13 Test Activity

| Test Status | Validity Code | # |
|-----------------------------|---------------|----------|
| Acceptable Calibration Test | AC | 5 |
| Failed Calibration Test | OC | 0 |
| Operationally Invalid | LC | 0 |
| Aborted | XC | 0 |
| Total | | 5 |

T-13 Failed Tests

| Failed Parameter | Number of Tests |
|------------------|-----------------|
| No failed tests | 0 |
| Total | 0 |

T-13 Lost Tests*

| Status | Cause | # |
|--------------|------------------|----------|
| Invalid | No invalid tests | 0 |
| Aborted | No aborted tests | 0 |
| Total | | 0 |

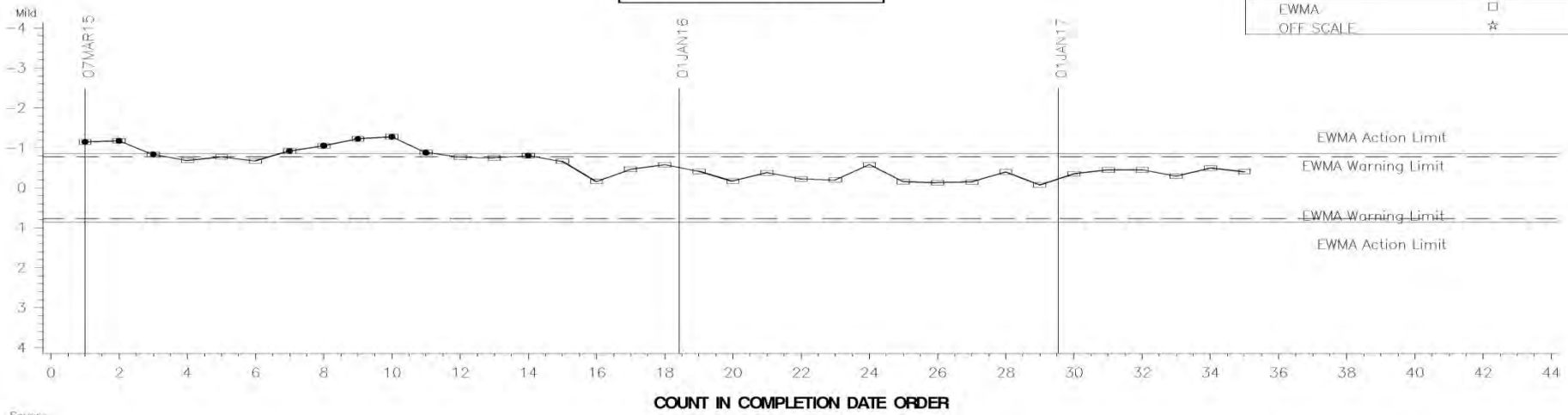
*Invalid and aborted tests

T-13 Test Severity

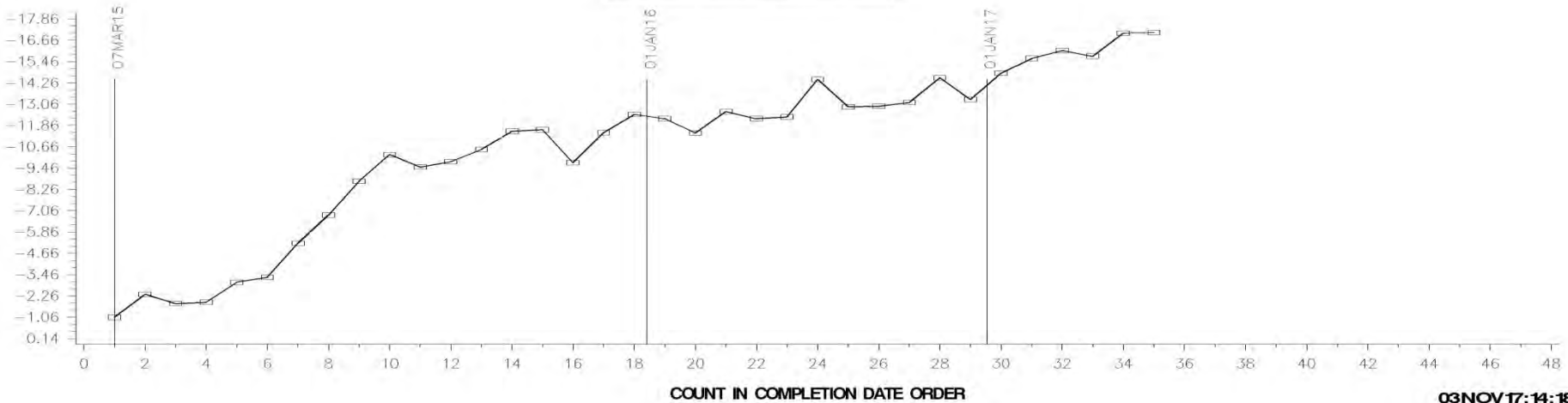
- ▶ IRPH is in control.
- ▶ KV40PC in Level 2 Zi alarm in the mild direction.

FINAL ORIGINAL PEAK HEIGHT IR AT EOT

LTMS Severity Analysis



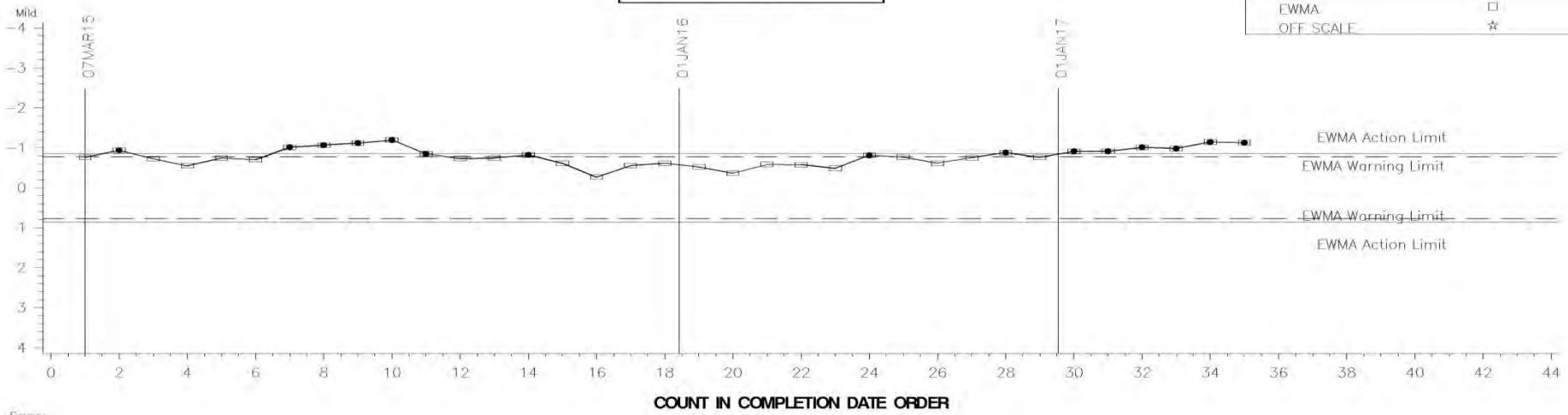
CUSUM Severity Analysis



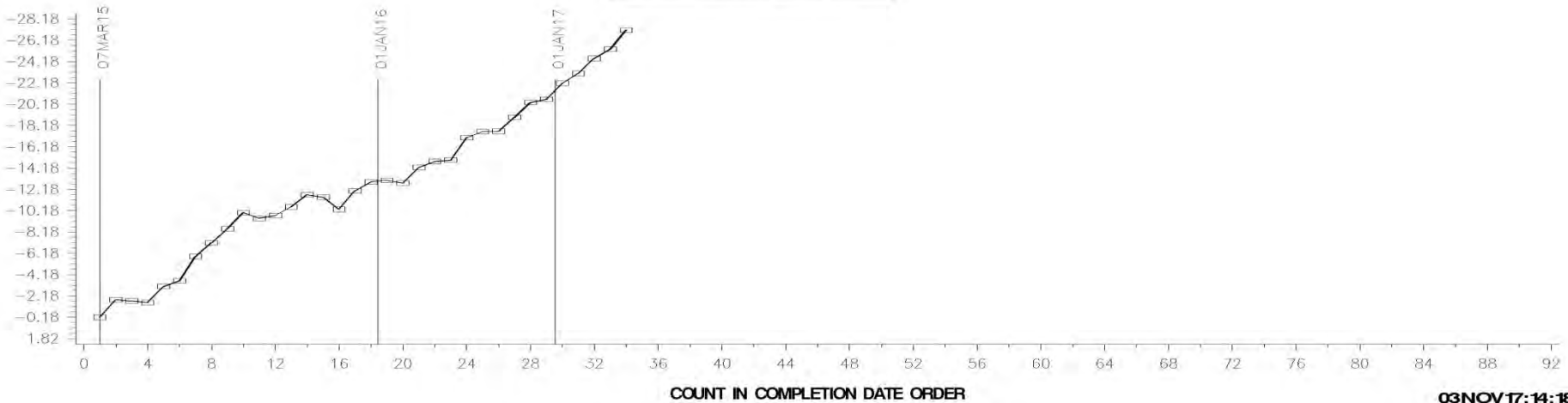
03NOV17:14:18

FNL. ORIG. UNIT KINEMATIC VISCOSITY AT 40 DEG C % CHANGE 300-360 HRS

LTMS Severity Analysis

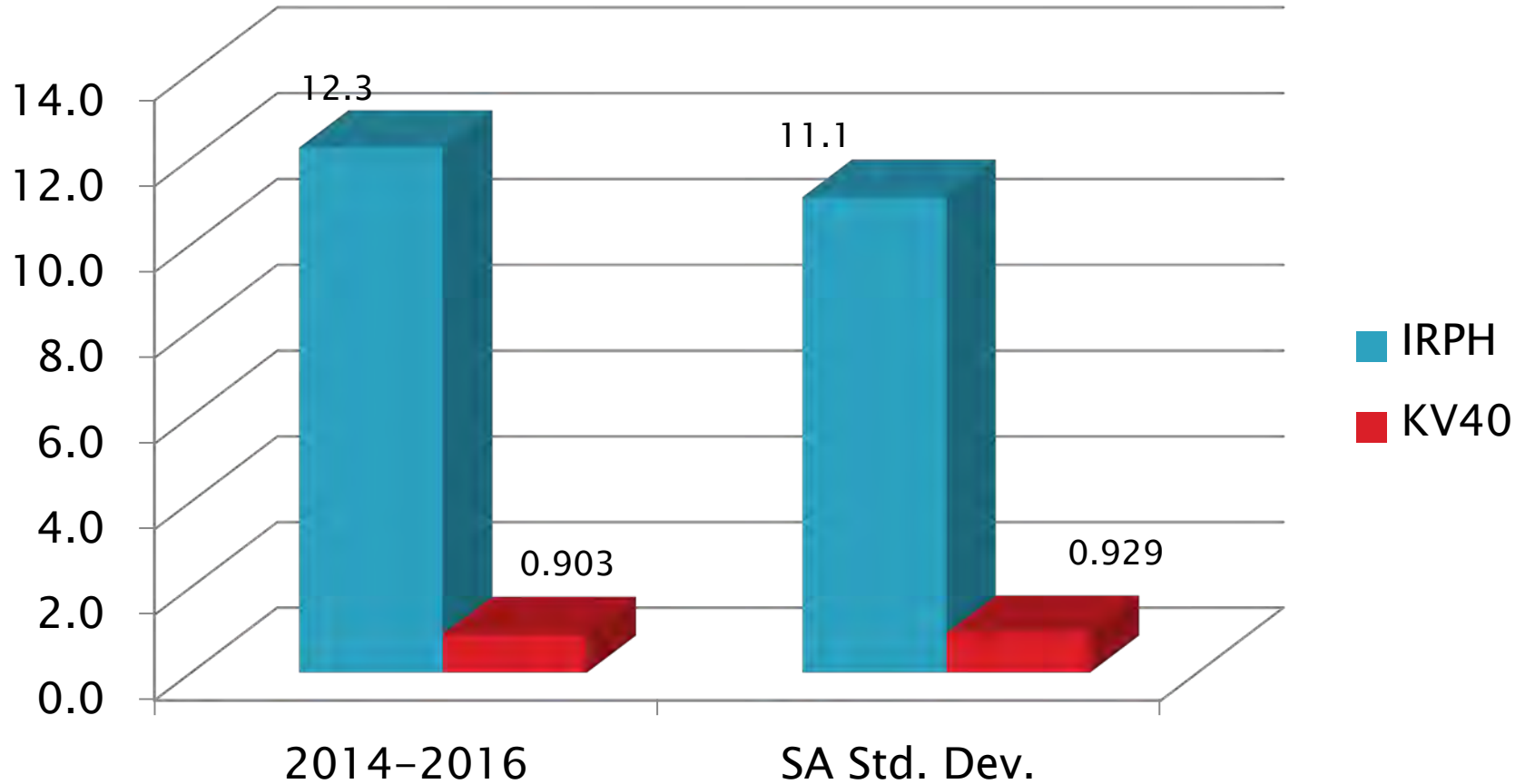


CUSUM Severity Analysis



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T-13 Precision Estimates



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Information Letters

»» April 1, 2017 –

September 30, 2017

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Information Letters*

| Test | Date | IL | Topic |
|------|-----------|------|--|
| COAT | 4/14/2017 | 17-1 | COAT Test Numbering Change |
| DD13 | 6/13/2017 | 17-1 | DD13 General Procedure Revisions |
| 1K1N | 9/27/2017 | 17-1 | Changes to 1K/1N Part Number Reporting |

*Available from TMC Website

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Reference Oil Inventory

»» Actions, Re-blends, Inventories
and Estimated Life

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Reference Oil Reblends

- ▶ Re-blend of 833-1 complete
 - 833-1 has been received at TMC and QA is in process.
- ▶ Re-blend of 832 requested from supplier

Reference Oil Inventory Estimated Life

| Oil | Tests | Original Blend Amount | Quantity Shipped in last 6 months | TMC Inventory | Lab Inventory | Estimated Life |
|-------|----------|-----------------------|-----------------------------------|---------------|---------------|----------------|
| 809-1 | 1K, 1N | 9134 | 65 | 2133 | 136 | 5+ years |
| 811-2 | 1K, 1N | 1732 | 50 | 908 | 70 | 5+ years |
| 821-4 | T-12 | 4495 | 175 | 2726 | 250 | 5+ years |
| 822-2 | 1R, T-11 | 4386 | 224 | 2955 | 224 | 5+ years |
| 823 | T-13 | 1796 | 180 | 1008 | 200 | 5 years |
| 830-2 | ISM | 3786 | 25 | 140 | 225 | 1.5 years |
| 830-3 | ISM | 2891 | 0 | 2891 | 0 | 5+ years |
| 831-3 | C13, ISB | 972 | 40 | 106 | 280 | 1 year |
| 831-4 | C13, ISB | 1699 | 160 | 1699 | 0 | 5+ years |

Reference Oil Inventory Estimated Life

| Oil | Tests | Original Blend Amount | Quantity Shipped in last 6 months | TMC Inventory | Lab Inventory | Estimated Life |
|--------|---------------------------|-----------------------|-----------------------------------|---------------|---------------|----------------|
| 832 | COAT | 1166 | 168 | 515 | 140 | 1.5 years |
| 833 | COAT | 1152 | 280 | 383 | 168 | 1 year |
| 864 | DD13 | 121 | 0 | 21 | 0 | 0.1 years |
| 864-1 | DD13 | 1576 | 0 | 1324 | 175 | 5+ years |
| 866 | DD13 | 341 | 0 | 266 | 25 | 3 years |
| 873-2 | 1M-PC | 1650 | 0 | 57 | 40 | 2.5 years |
| 1005-4 | 1P, 1R, EOAT, RFWT, T-8/E | 2000 | 0 | 74 | 30 | < 0.5 years |
| 1005-5 | 1P, 1R, EOAT, RFWT, T-8/E | 3826 | 349 | 2908 | 204 | 3 years |

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LTMS Deviations

»» April 1, 2017 – September 30,
2017

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LTMS Deviations

- No LTMS Deviations in Current Period

Historical Count of HD LTMS Deviations

| Test | LTMS Deviations |
|-------|-----------------|
| 1M-PC | 2 |
| 1N | 2 |
| T-8/E | 2 |
| T-10A | 1 |
| T-12 | 1 |

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Quality Index Deviations

»» April 1, 2017 –

September 30, 2017

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Quality Index Deviations

- ▶ One quality index deviation this period
 - COAT-Oil gallery temperature

Quality Index Deviations

Historical Count of HD Quality Index Deviations

| Test | Qi Deviations |
|-------|---------------|
| 1P | 14 |
| 1R | 1 |
| ISM | 3 |
| C13 | 2 |
| T-10A | 1 |
| T-11 | 3 |
| T-12 | 6 |
| T-13 | 1 |
| COAT | 4 |

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TMC Laboratory Visits

»» April 1, 2017 –

September 30, 2017

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TMC Lab Visits

- ▶ No Heavy-Duty lab visits were conducted during this period

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Test Area Timelines

»» April 1, 2017 –
September 30, 2017

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Test Area Timeline Additions*

| Test | Date | IL/Memo | Topic |
|------|-----------|---------|--|
| COAT | 4/14/2017 | 17-1 | COAT Test Numbering Change |
| COAT | 5/31/2017 | N/A | COAT Reference Testing Resumed |
| DD13 | 6/13/2017 | 17-1 | DD13 General Procedure Revisions |
| 1K1N | 9/27/2017 | 17-1 | Changes to 1K/1N Part Number Reporting |

*As of 3/31/2017

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Rating Workshop Data

»» 2017 Heavy Duty Workshop

Test Monitoring Center

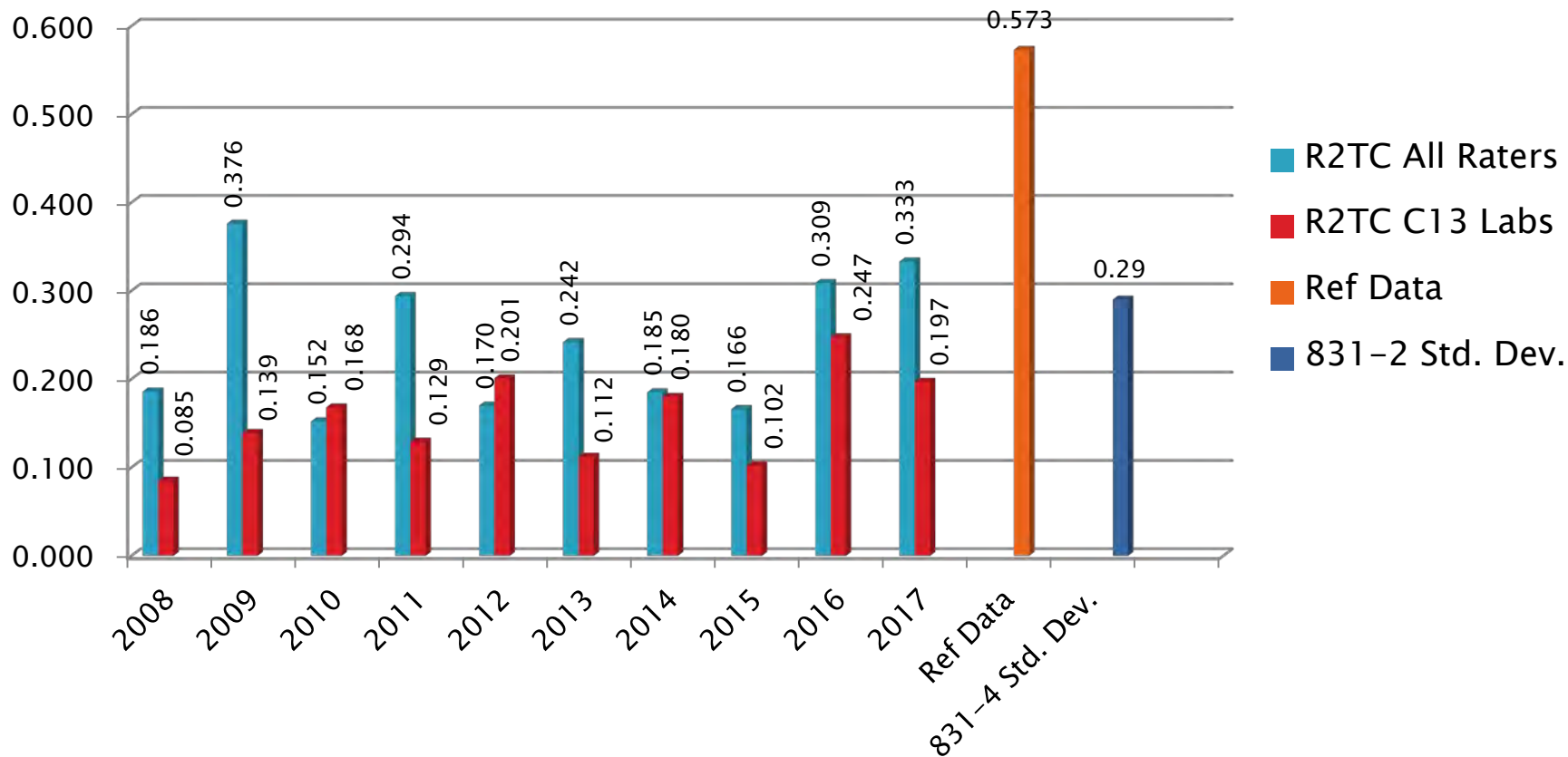
<http://astmtmc.cmu.edu>



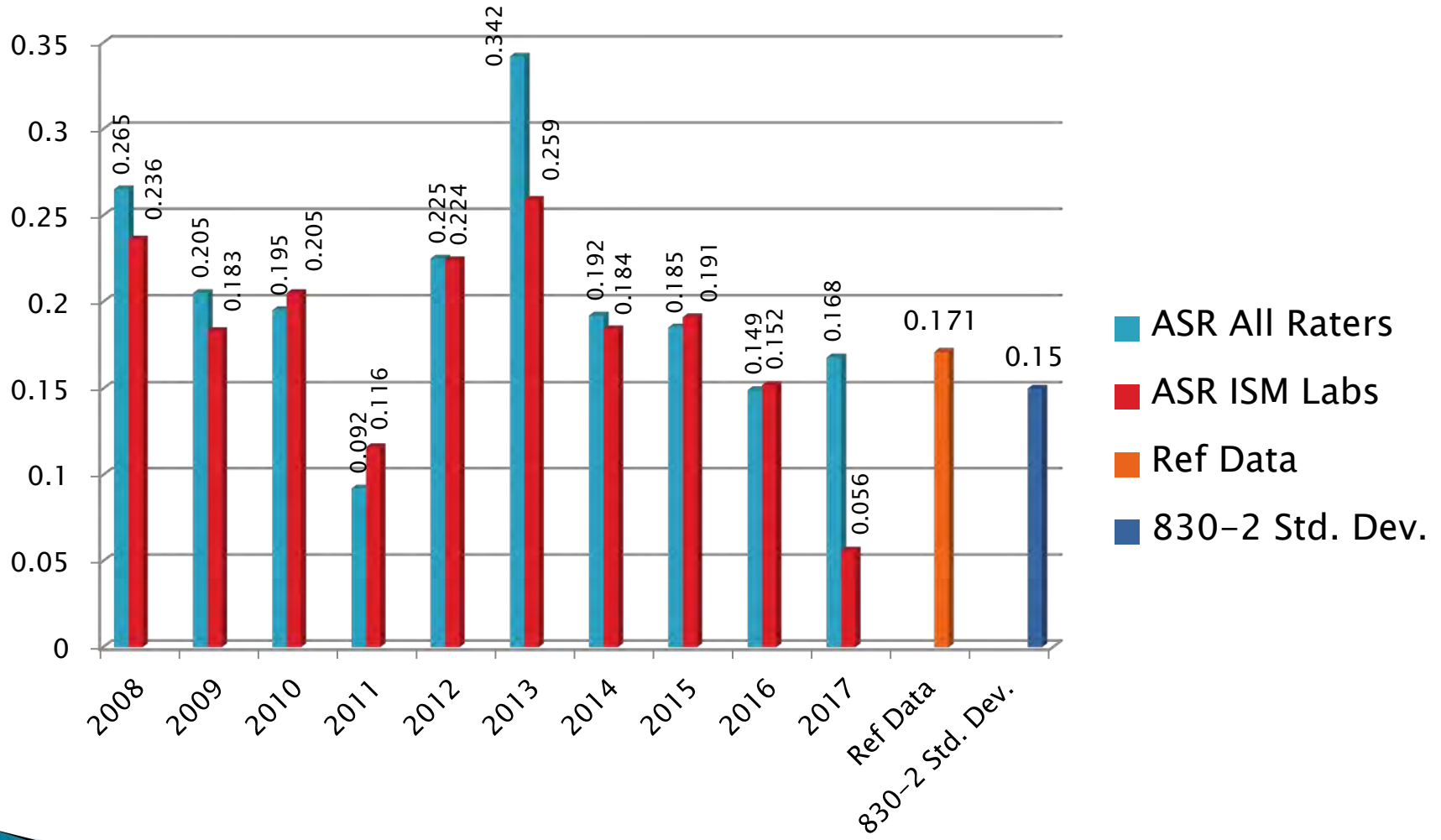
A Program of ASTM International

C13 2nd Ring Carbon Precision – Rating Workshop Data

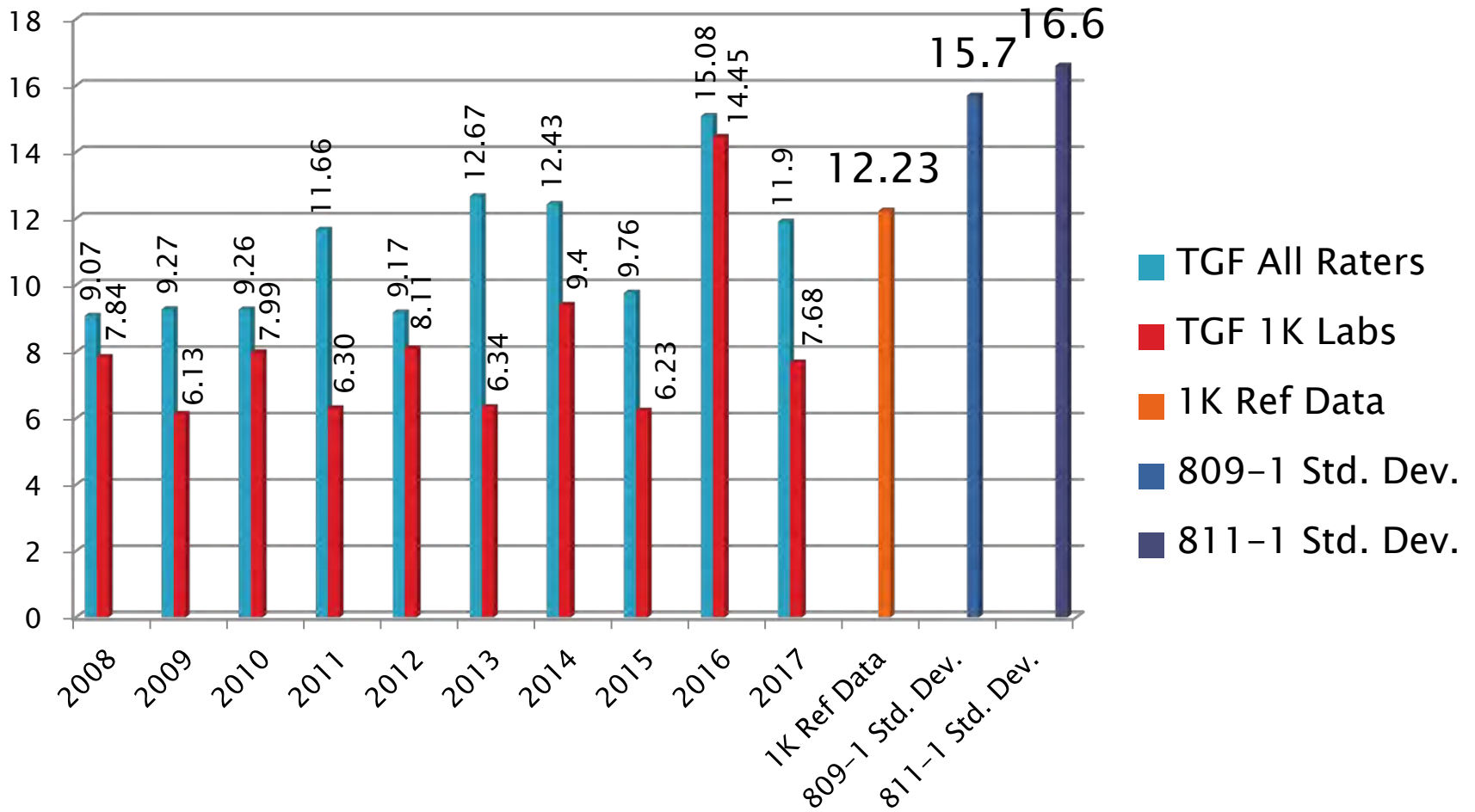
R2TC



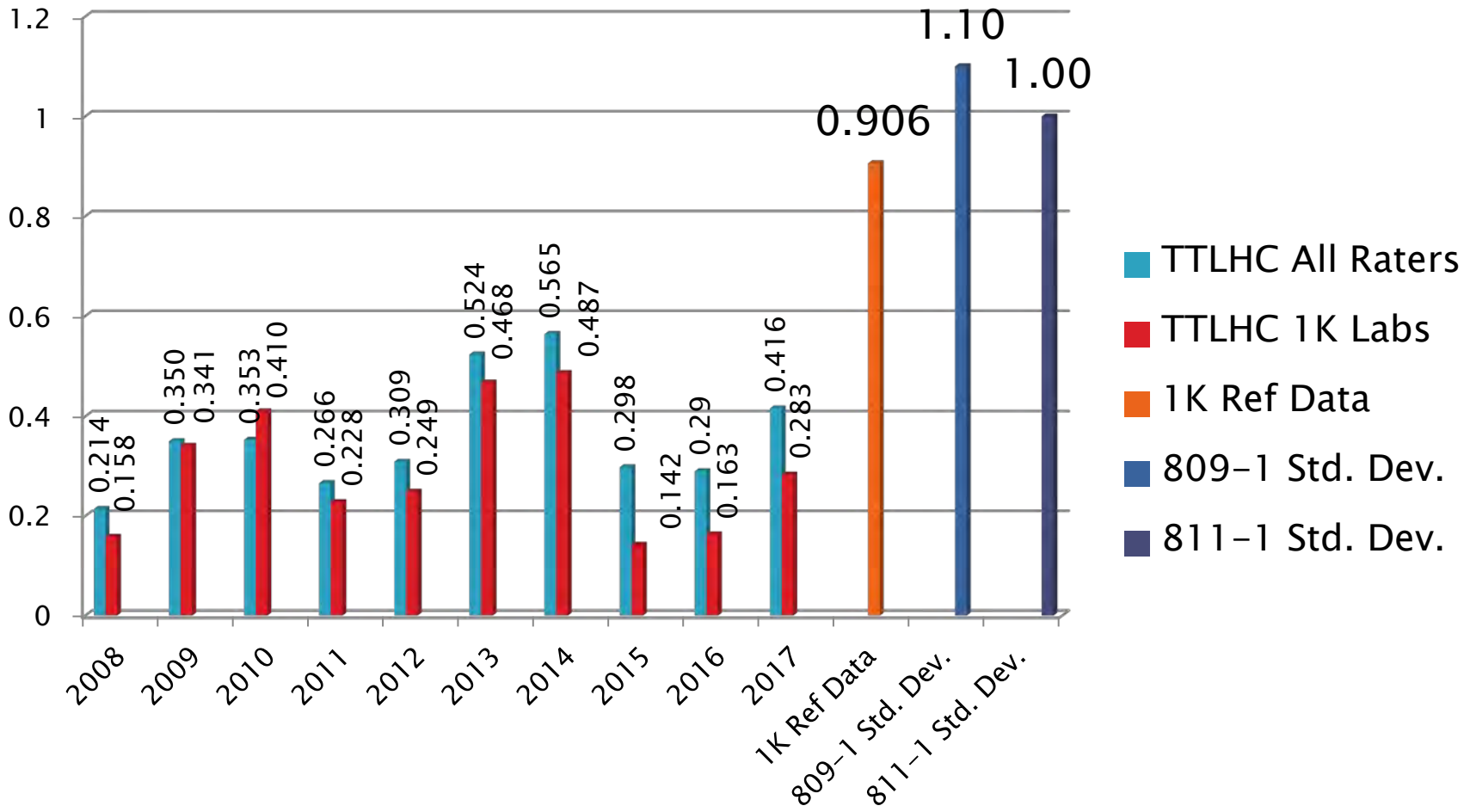
ISM Sludge Rating Precision – Rating Workshop Data



Deposit Rating Precision - Rating Workshop Data



Deposit Rating Precision - Rating Workshop Data



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Miscellaneous Information

- ▶ Available on TMC Website:
 - Oil Assignment Request and Test File Upload
 - Live Reference Test Data Bases
 - Surveillance Panel Meeting Minutes
 - Test Area Alarm Logs
 - Complete Test Area Timelines
 - LTMS Manual

- ▶ www.astmtmc.cmu.edu

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