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# **Test Monitoring Center**

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

April 2013

# Heavy Duty Testing

## Executive Summary

### ▶ Reference Oils

- [820-3 replacement](#)

- New oil designated 822. Final approved blend designated 822-1 on March 5<sup>th</sup> 2013

- [821-3 Supply being rapidly depleted](#)

- Current estimate ~1 - 1.5 year supply remains.

### ▶ T-12 Hardware

- [Industry working to validate new hardware batch to carry test into future.](#)

# Calibrated Labs and Stands\*

Test	Labs	Stands
1K	3	4
1N	4	7
1M-PC	2	2
1P	3	3
1R	1	1
C13	2	4
ISB	3	6
ISM	5	6
EOAT	1	1
RFWT	2	2
T-8/E	2	5
T-10A	1	1
T-11	4	5
T-12	4	8
T-12A	4	9

\*As of 3/31/2013

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# Test Activity Levels

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# CAT – SCOTE Tests

Test Status	Validity Code	1K	1N	1M-PC	1P	1R
Acceptable Calibration Test	AC	1	4	1	2	1
Failed Calibration Test	OC	0	0	0	0	0
Operationally Invalid	LC	0	0	0	0	0
Aborted	XC	0	0	0	0	1
<b>Total</b>		<b>1</b>	<b>4</b>	<b>1</b>	<b>2</b>	<b>1</b>

# CAT - C13 Test

Test Status	Validity Code	C13
Acceptable Calibration Test	AC	1
Failed Calibration Test	OC	0
Operationally Invalid	LC	0
Aborted	XC	0
<b>Total</b>		<b>1</b>

# Cummins Tests

Test Status	Validity Code	ISB	ISM
Acceptable Calibration Test	AC	3	2
Failed Calibration Test	OC	0	0
Operationally Invalid	LC	0	0
Aborted	XC	0	0
<b>Total</b>		<b>3</b>	<b>2</b>

# Light Duty Diesel Tests

Test Status	Validity Code	EOAT	RFWT
Acceptable Calibration Test	AC	0	3
Failed Calibration Test	OC	0	0
Operationally Invalid	LC	0	0
Aborted	XC	0	0
<b>Total</b>		<b>0</b>	<b>3</b>



# Mack Tests

Test Status	Validity Code	T-8/E	T-10A	T-11	T-12	T-12A
Acceptable Calibration Test	AC	3/3	1	5	1	1
Failed Calibration Test	OC	0/0	0	0	0	0
Operationally Invalid	LC	0	0	1	1	1
Aborted	XC	4/4	0	1	2	2
Pending Tests	PC	0	0	0	5	5
Donated Test	AG	0	0	2	0	0
Information Test	NN	0	0	3	0	0
<b>Total</b>		<b>7</b>	<b>1</b>	<b>12</b>	<b>9</b>	<b>9</b>

# Failed Tests

Test Status	Test	Number of Tests
Total		0

# Lost Tests\*

\*Invalid and aborted tests

Test	Status	Cause
T1R	Aborted	Copper in Oil
T8/E	Aborted	Wrong Oil Added
T8/E	Aborted	High Fuel Dilution
T8/E	Aborted	High Soot
T8/E	Aborted	Missed Window
T11	Aborted	Exhaust Valve Failure
T11	Invalid	High Oil Consumption/Abnormal Timing Adjustment
T12/A	Aborted	Lost Oil Charge
T12/A	Aborted	Stuck 3 <sup>rd</sup> Top Ring
T12/A	Invalid	Bad CO2 Measurement

# Pending and Donated Tests

- ▶ Pending T-12 Tests (PC)
  - 5 Pending T12 tests awaiting Surveillance Panel disposition. Tests were run on new hardware batch.
- ▶ Donated Tests (AG & NN)
  - 2 donated T-11 tests were for new reference oil blend evaluation
  - 3 Information tests were also for new reference oil blend evaluation

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# Test Severity

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# CAT Test Severity

## ▶ 1K

- WDK, TLHC, ETOC are in control.
- TGF and BSOC
  - Within Chart Limits
  - Long-term mild trend continuing

- Charts shown in [Appendix 1.a.](#)

## ▶ 1N

- TGF, WDN, TLHC, and BSOC trending mild
- TGF and WDN alarm
- TLHC and BSOC in action alarm

- Charts shown in [Appendix 1.b.](#)

# CAT Test Severity

## ▶ 1M-PC

- Both parameters (TGF & WTD) are in control.

- Charts shown in [Appendix 1.c.](#)

## ▶ 1P

- All parameters (TGC,WD,TLC,OC and ETOC) are in control.

- Charts shown in [Appendix 1.d.](#)

# CAT Test Severity

## ▶ 1R

- BTOC is in control but trending mild.
- WD and ETOC in severity alarm, severe direction
- WD, TLC, TGC and ETOC in precision alarm

- Charts shown in [Appendix 1.e.](#)

## ▶ C13

- TLC are in control.
- R2TC and TGC in alarm, mild direction.
- OC in precision alarm.

- Charts shown in [Appendix 1.f.](#)



# Cummins Test Severity

## ▶ ISB

- Both ACSW and ATWL are in control with slight mild trends.

- Charts shown in [Appendix 1.g.](#)

## ▶ ISM

- CWL, FPD and ASR in control.
  - CWL trending mild.
  - FPD mild trend may be ending.
  - ASR possibly trending severe.
- IAS in action alarm severe direction

- Charts shown in [Appendix 1.h.](#)

# Light Duty Diesel Test Severity

## ▶ EOAT

- AEOA in control.

- Charts shown in [Appendix 1.i.](#)

## ▶ RFWT

- AFW in control but trending mild.

- Charts shown in [Appendix 1.j.](#)

# Mack Test Severity

- ▶ T-8/E
  - All parameters are in control.
  - Charts shown in [Appendix 1.k.](#)
- ▶ T-10A
  - MRV in severity alarm (severe) and still trending severe.
  - Charts shown in [Appendix 1.l.](#)

# Mack Test Severity

## ▶ T-11

- SOOT, SOOT4 and SOOT5 within chart limits.
- MRV in alarm (mild direction)
  - SOOT and MRV trending mild.
  - SOOT5 mild trend ending.

- Charts shown in [Appendix 1.m.](#)

## ▶ T-12

- OC, PB and TRWL parameters within chart limits
- CLW and PB2 in alarm (severe direction)
  - CLW and OC trending severe.
  - TRWL long-term mild trend may be ending.

- Charts shown in [Appendix 1.n.](#)

# Mack Test Severity

- ▶ T-12A
  - MRV is in control.
- Charts shown in [Appendix 1.o.](#)

# Test Precision

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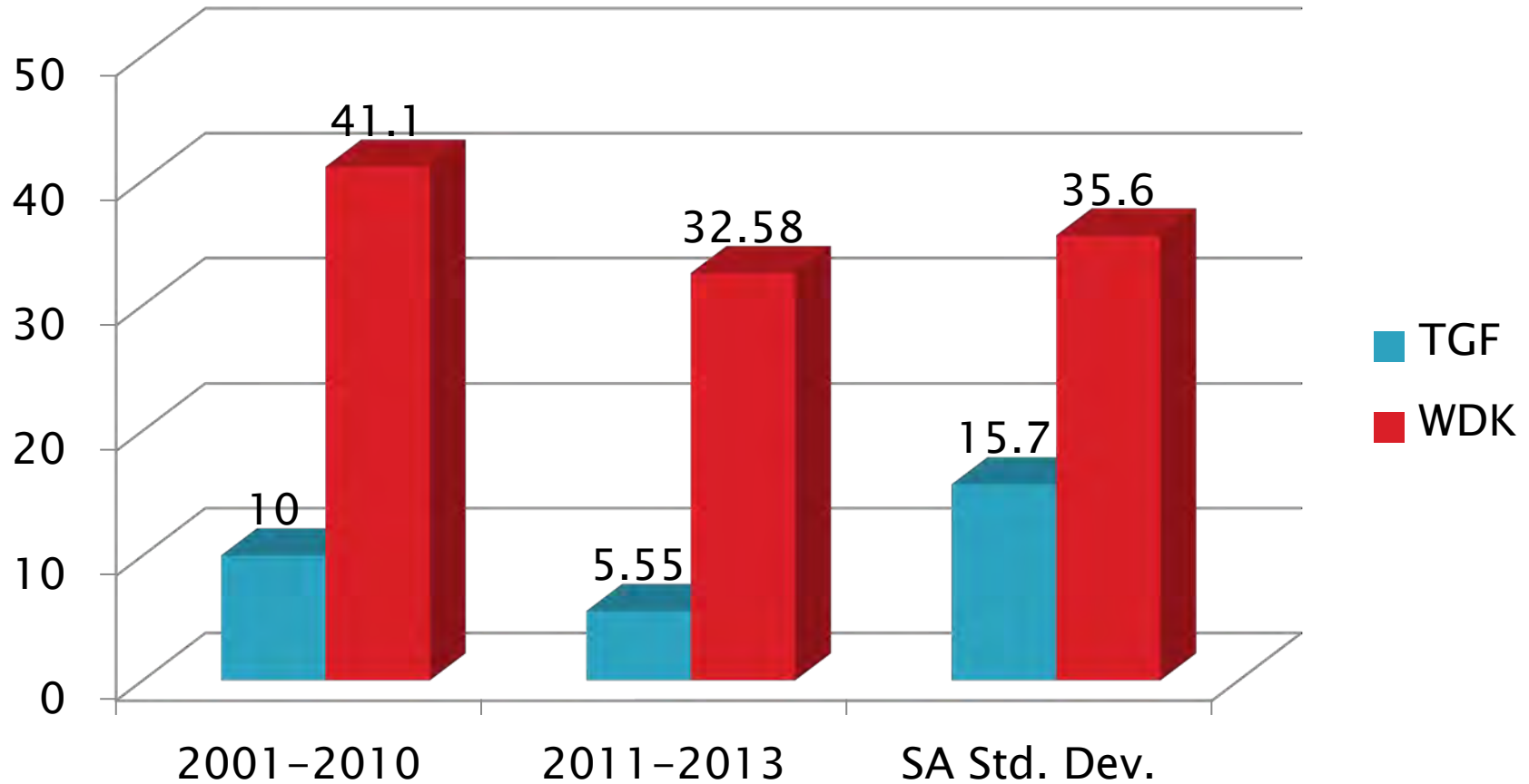


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# Test Precision Estimates

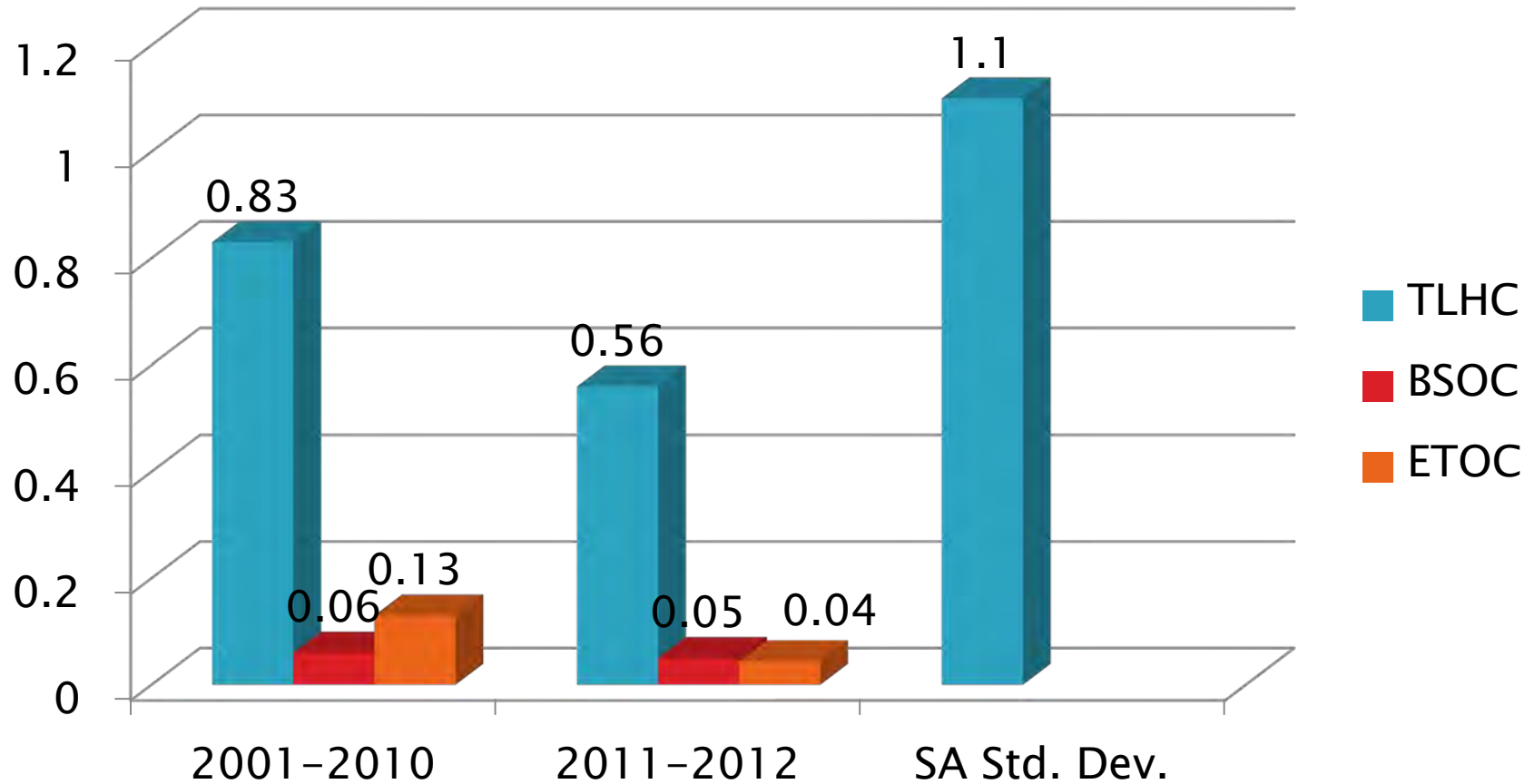
- ▶ Presented for years where sufficient data exist
- ▶ Precision estimates are shown with reference oil std. deviations, or where applicable, with Severity Adjustment std. deviations
- ▶ For several test types, precision estimates are not available due to low activity levels

# 1 K Precision Estimates

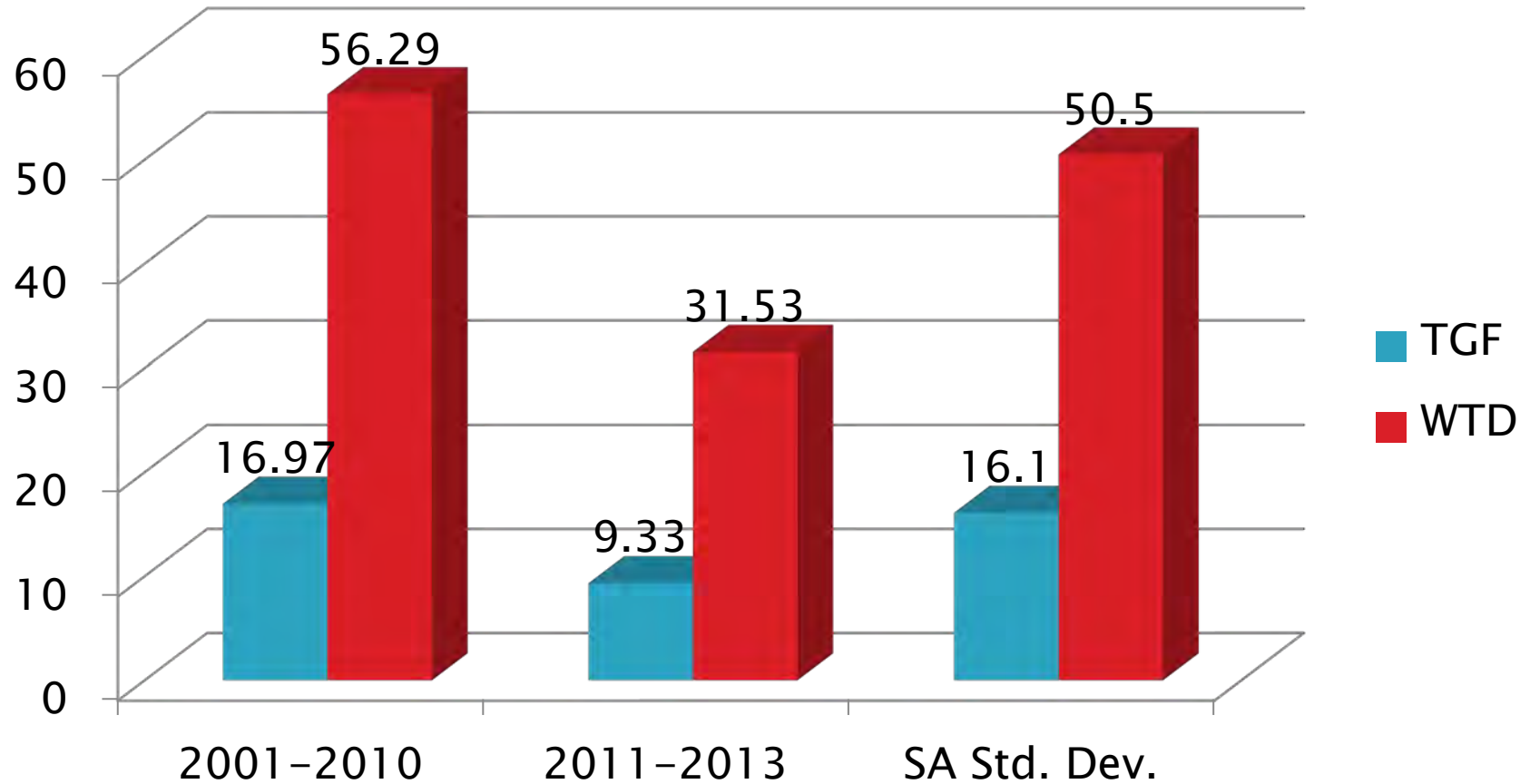




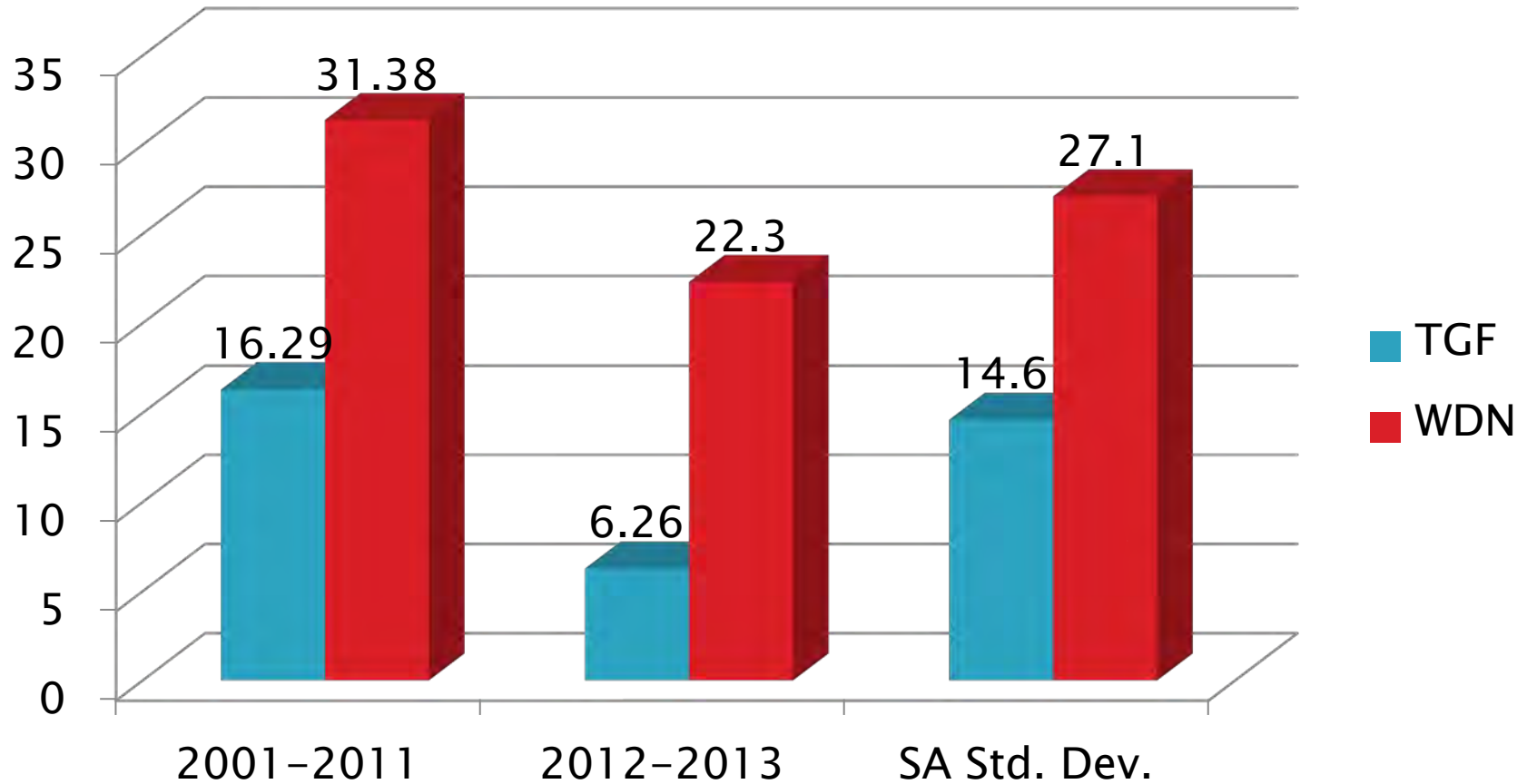
# 1 K Precision Estimates



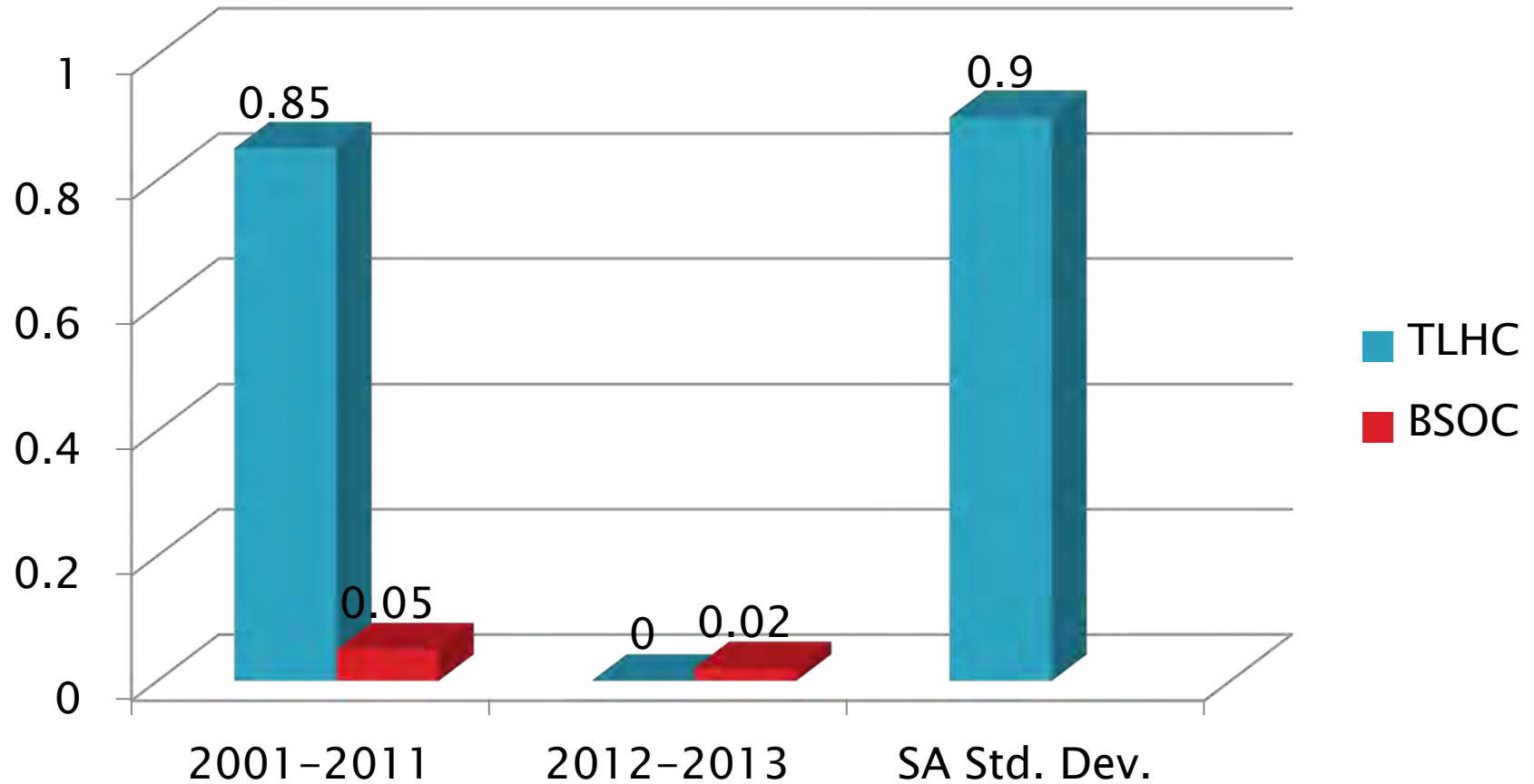
# 1 MPC Precision Estimates



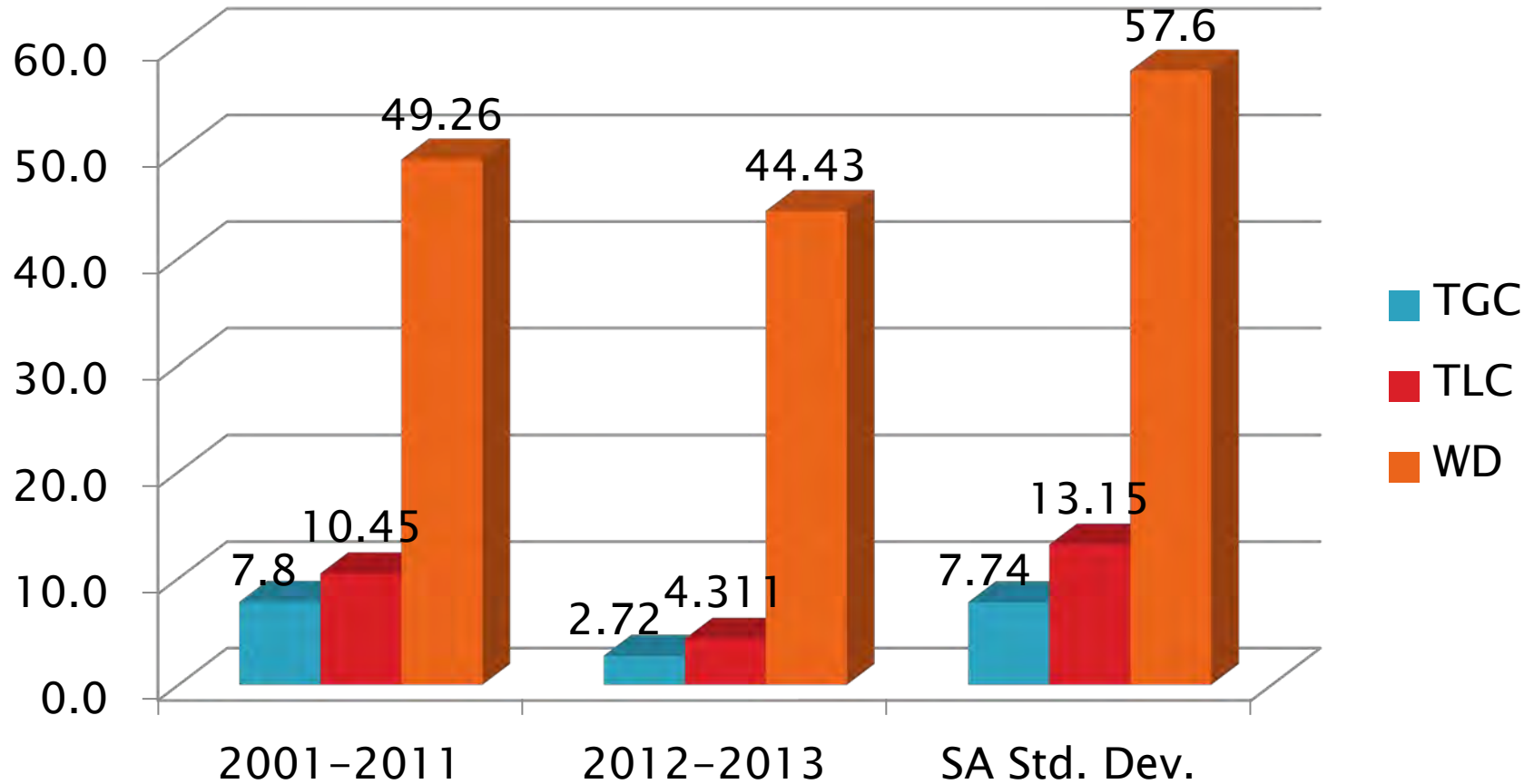
# 1 N Precision Estimates



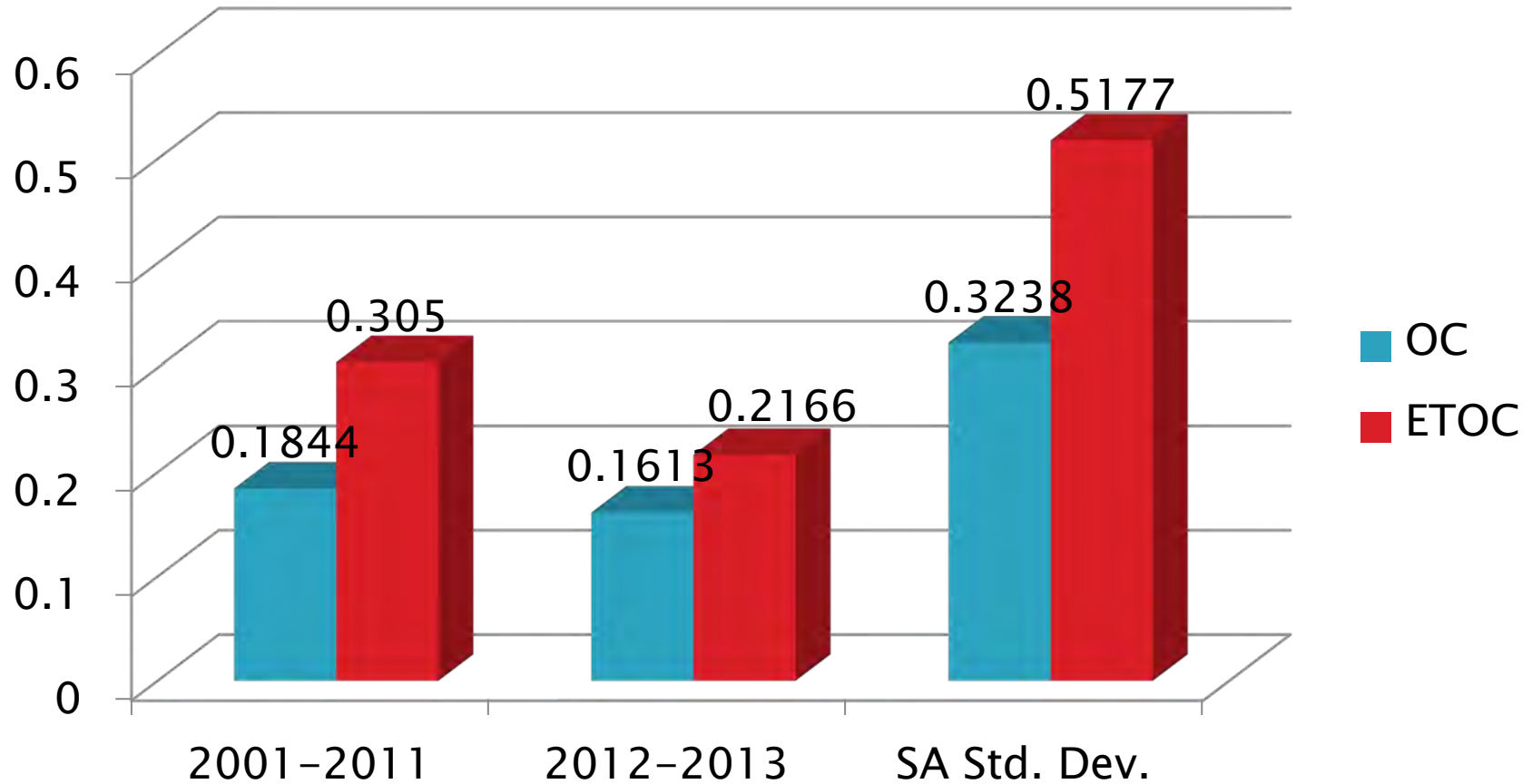
# 1 N Precision Estimates



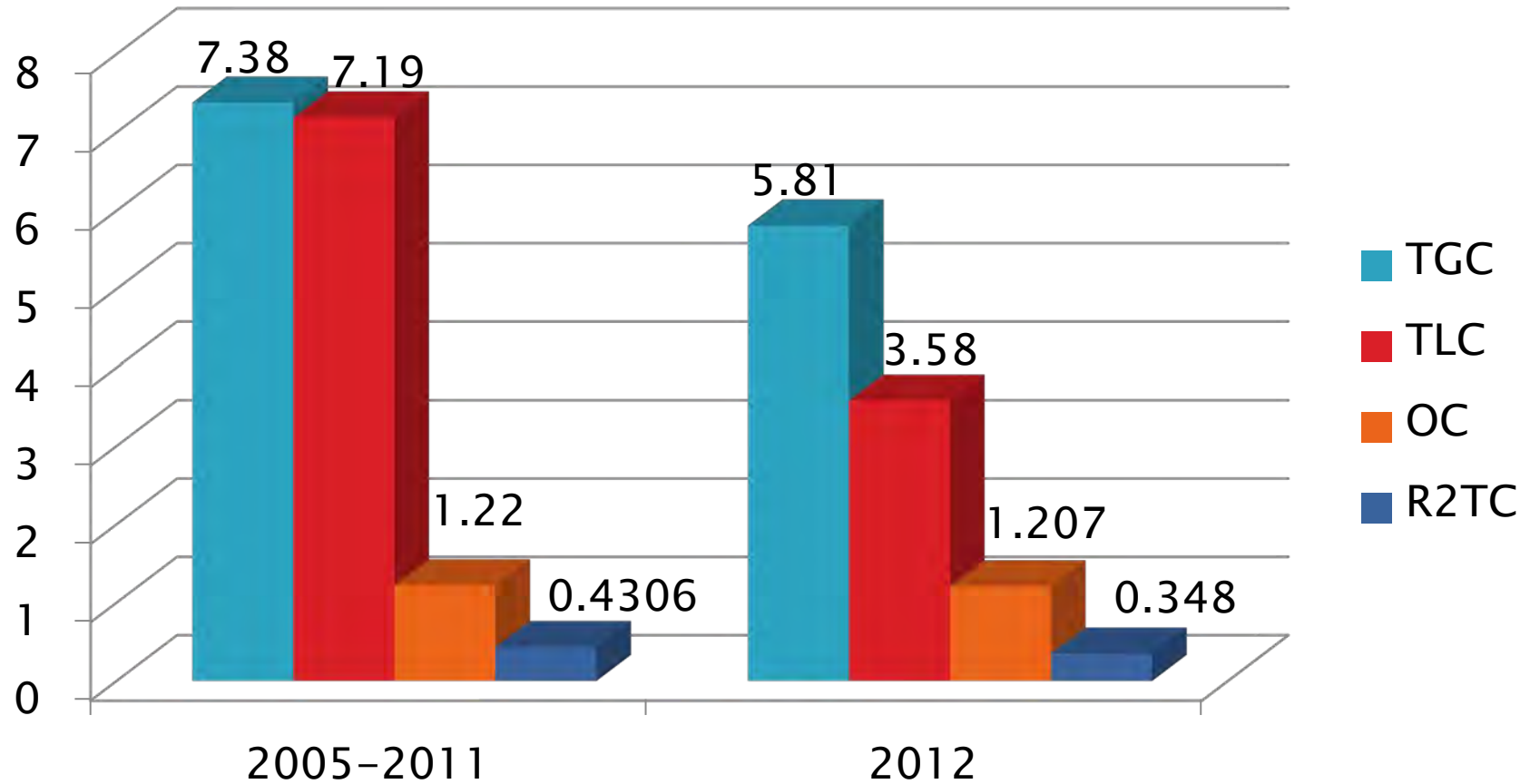
# 1P Precision Estimates



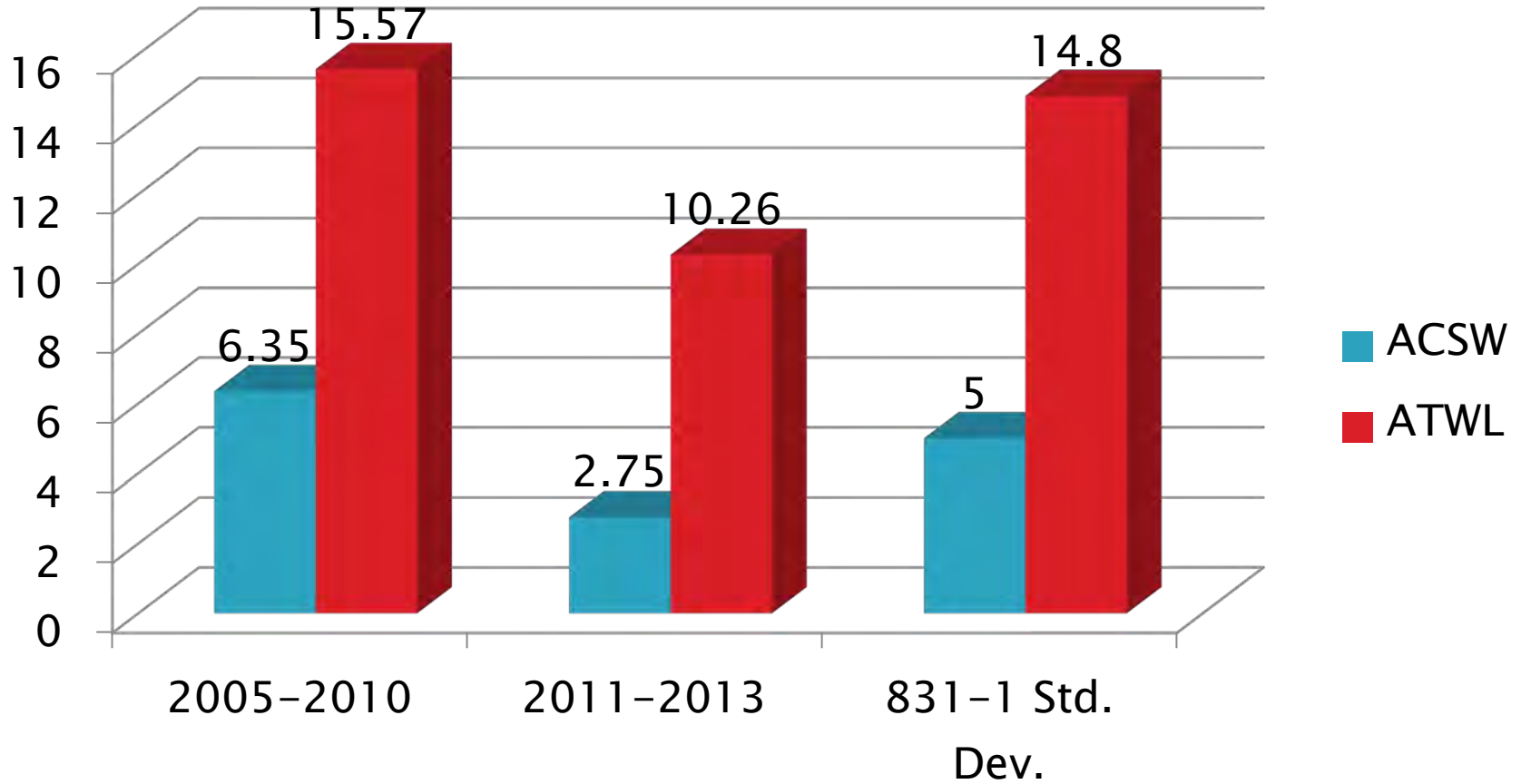
# 1 P Precision Estimates



# C13 Precision Estimates

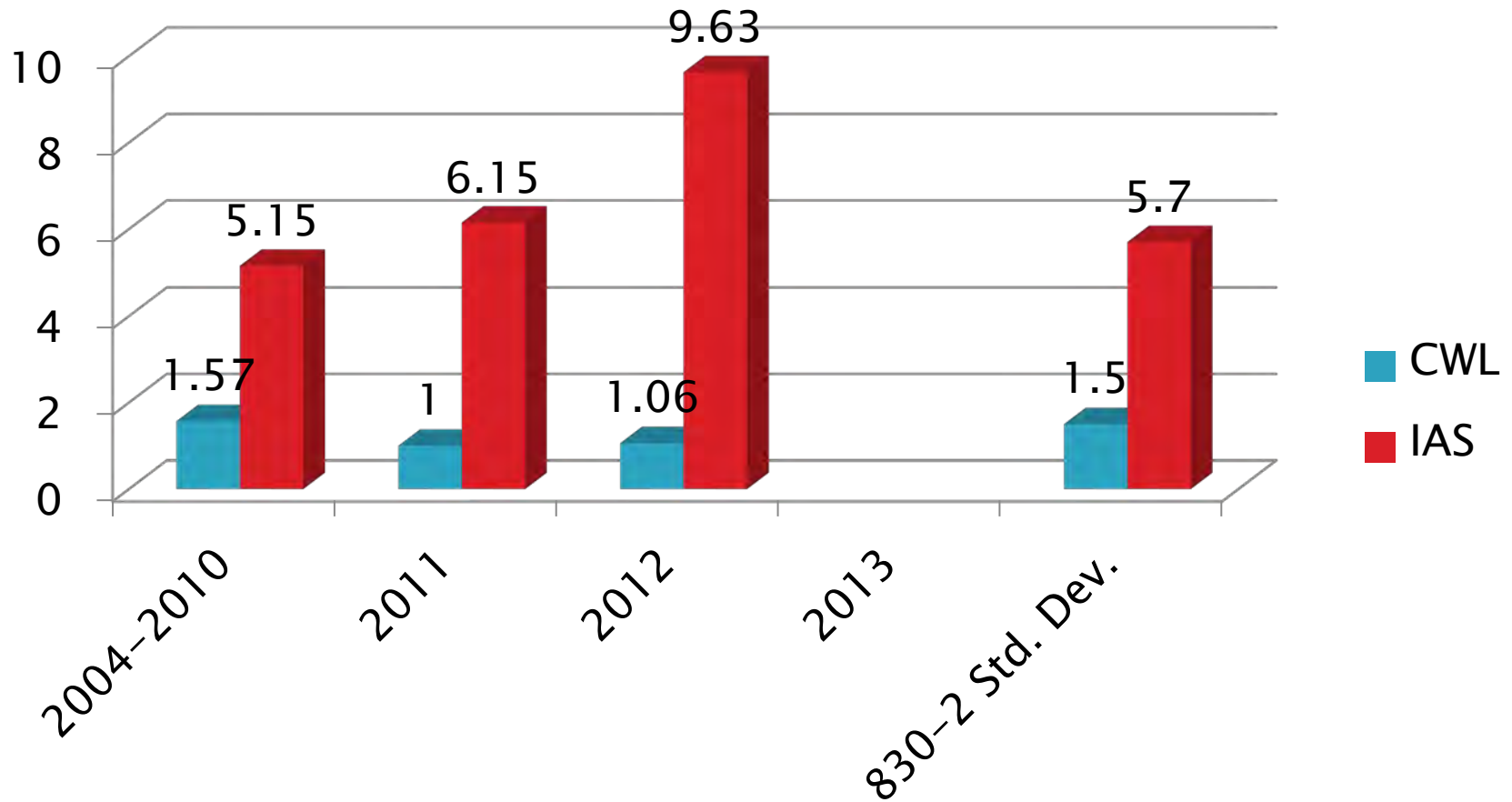


# ISB Precision Estimates

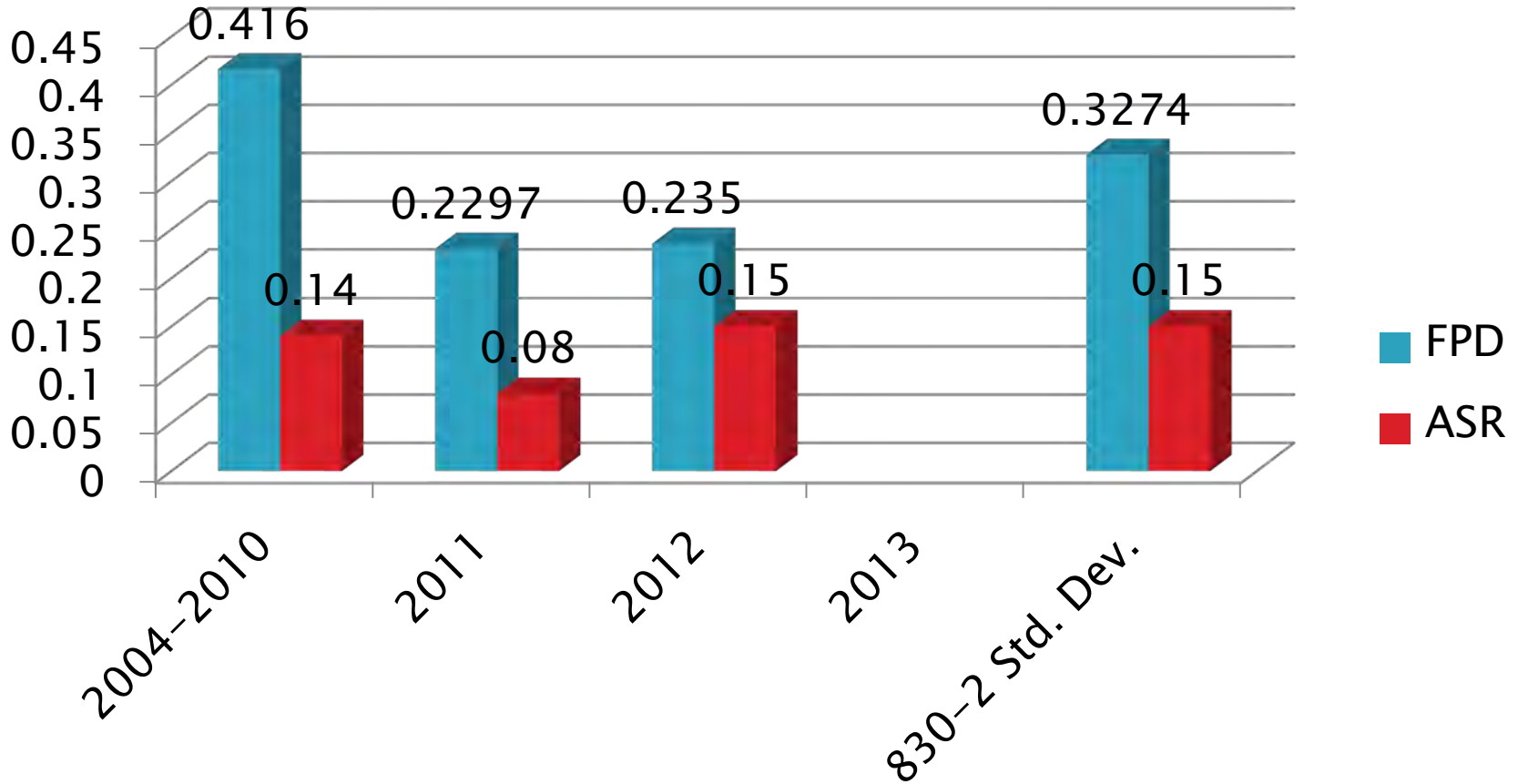




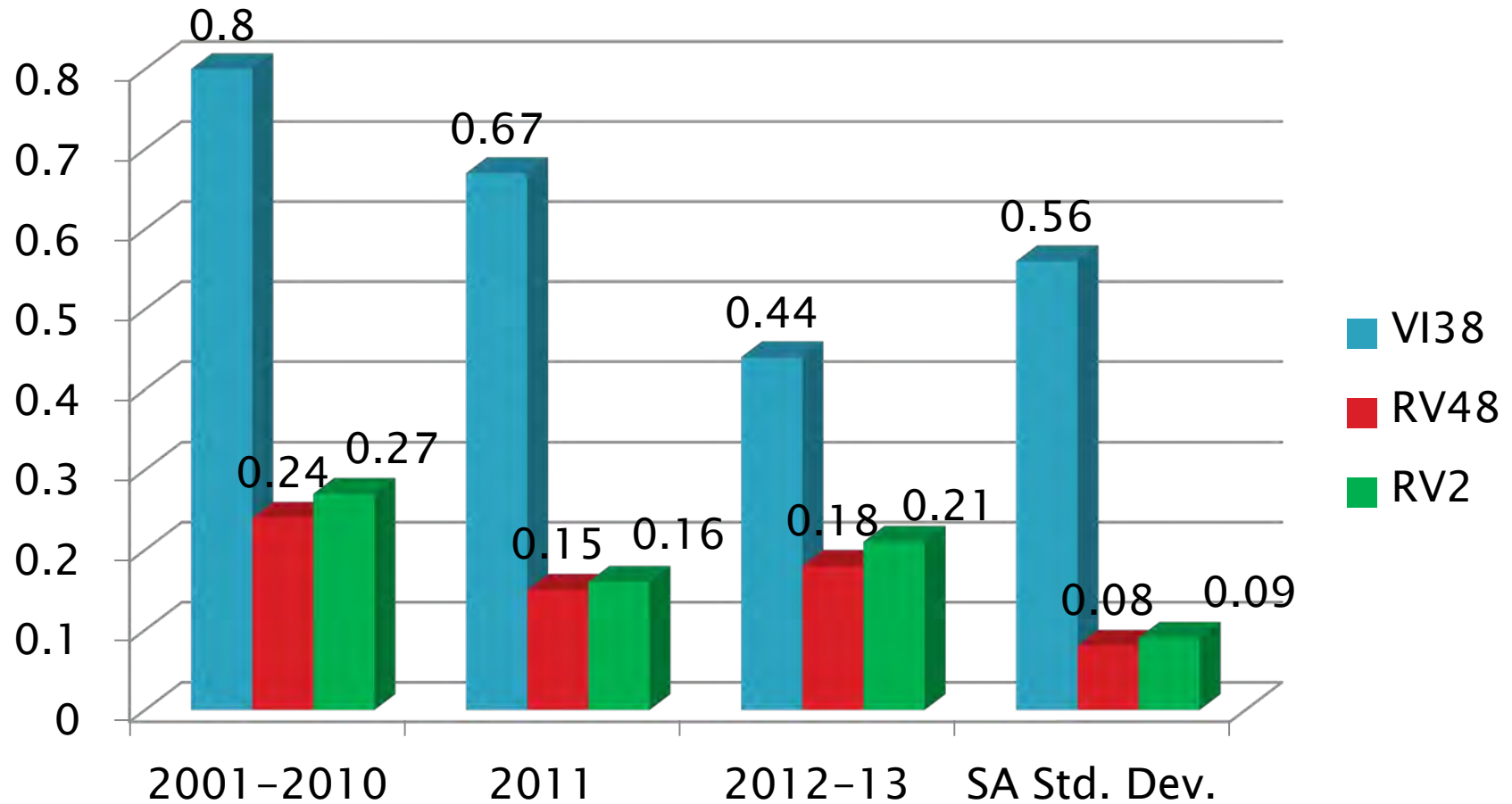
# ISM Precision Estimates



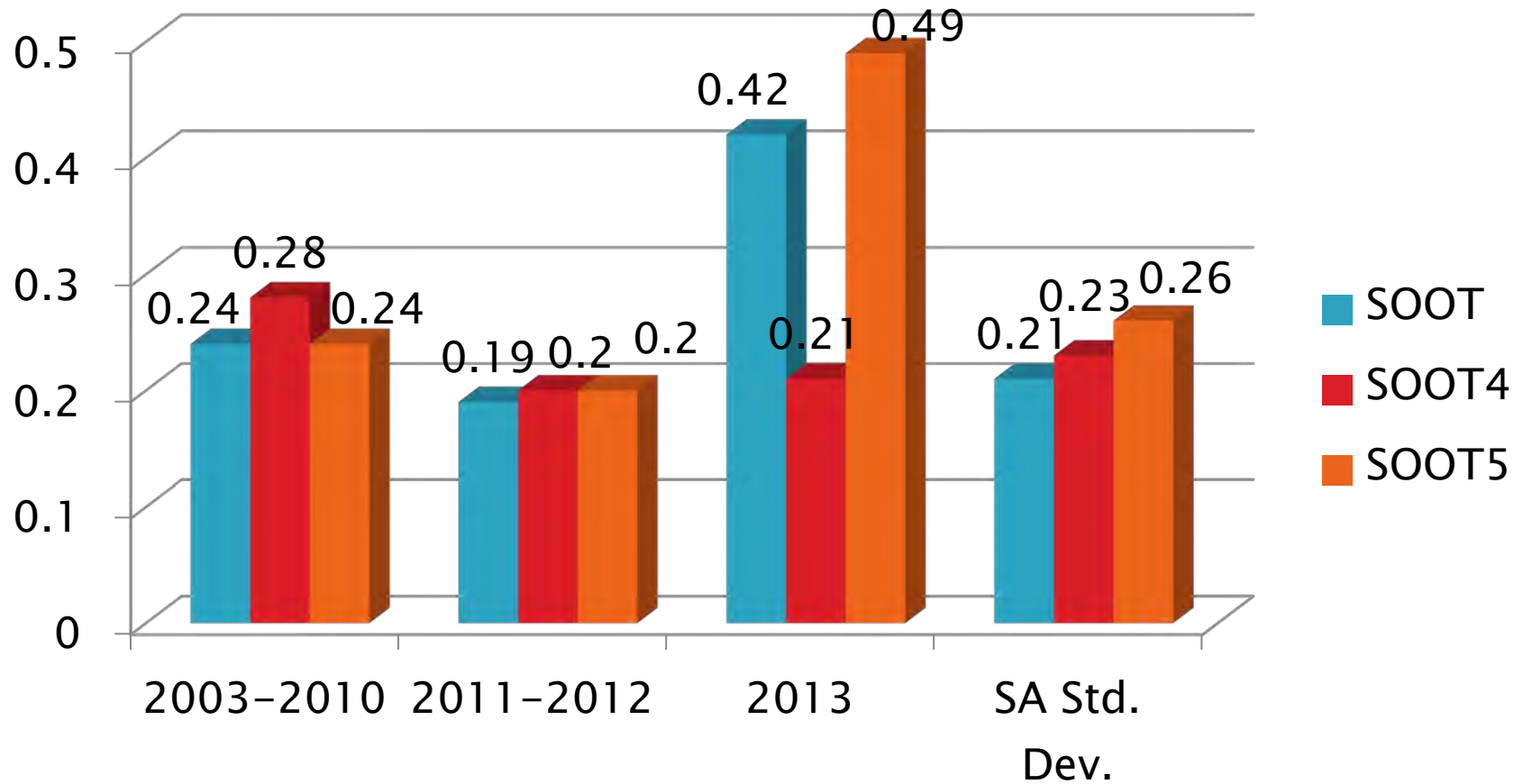
# ISM Precision Estimates



# T-8/E Precision Estimates

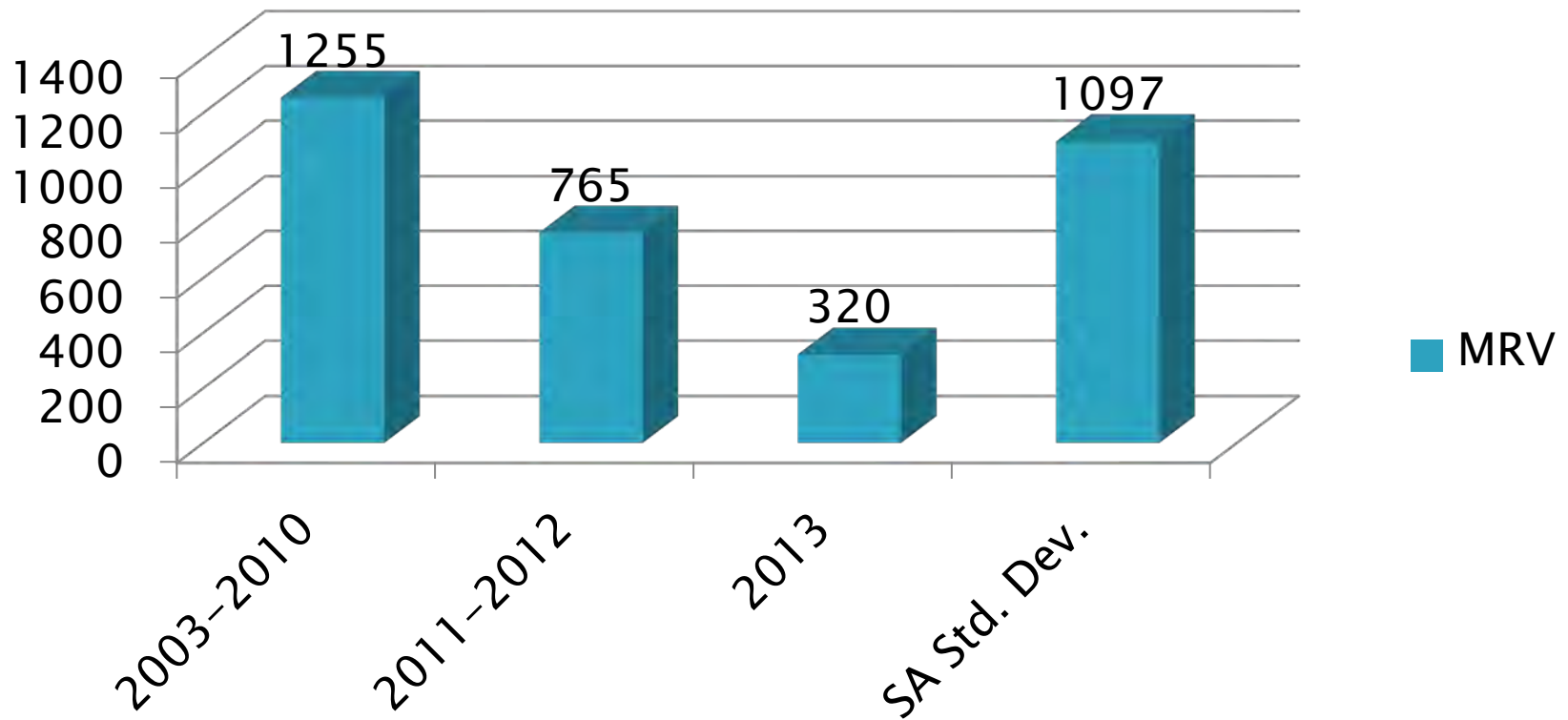


# T-11 Precision Estimates

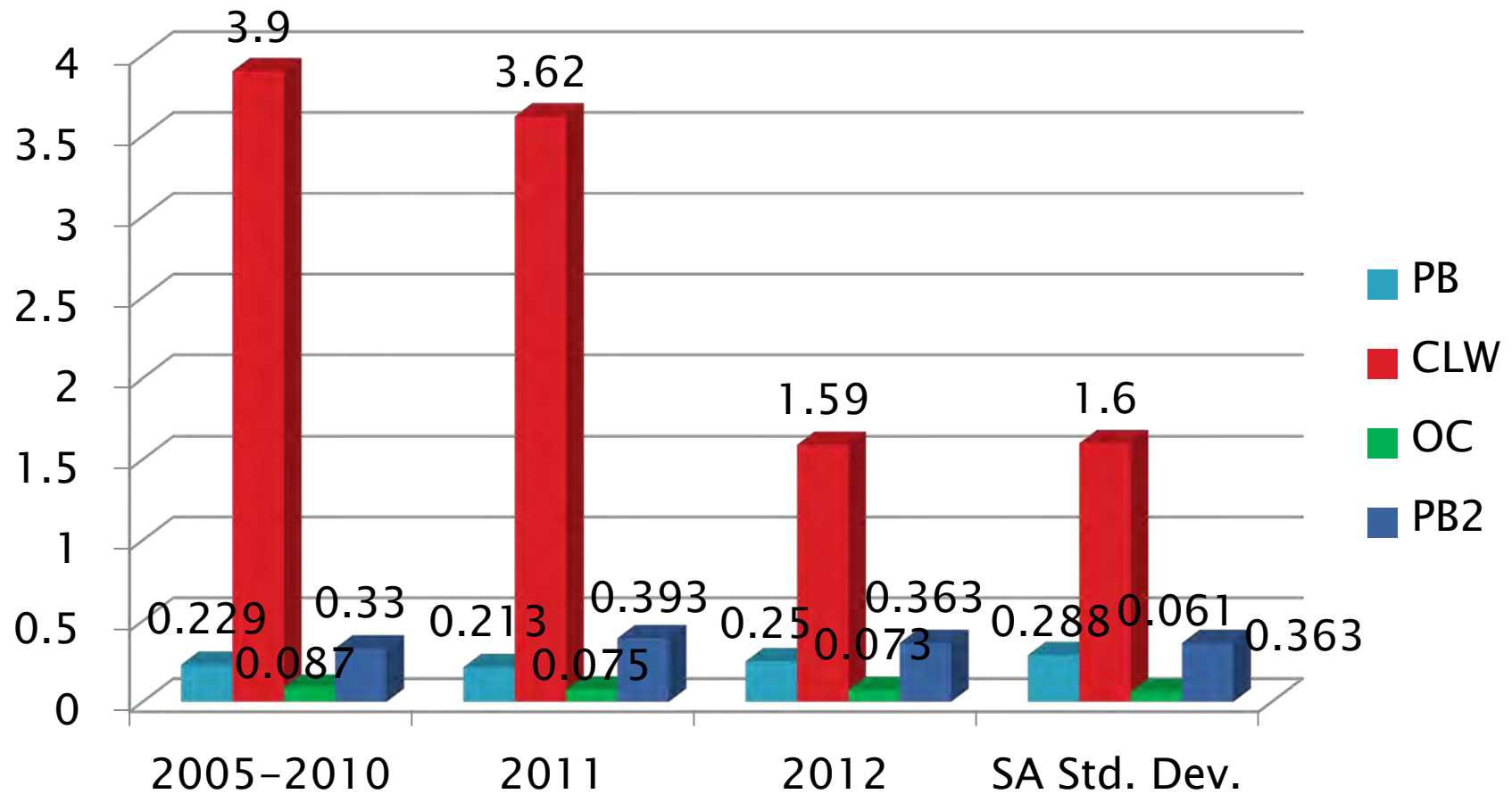


# T-11 Precision Estimates

## MRV

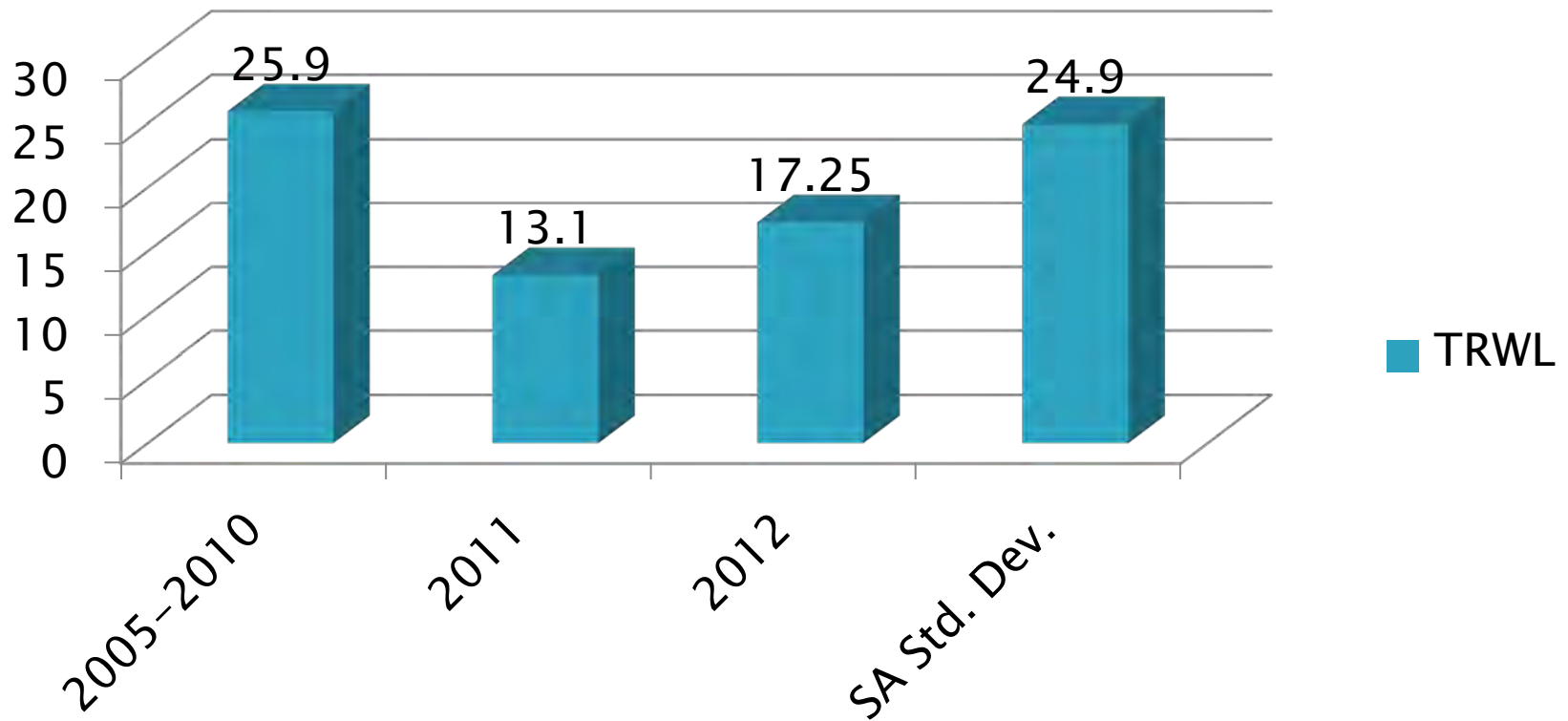


# T-12 Precision Estimates



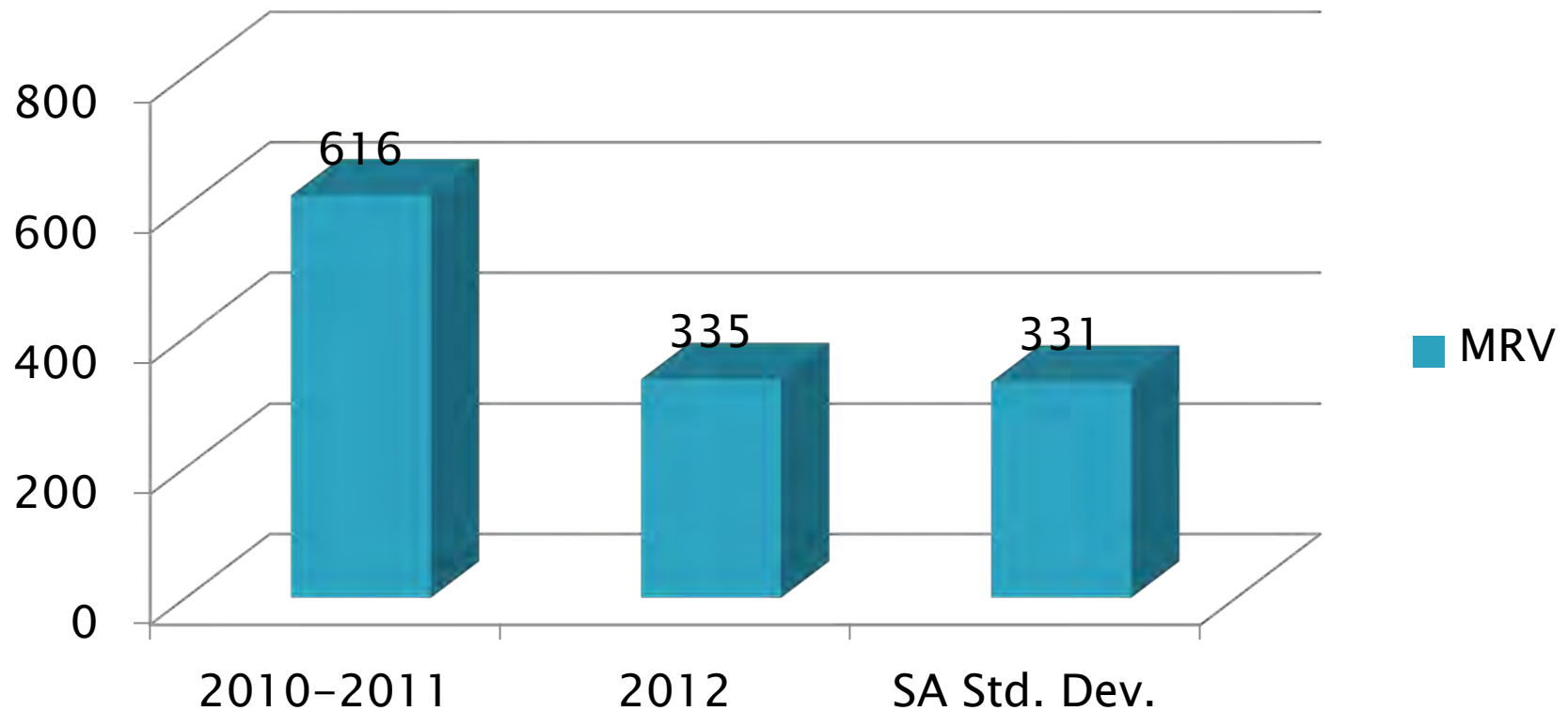
# T-12 Precision Estimates

## TRWL



# T-12A Precision Estimates

## MRV





# Information Letters

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# Information Letters\*

Test	Date	IL	Topic
ISB	11/15/2012	12-3	ACSW and ATWL Correction Factors
T-10A	2/22/2013	13-1	T-10A Calibration Period Change

\*Available from TMC Website

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# Reference Oil Inventory

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

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# New Reference Oils

## ➤ T11 Oil Supply

- 822-1 approved as reference oil. All materials to complete next reblend of 822 are at the TMC.

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# Reference Oil Re-blends

## ➤ T12 Oil Supply

- Need to consider acquiring more oil if T-12 is not replaced by T-13
- T-12 Supply is being used rapidly
  - ~1-1.5 year supply remains

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# 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	20	2508	136	5+ years
811-2	1K, 1N	1732	10	1275	60	5+ years
820-3	1R, T-10A, T-11	2750	0	0	168	~ 1 year
822-1	1R, T-10A, T-11	560	336	156	140	5+ years
821-2	T-12	450	0	0	0	N/A
821-3	T-12	1500	225	799	225	1-1.5 years
830-2	ISM	3786	125	858	403	3.8 years
831-1	C13, ISB	1300	0	59	131	~ .2 years
831-2	C13, ISB	880	0	880	0	5+ years
873-2	1M-PC	1650	20	207	40	5+ years
1005-3	1P, 1R, EOAT, RFWT, T-8/E	2000	265	22	341	~ 1 year
1005-4	1P, 1R, EOAT, RFWT, T-8/E	2000	60	1940	45	5+ years

# LTMS Deviations

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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



# Quality Index Deviations

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# Quality Index Deviations

- T12 Quality Index Deviation

- Intake Manifold Temperature Control

- Caused by EGR cooler fouling and erroneous phase 2 adjustment

- ISM Quality Index Deviation

- Fuel Flow

- Result of engine derate due to boost leak

- 1P Quality Index Deviation

- Engine Speed

- Engine control tuned to bring engine speed inline. Suspected dyno issue. Dyno replaced.

# Quality Index Deviations

## Historical Count of HD Quality Index Deviations

Test	Qi Deviations
1P	12
1R	1
ISM	3
C13	1
T-10A	1
T-11	3
T-12	5

# TMC Laboratory Visits

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# TMC Lab Visits

Test	Number of Labs Visited
ISB	1
ISM	2
T11	2
T12	2
T8	1

# TMC Lab Visits

- ISB and ISM lab visits this period
  - Stands using Fleetguard Compleat EG versus specified Fleetguard Compleat PG
- T11 and T12 visits this period
  - Full instrumentation calibration before reference test not completed.

# Test Area Timelines

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# Test Area Timeline Additions\*

Test	Date	Topic	IL
ISB	20121115	Batch J Cams Approved/New Correction Factors for ACSW and ATWL	12-3
T10A	20130222	CALIBRATION PERIOD CHANGE	13-1
T-11	20130305	TMC 822-1 Introduced	

\*As of 3/31/2012

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# Additional Information



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# Additional 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](http://www.astmtmc.cmu.edu)



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## Appendix 1 Heavy Duty Reference Oil Testing Control Charts October 2012

# Appendix 1.a

# 1 K Control Charts

» Severity, Precision, and CuSum

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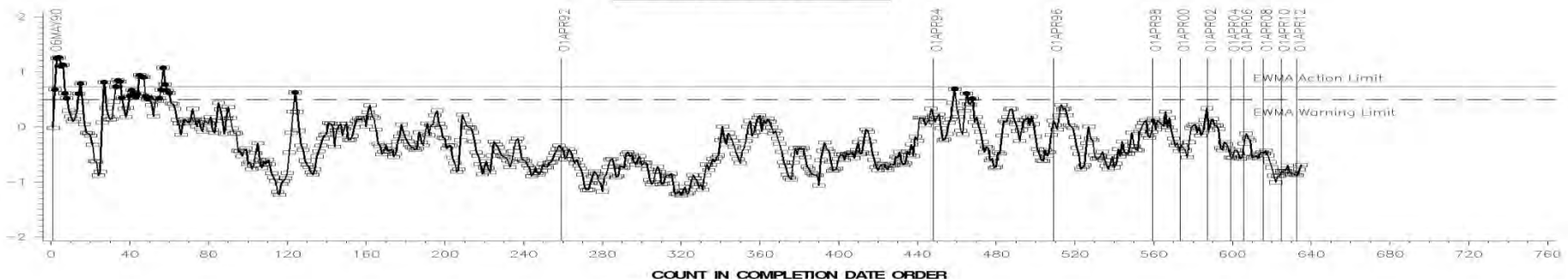


Top Groove Fill

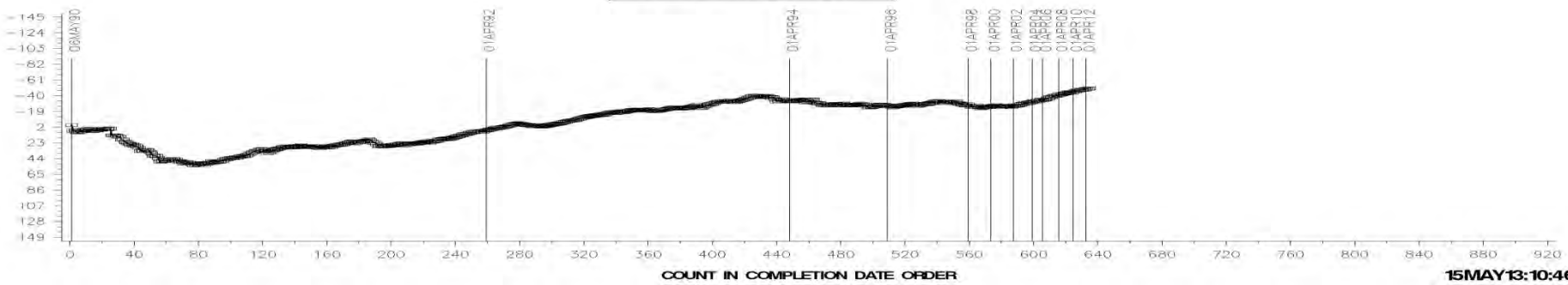
LTMS Severity Analysis



LTMS Precision Analysis



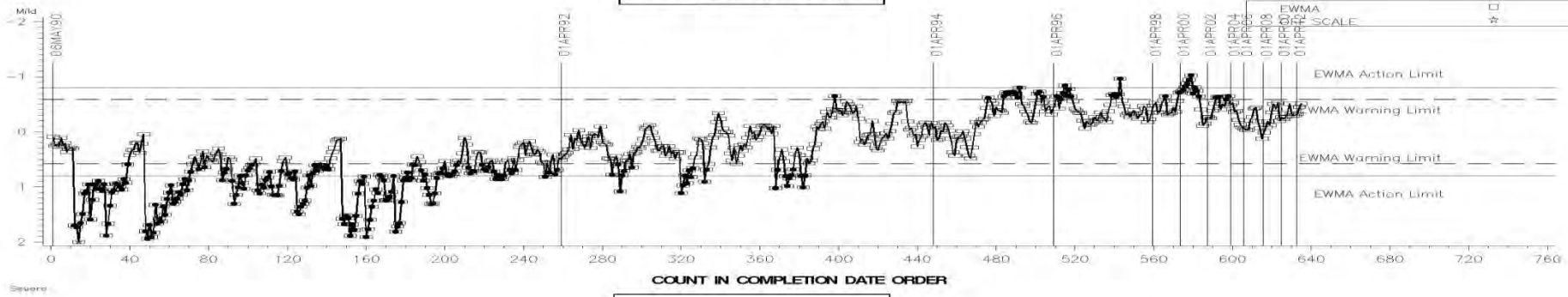
CUSUM Severity Analysis



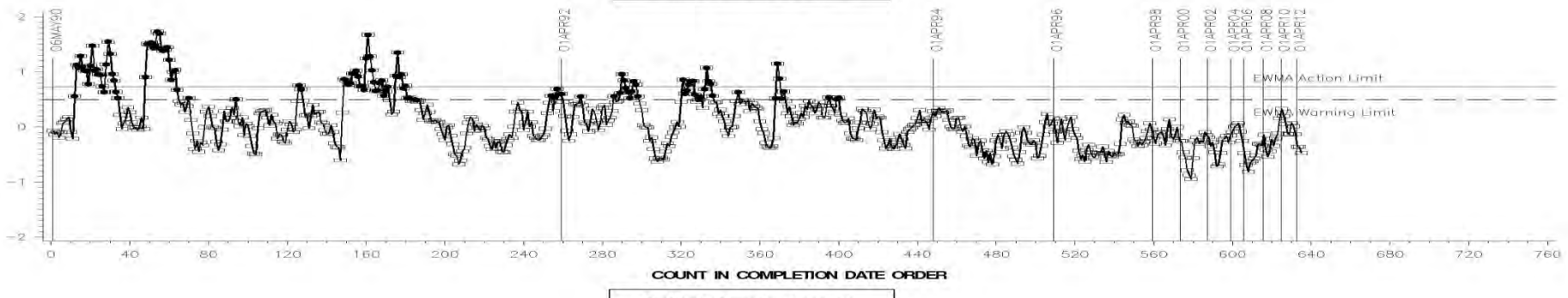
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Weighted Total Demerits

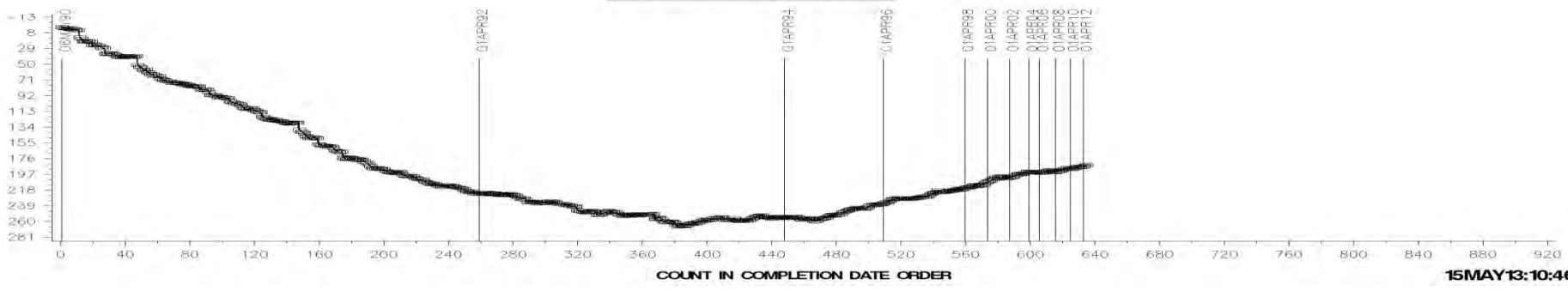
LTMS Severity Analysis



LTMS Precision Analysis



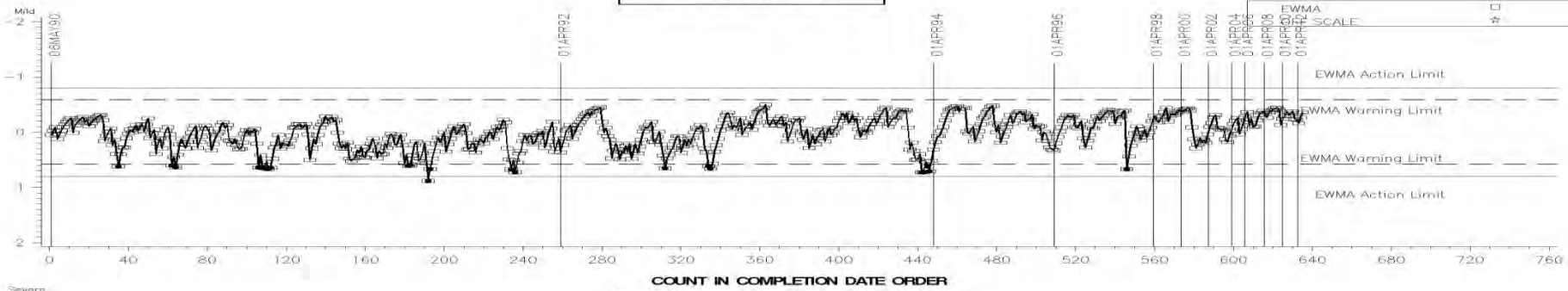
CUSUM Severity Analysis



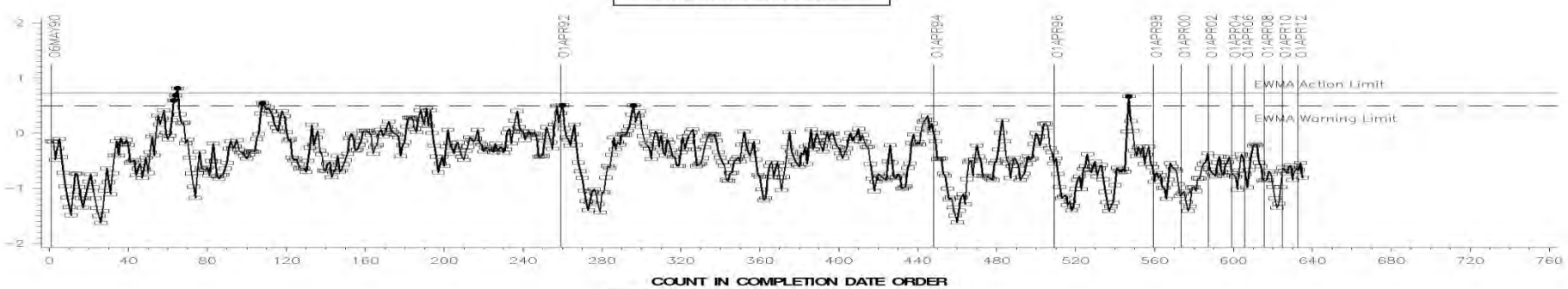
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## FINAL TRANSFORMED TOP LAND HEAVY CARBON

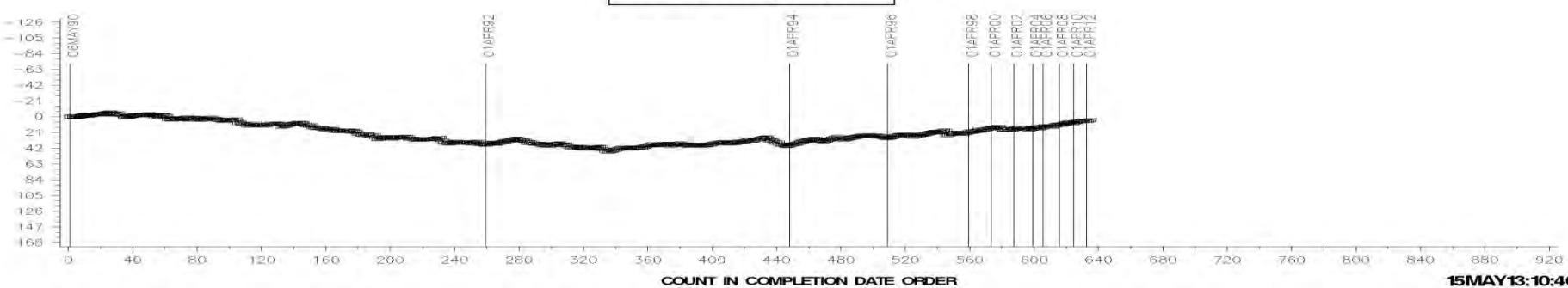
### LTMS Severity Analysis



### LTMS Precision Analysis



### CUSUM Severity Analysis



15MAY13:10:46

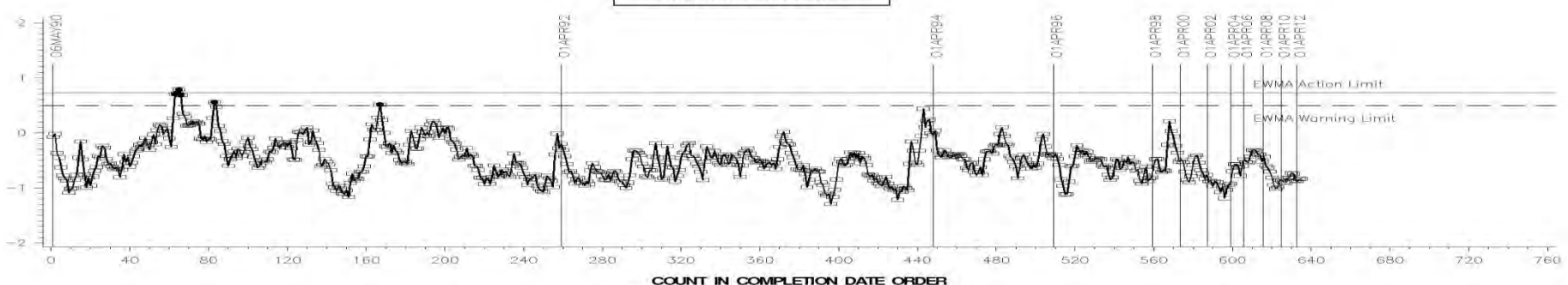


BSOC

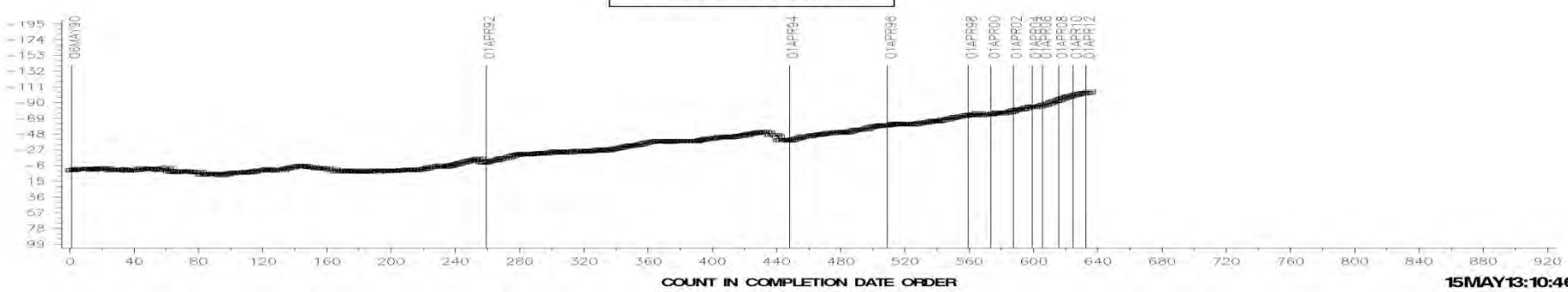
LTMS Severity Analysis



LTMS Precision Analysis



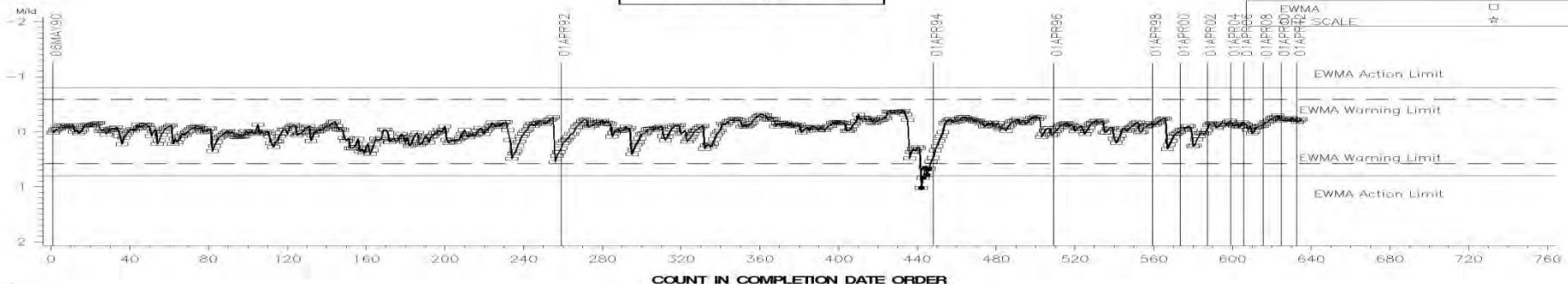
CUSUM Severity Analysis



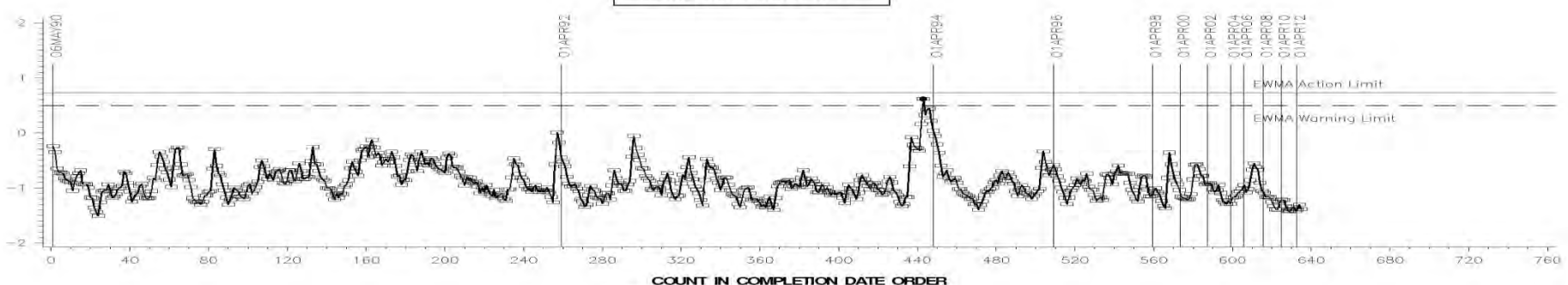
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EOTOC

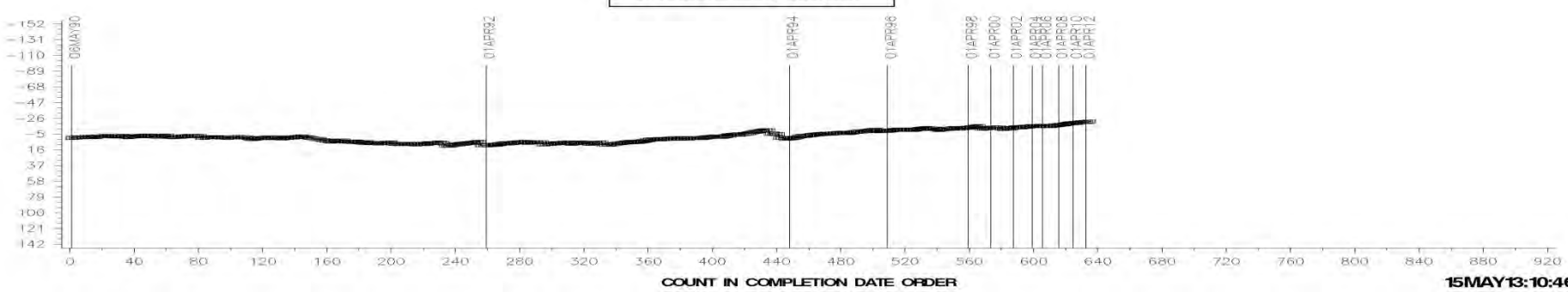
LTMS Severity Analysis



LTMS Precision Analysis



CUSUM Severity Analysis



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# Appendix 1.b

## 1 N Control Charts

» Severity, Precision, and CuSum

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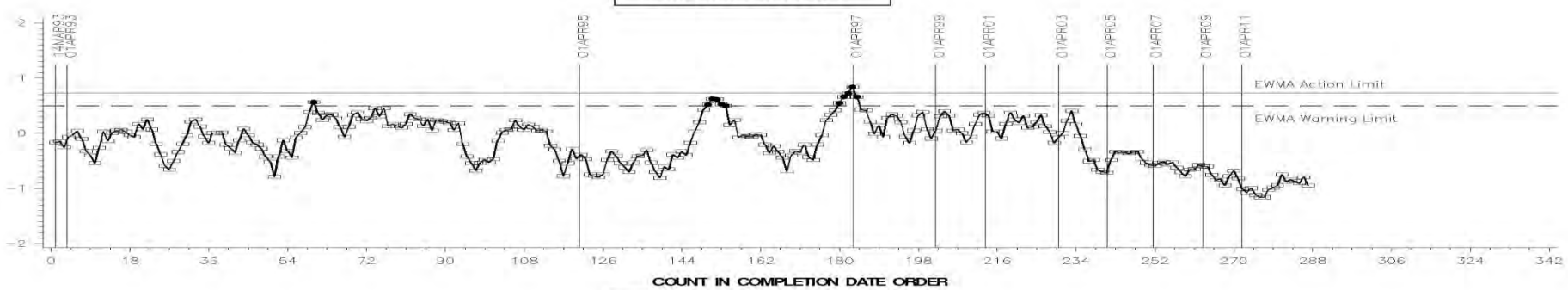
# CATERPILLAR 1N INDUSTRY OPERATIONALLY VALID DATA

## Top Groove Fill

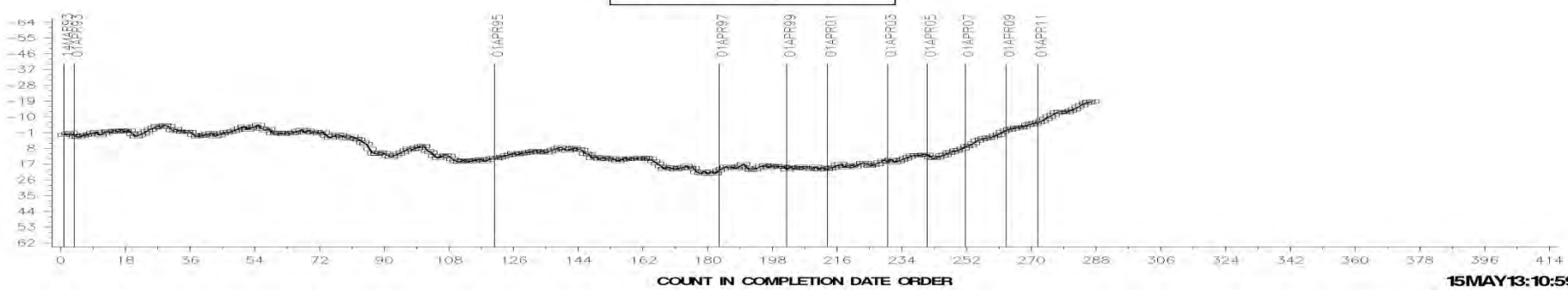
### LTMS Severity Analysis



### LTMS Precision Analysis



### CUSUM Severity Analysis



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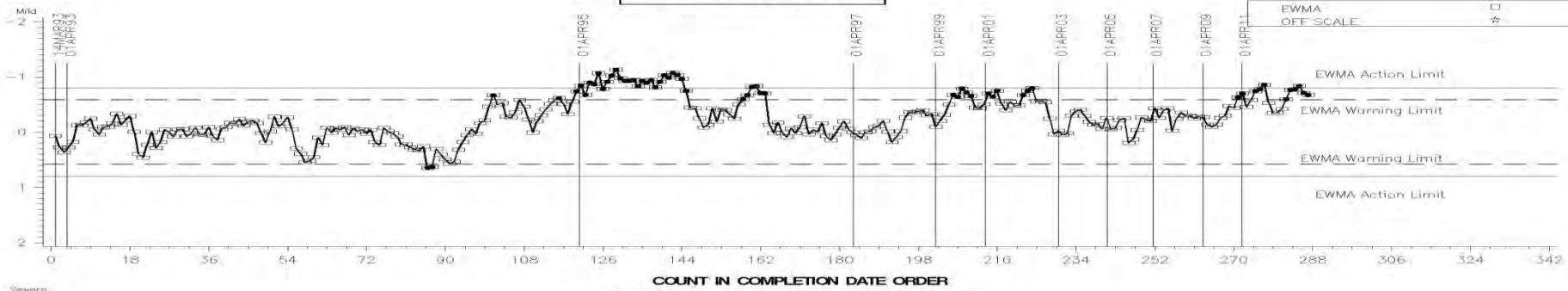


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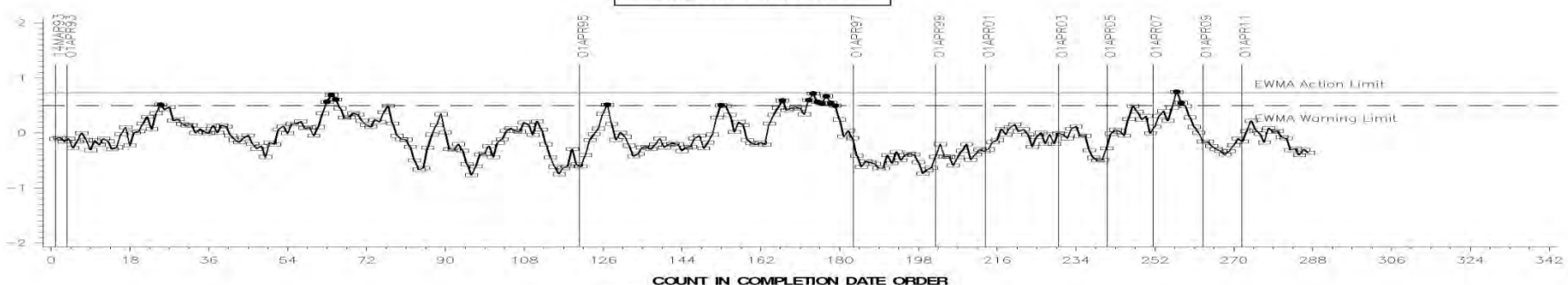
## Weighted Total Demerits

### LTMS Severity Analysis



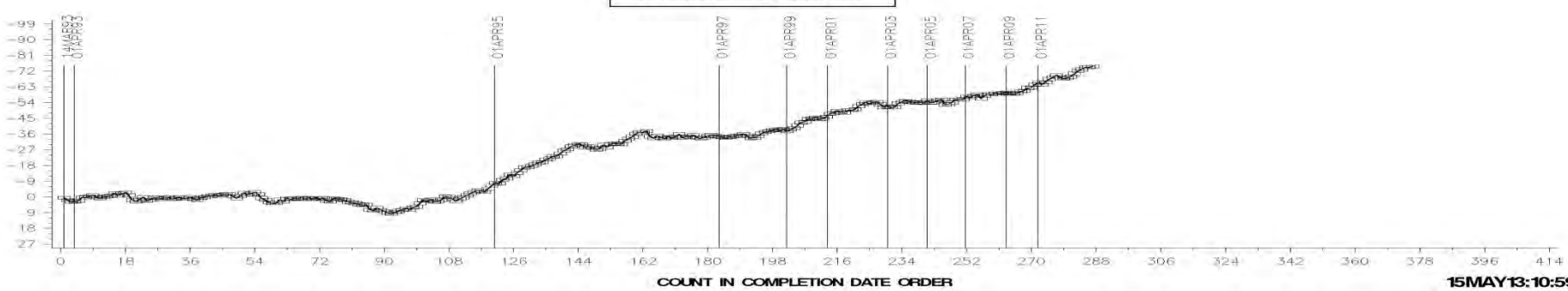
COUNT IN COMPLETION DATE ORDER

### LTMS Precision Analysis



COUNT IN COMPLETION DATE ORDER

### CUSUM Severity Analysis

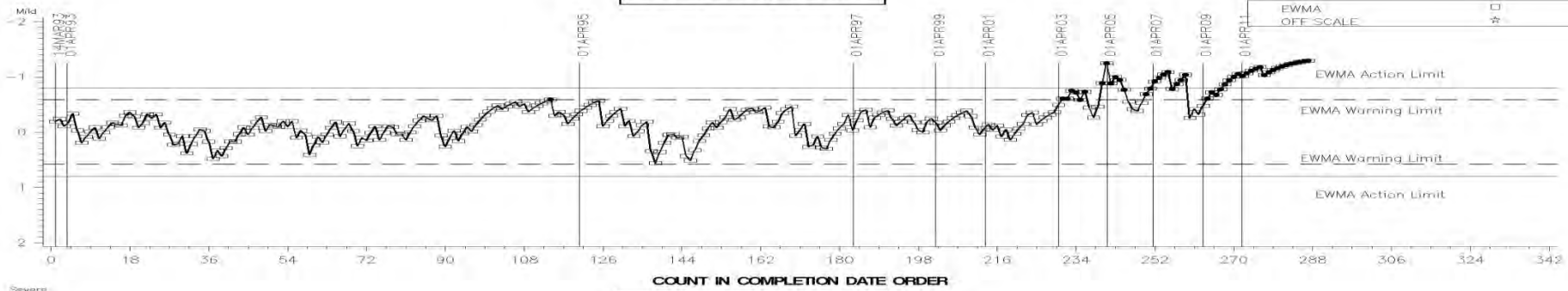


COUNT IN COMPLETION DATE ORDER

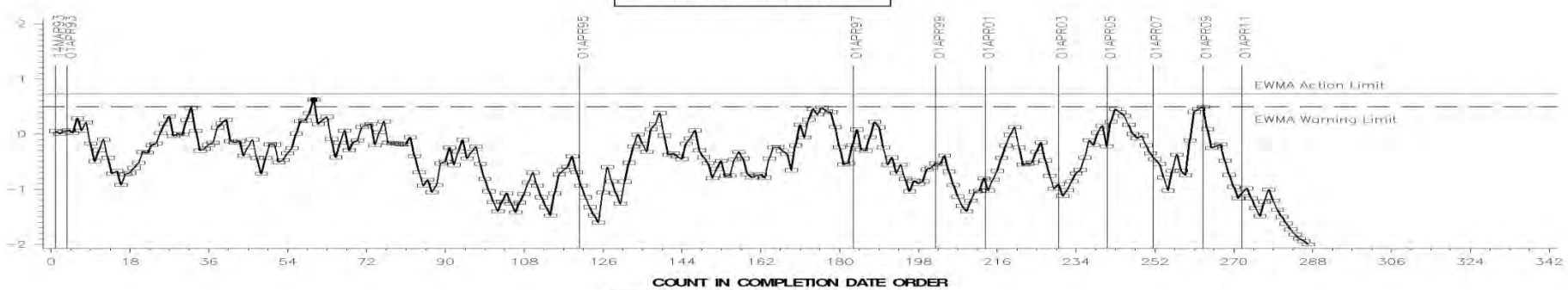
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FINAL TRANS. TOP LAND HEAVY CARBON

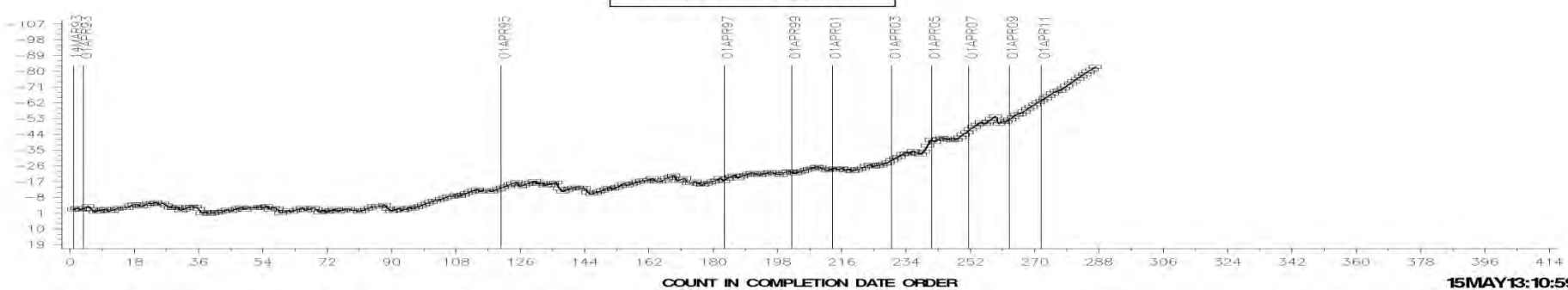
LTMS Severity Analysis



LTMS Precision Analysis



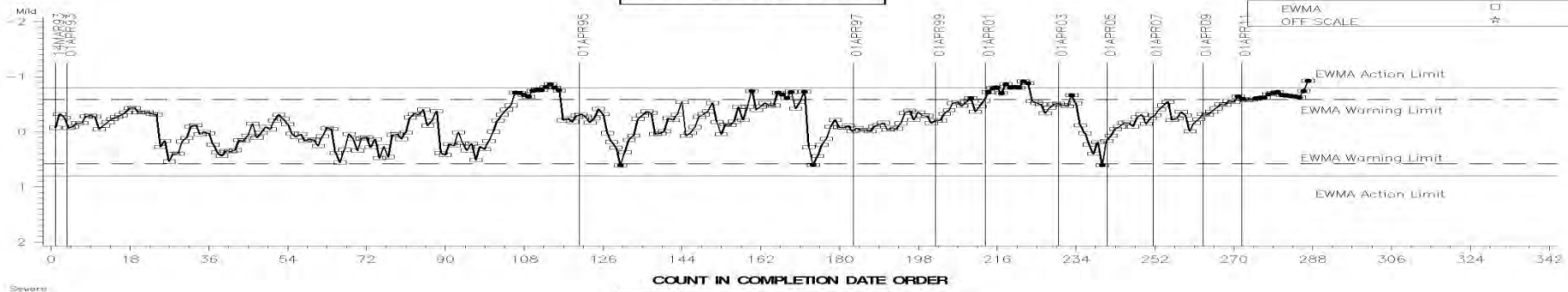
CUSUM Severity Analysis



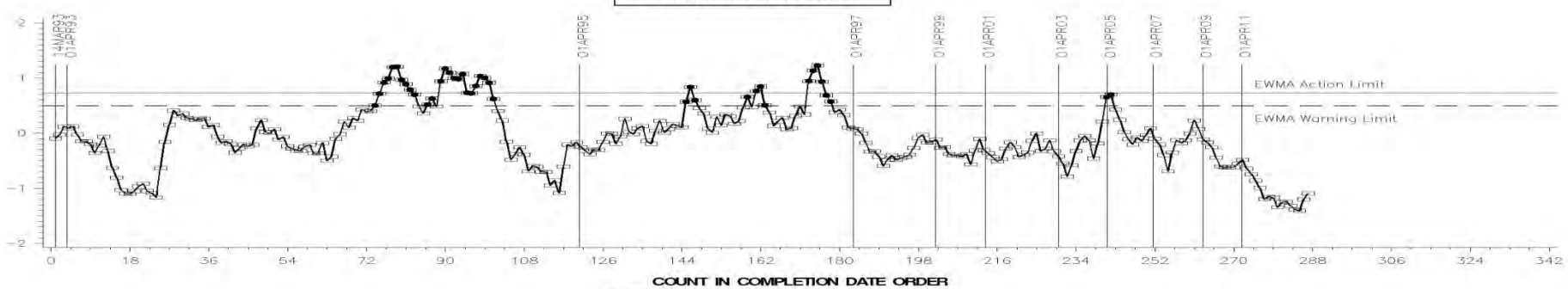
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BSOC

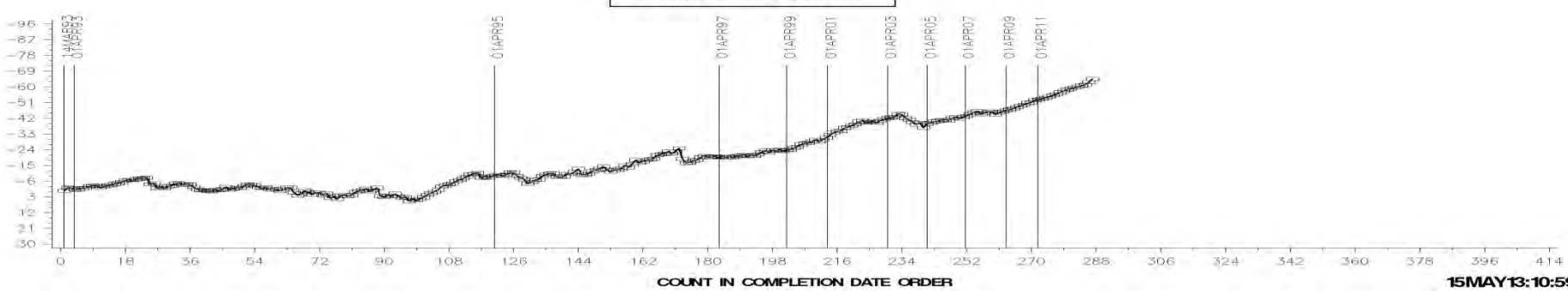
LTMS Severity Analysis



LTMS Precision Analysis



CUSUM Severity Analysis



15MAY13:10:59

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# Appendix 1.c

## 1 M-PC Control Charts

» Severity, Precision, and CuSum

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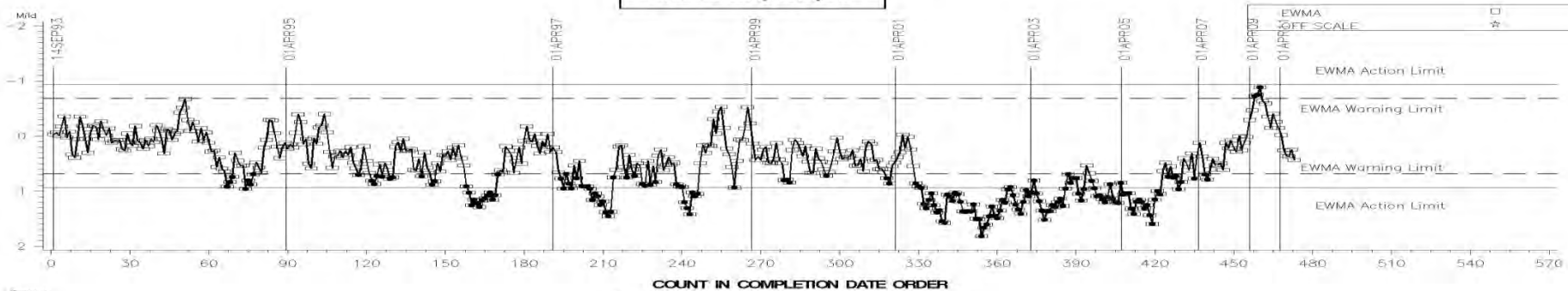


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FINAL TOP GROOVE FILLING

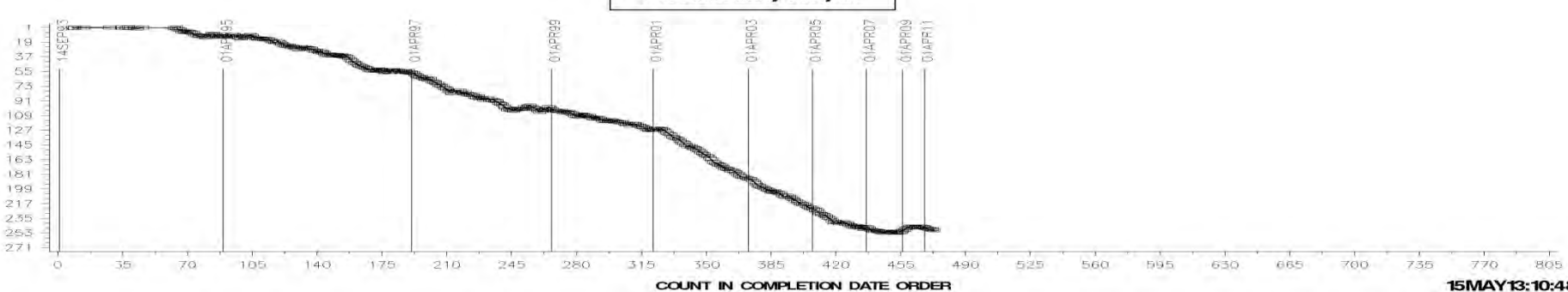
LTMS Severity Analysis



LTMS Precision Analysis



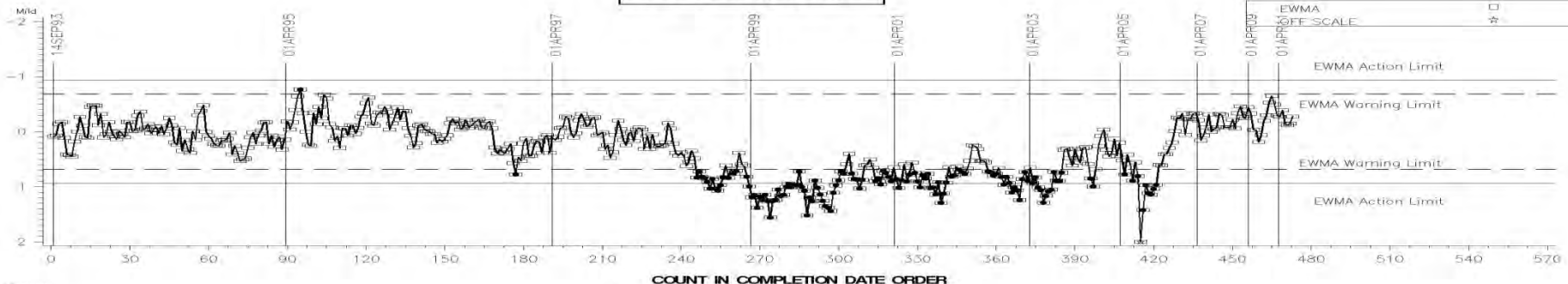
CUSUM Severity Analysis



15MAY13:10:48

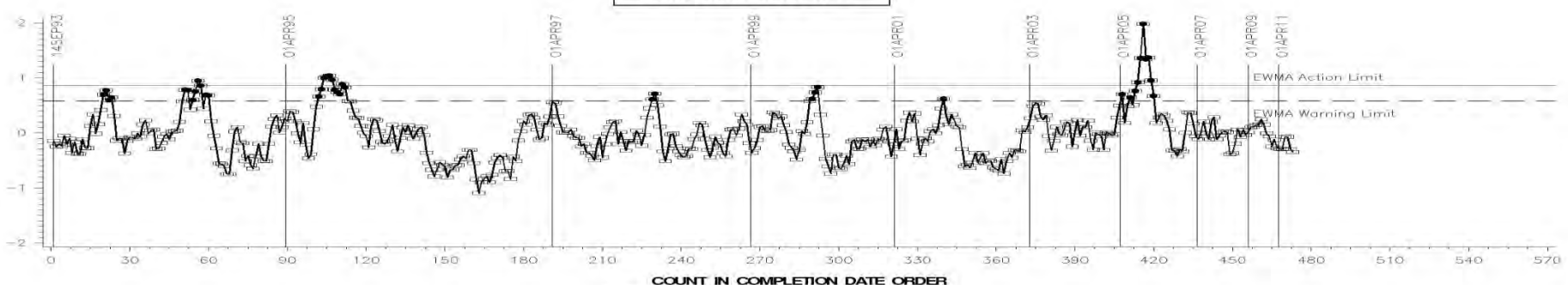
Weighted Total Demerits

LTMS Severity Analysis



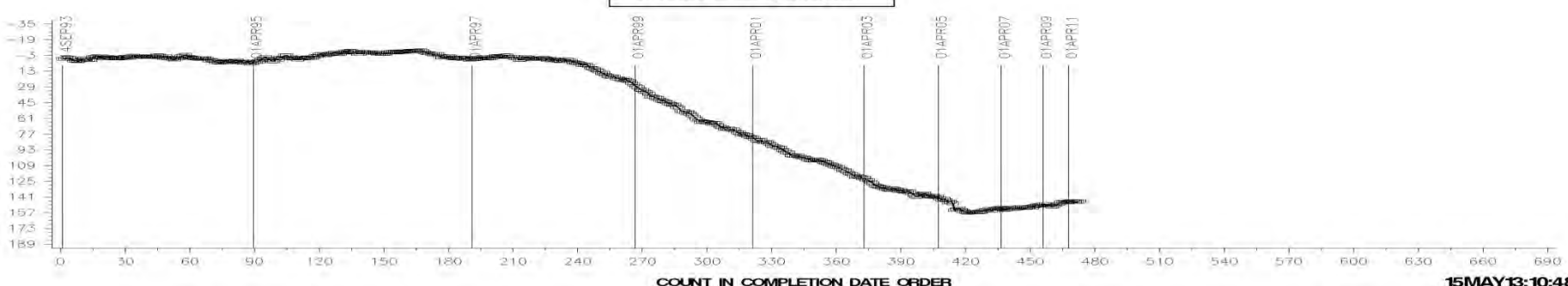
COUNT IN COMPLETION DATE ORDER

LTMS Precision Analysis



COUNT IN COMPLETION DATE ORDER

CUSUM Severity Analysis



COUNT IN COMPLETION DATE ORDER

15MAY13:10:48

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# Appendix 1.d

## 1 P Control Charts

» Severity, Precision, and CuSum

Test Monitoring Center

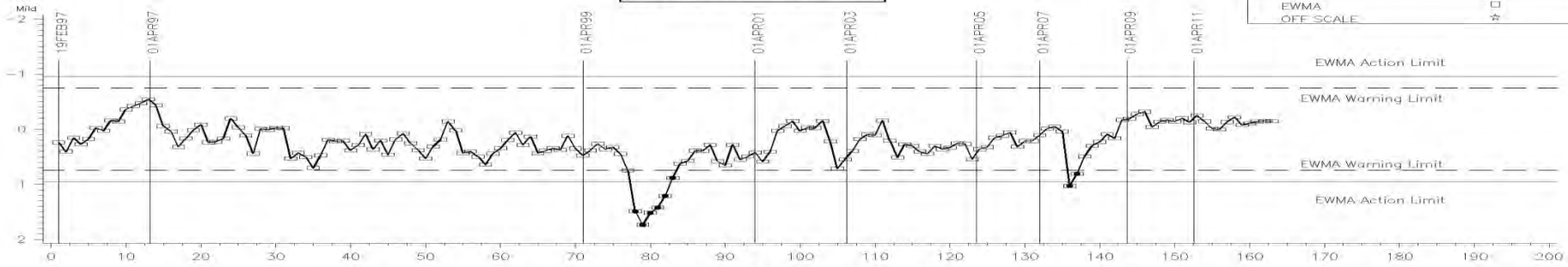
<http://astmtmc.cmu.edu>



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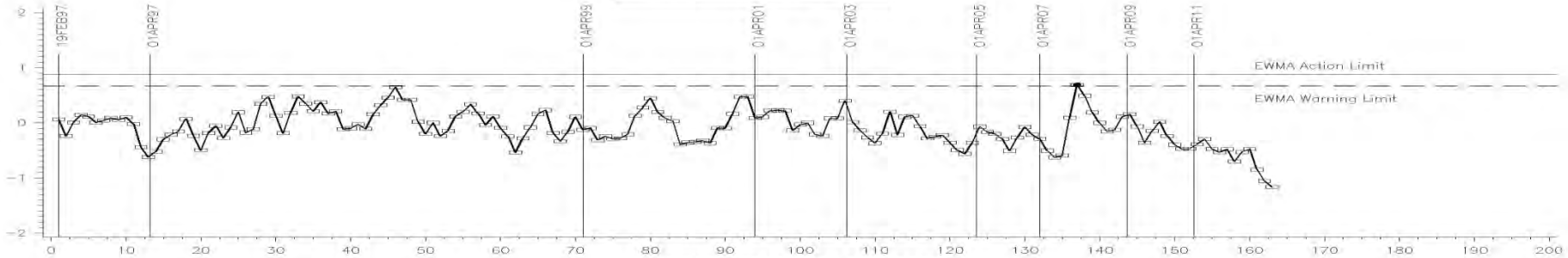
TOP GROOVE CARBON

LTMS Severity Analysis



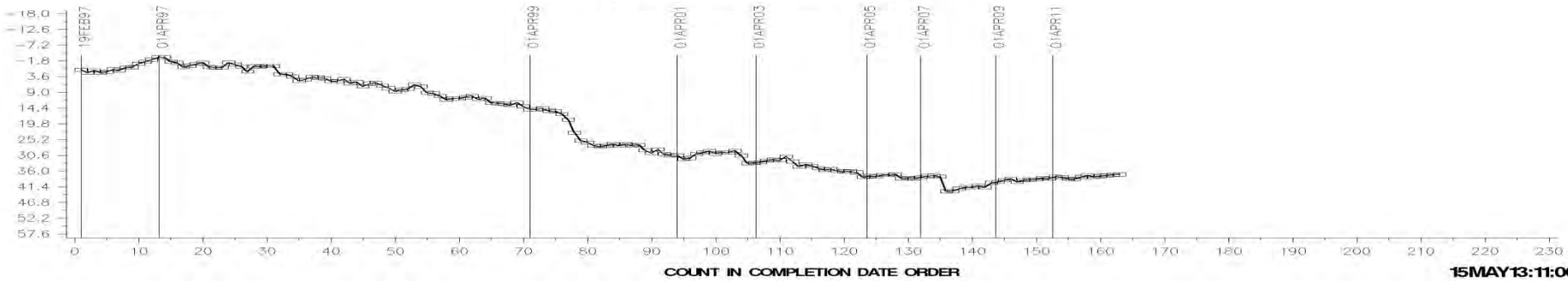
COUNT IN COMPLETION DATE ORDER

LTMS Precision Analysis



COUNT IN COMPLETION DATE ORDER

CUSUM Severity Analysis

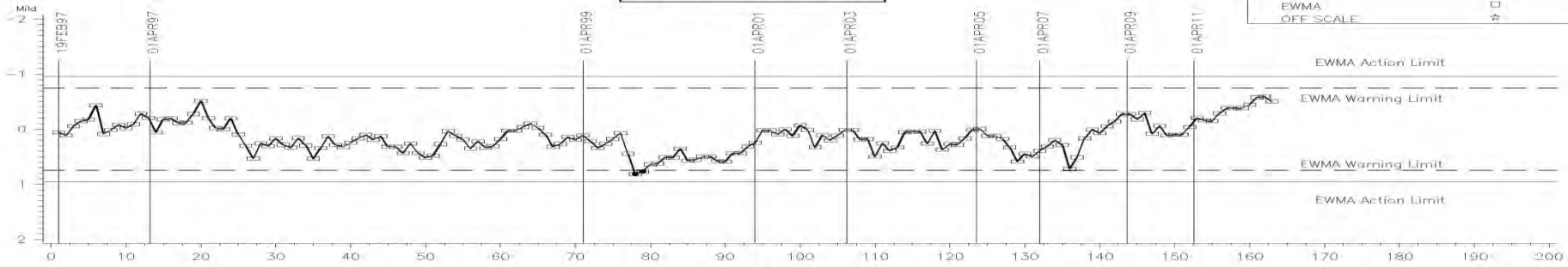


15MAY13:11:00



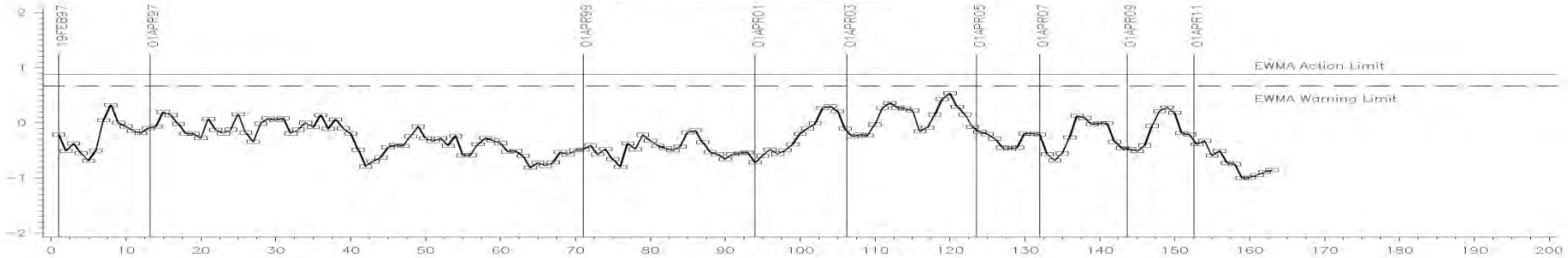
TOP LAND CARBON

LTMS Severity Analysis



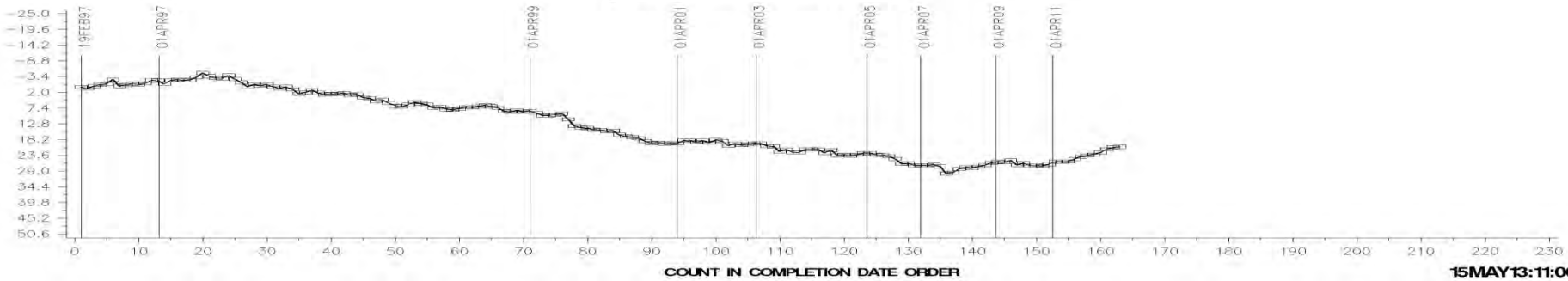
COUNT IN COMPLETION DATE ORDER

LTMS Precision Analysis



COUNT IN COMPLETION DATE ORDER

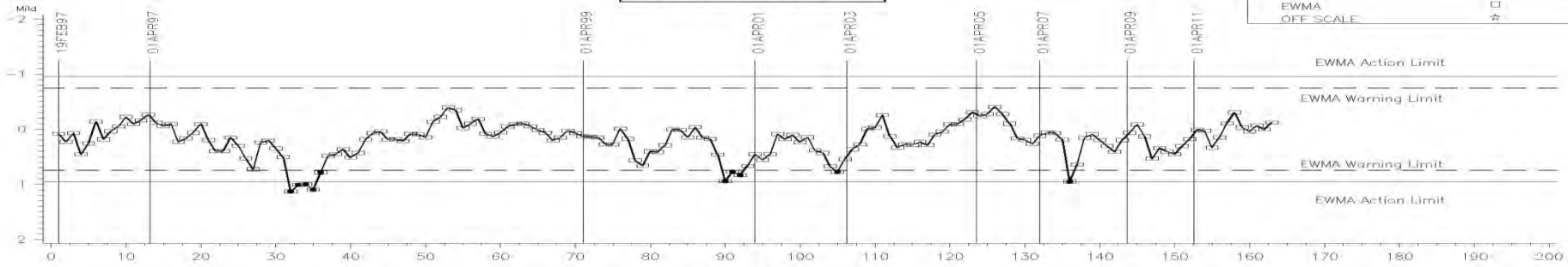
CUSUM Severity Analysis



15MAY13:11:00

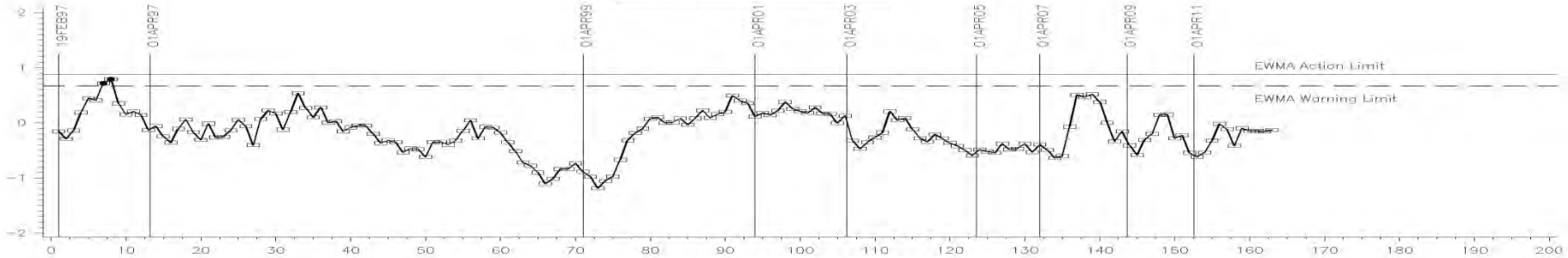
WEIGHTED TOTAL DEMERITS

LTMS Severity Analysis



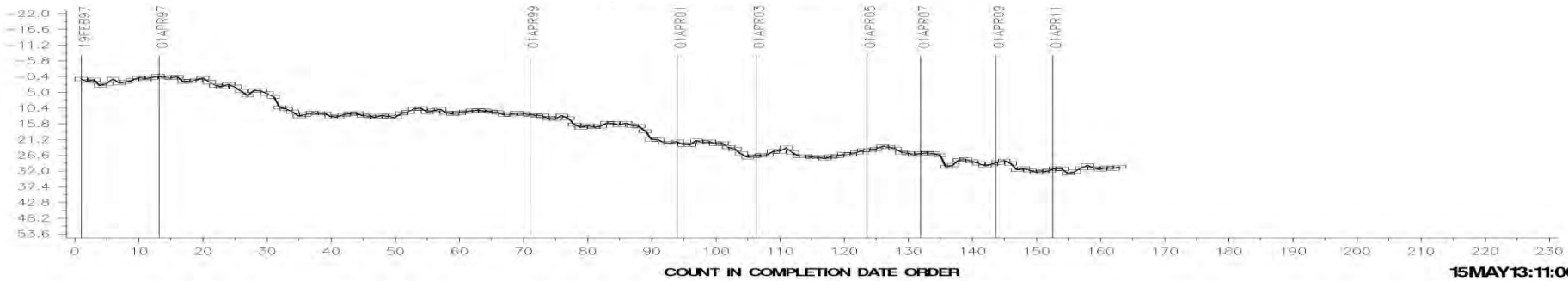
COUNT IN COMPLETION DATE ORDER

LTMS Precision Analysis



COUNT IN COMPLETION DATE ORDER

CUSUM Severity Analysis

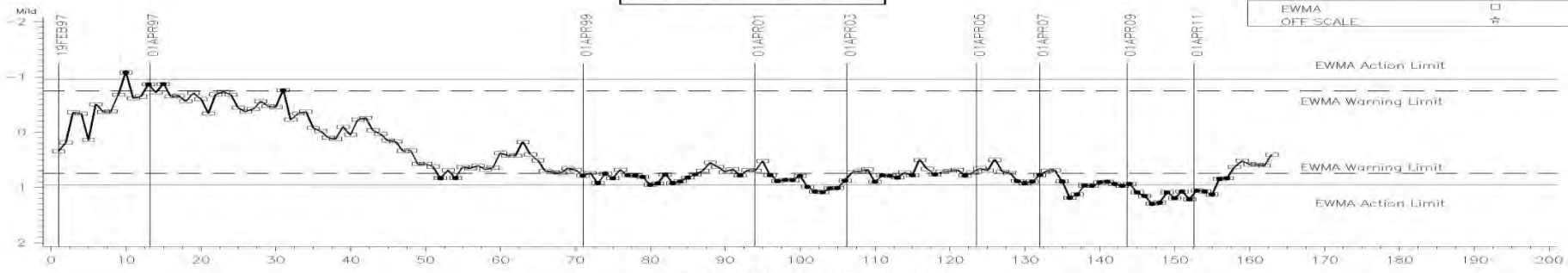


COUNT IN COMPLETION DATE ORDER

15MAY13:11:00

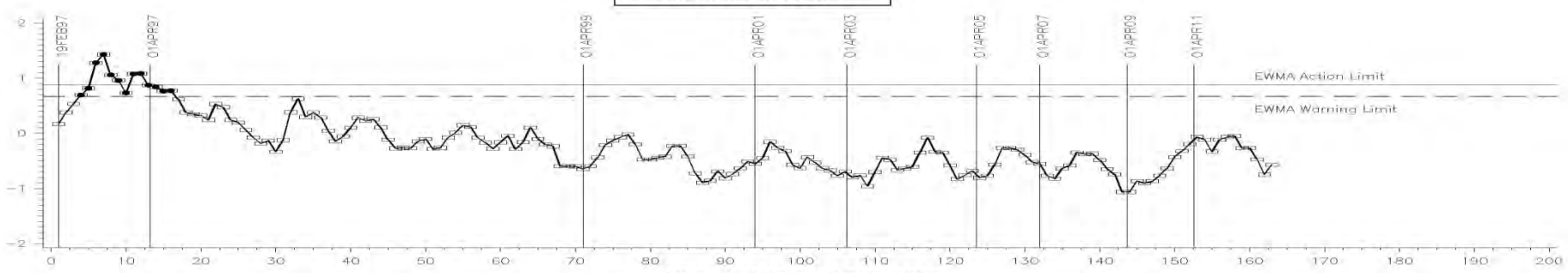
OIL CONSUMPTION

LTMS Severity Analysis



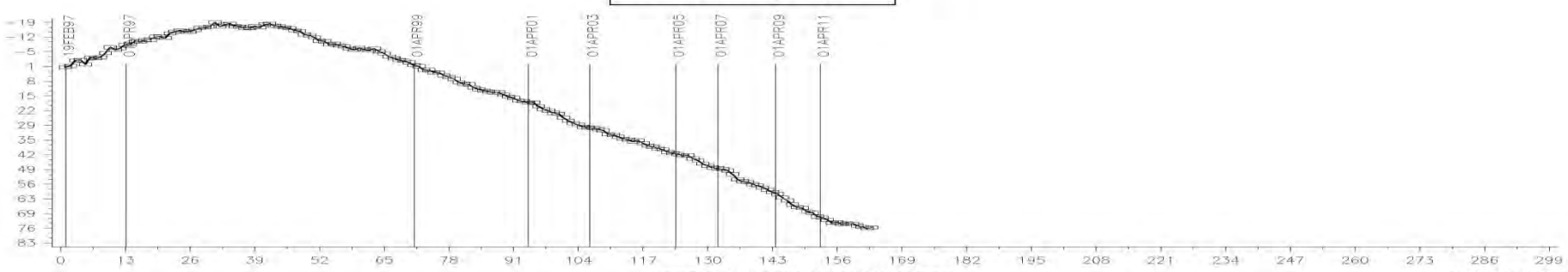
COUNT IN COMPLETION DATE ORDER

LTMS Precision Analysis



COUNT IN COMPLETION DATE ORDER

CUSUM Severity Analysis



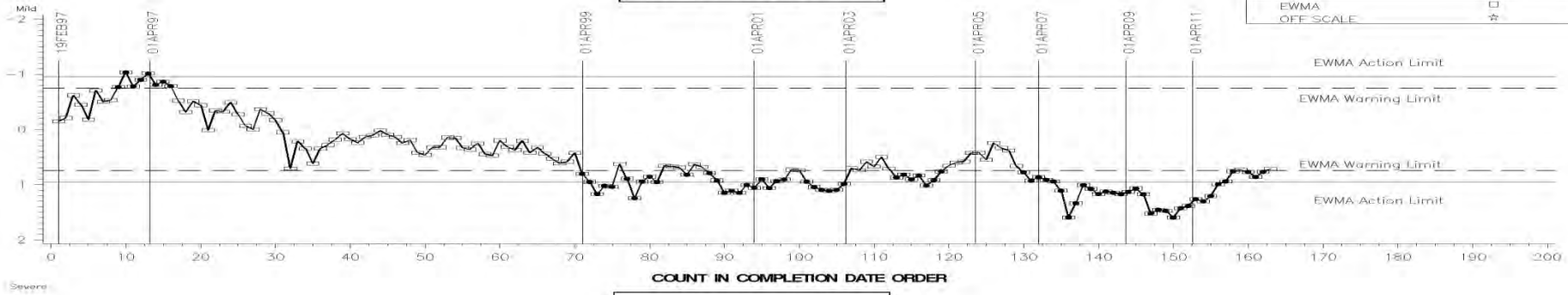
COUNT IN COMPLETION DATE ORDER

15MAY13:11:00

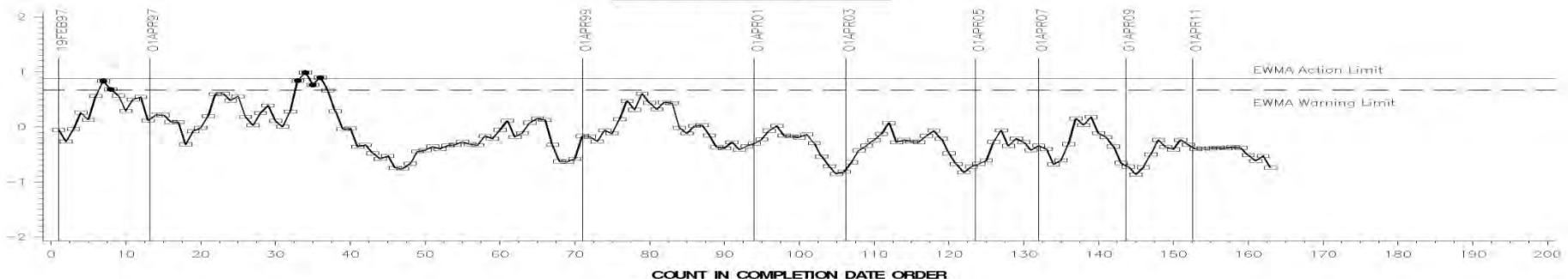


EOTOC

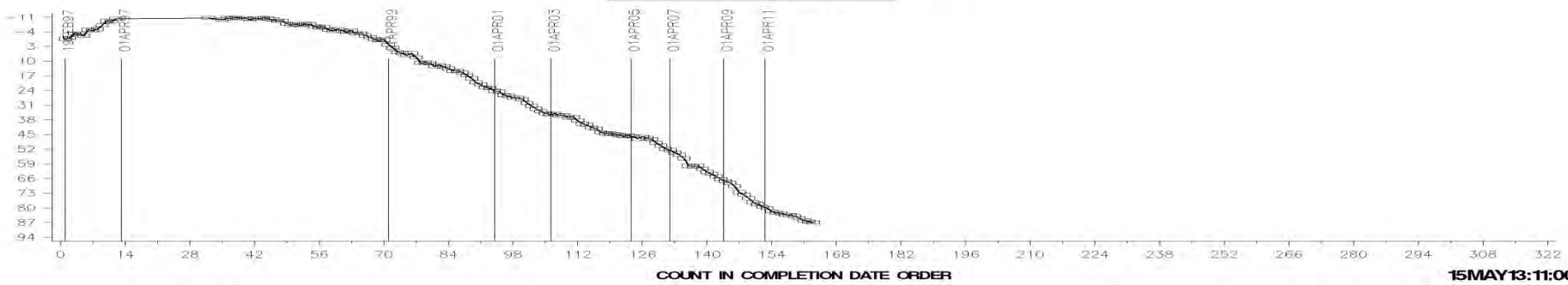
LTMS Severity Analysis



LTMS Precision Analysis



CUSUM Severity Analysis



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# Appendix 1.e

## 1 R Control Charts

» Severity, Precision, and CuSum

Test Monitoring Center

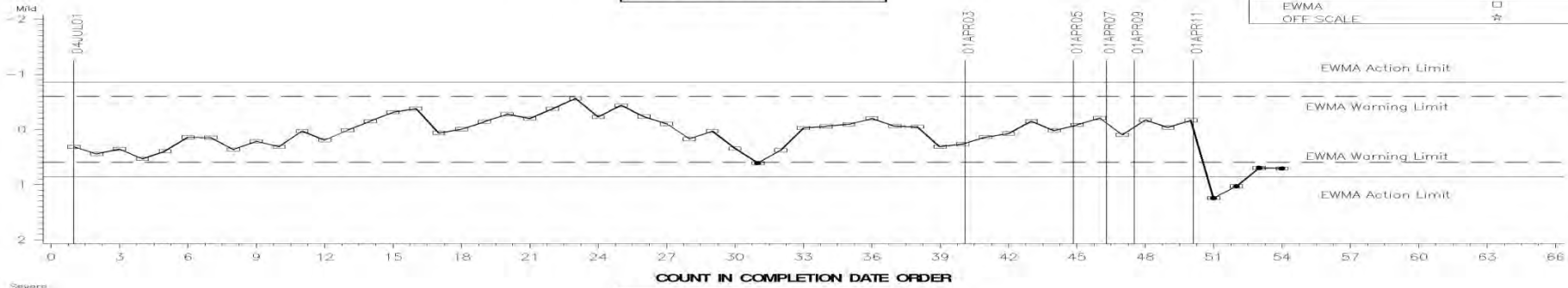
<http://astmtmc.cmu.edu>



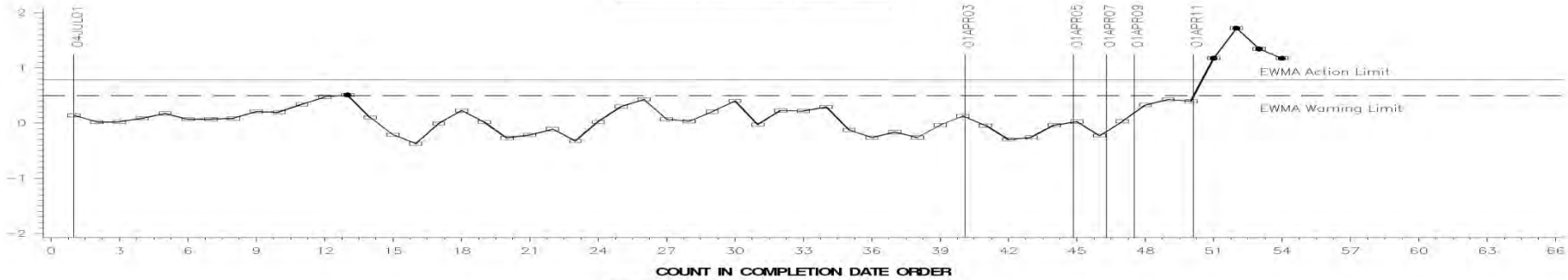
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## FINAL WEIGHTED TOTAL DEMERITS (DEMERITS)

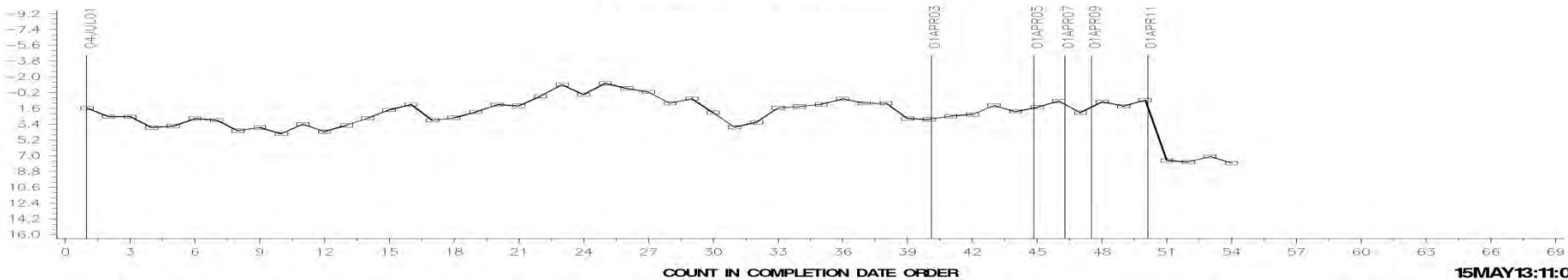
LTMS Severity Analysis



LTMS Precision Analysis



CUSUM Severity Analysis

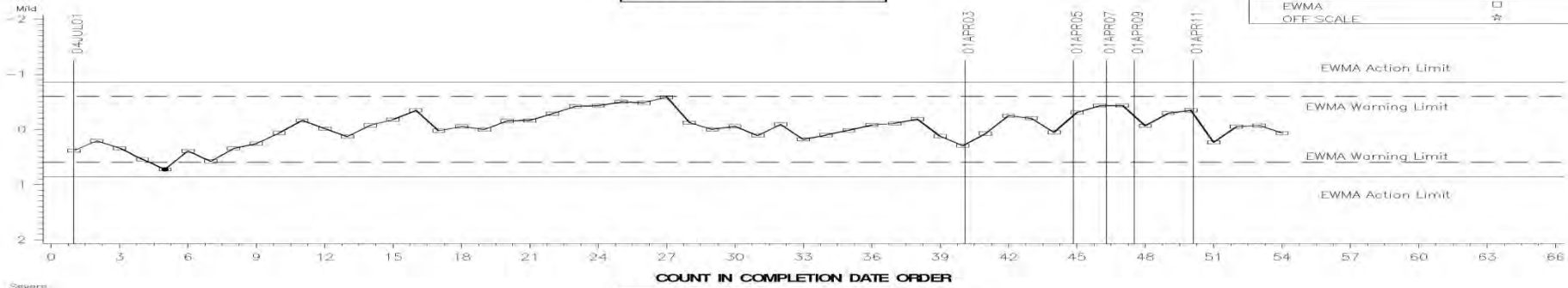


15MAY13:11:01

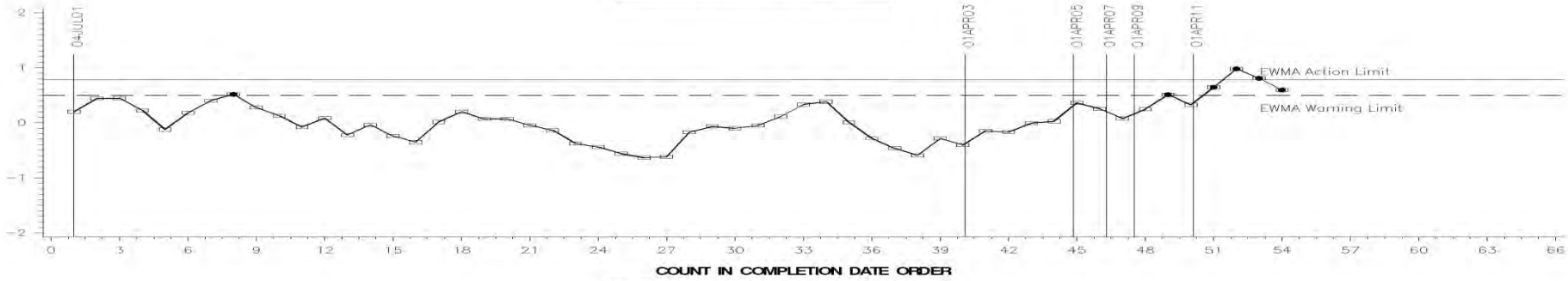
# CATERPILLAR 1R INDUSTRY OPERATIONALLY VALID DATA

## FINAL TOP GROOVE CARBON (DEMERITS)

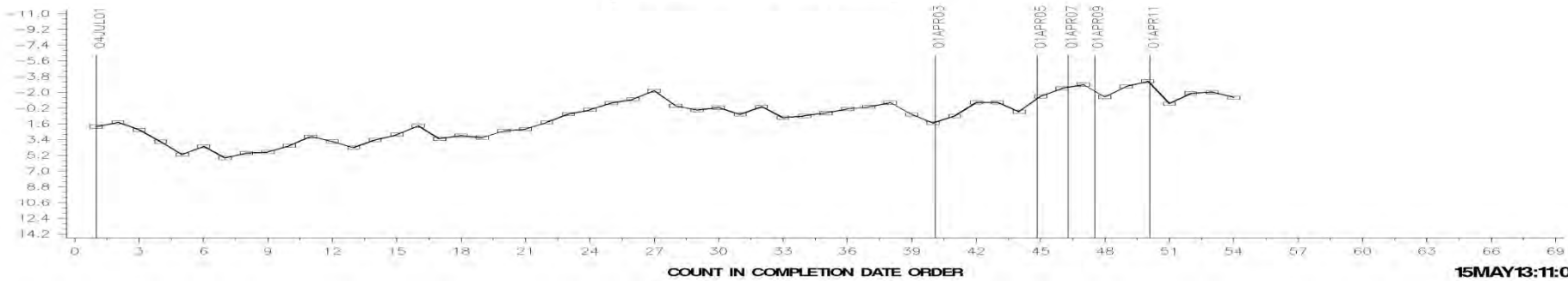
LTMS Severity Analysis



LTMS Precision Analysis



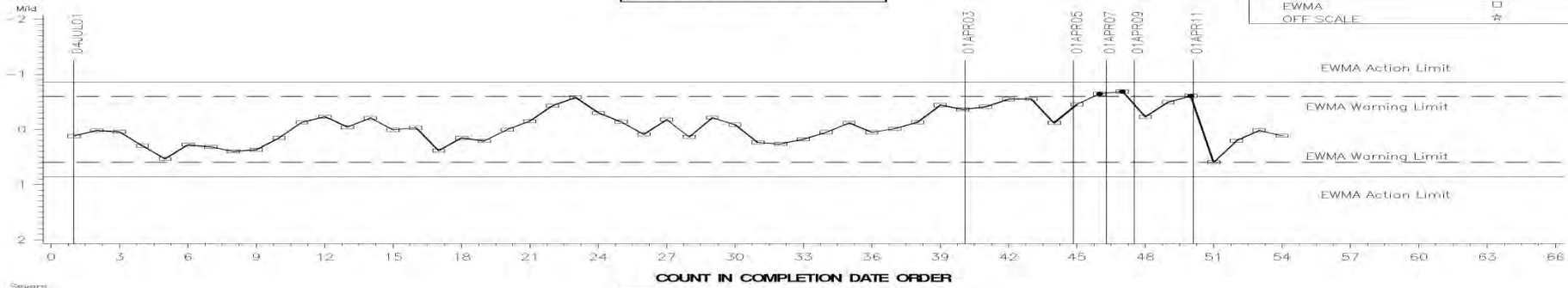
CUSUM Severity Analysis



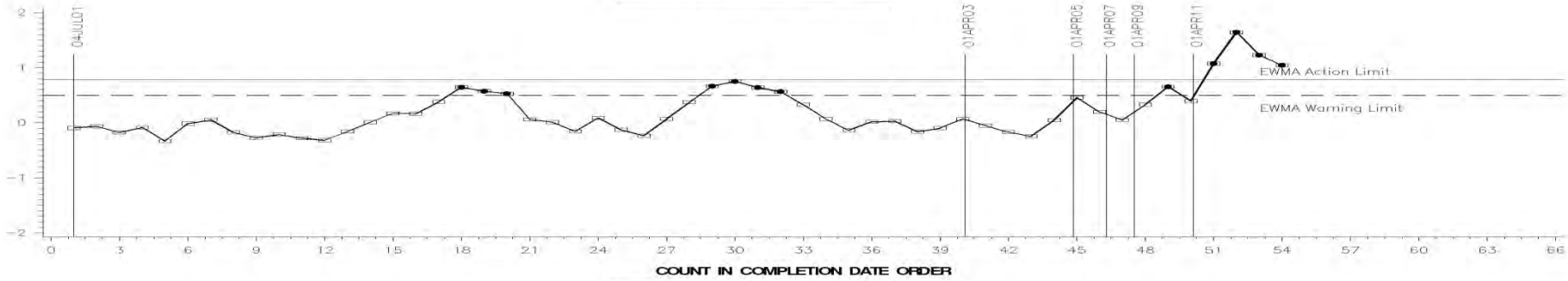
15MAY13:11:01

## FINAL TOP LAND CARBON (DEMERITS)

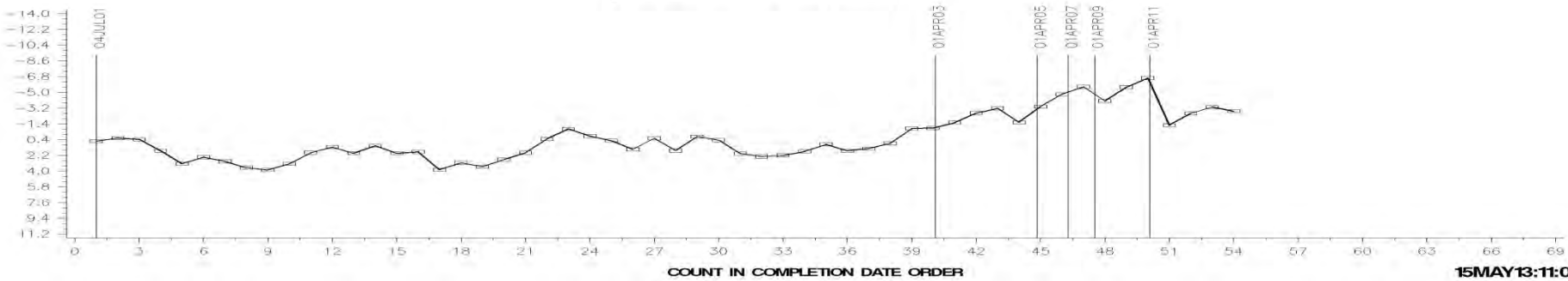
LTMS Severity Analysis



LTMS Precision Analysis



CUSUM Severity Analysis

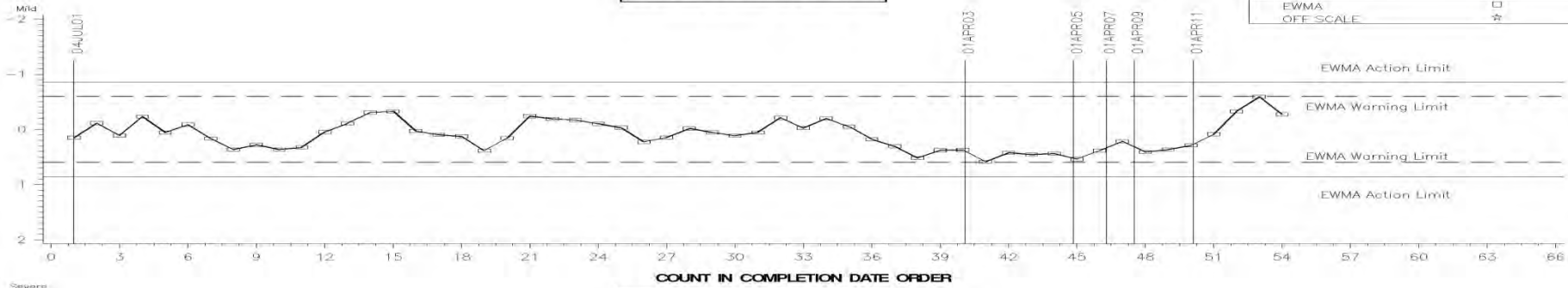


15MAY13:11:01

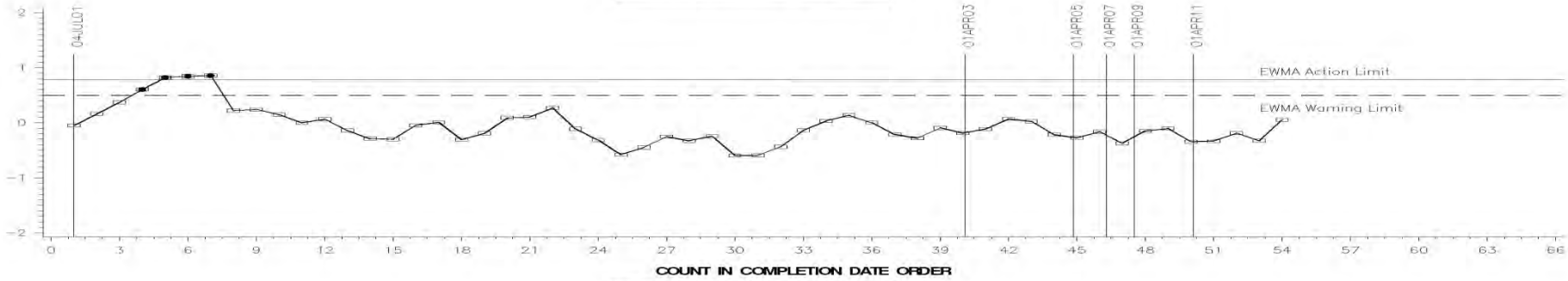


## FINAL BOTOC

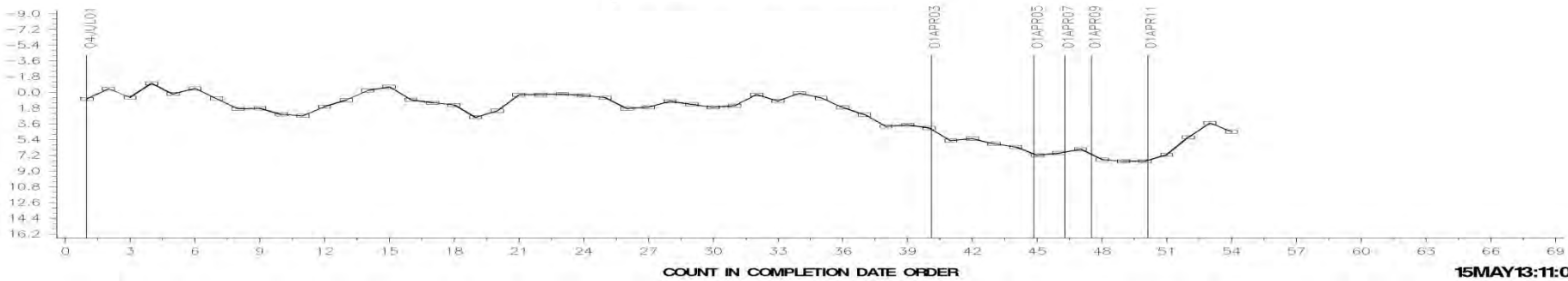
### LTMS Severity Analysis



### LTMS Precision Analysis



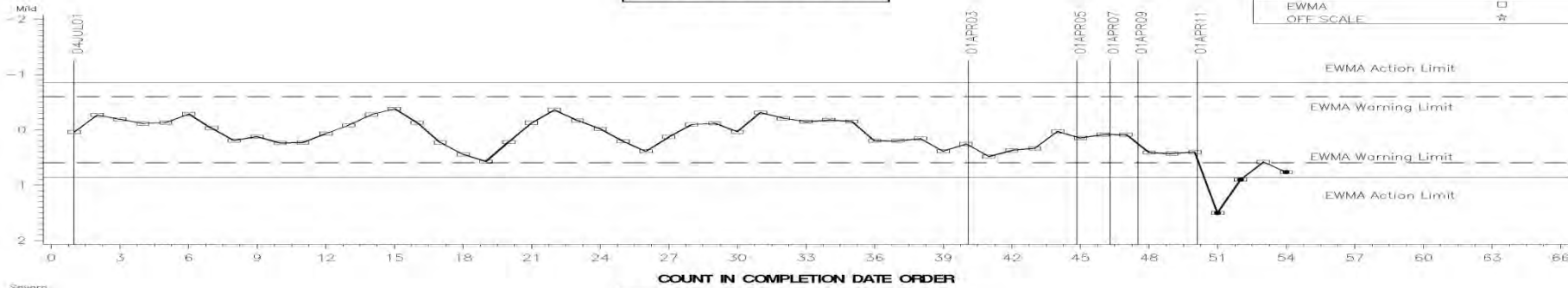
### CUSUM Severity Analysis



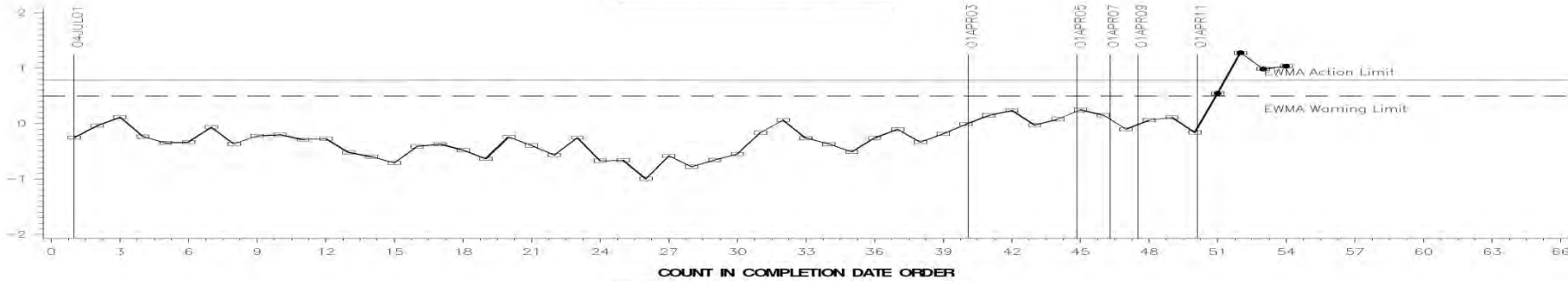
15MAY13:11:01

FINAL EOTOC (g/h)

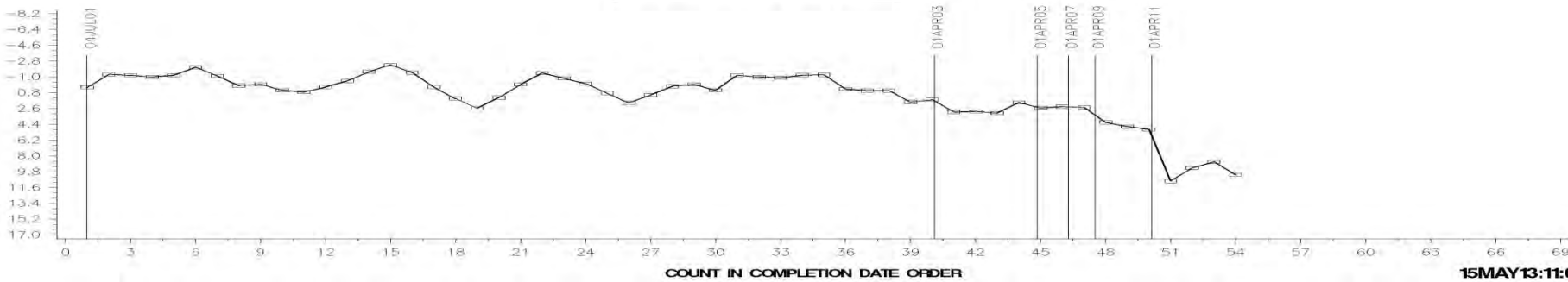
LTMS Severity Analysis



LTMS Precision Analysis



CUSUM Severity Analysis



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# Appendix 1.f

## C13 Control Charts

» Severity and CuSum

Test Monitoring Center

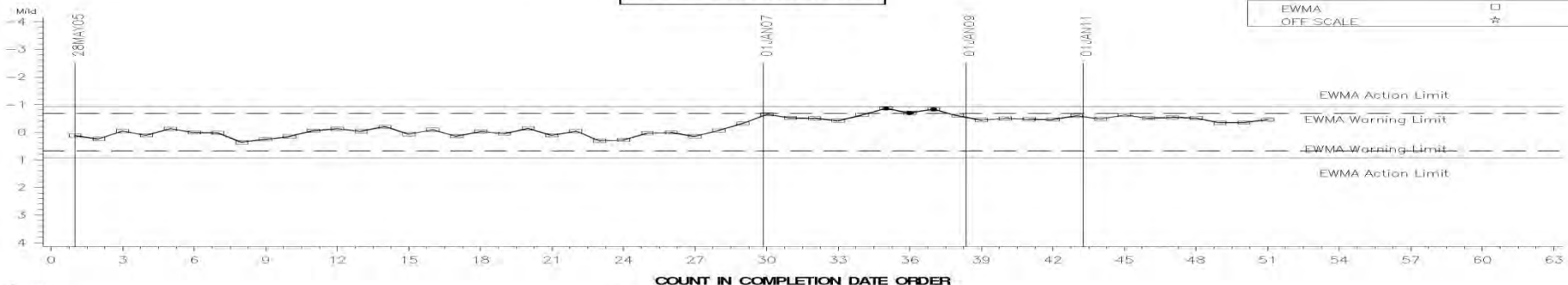
<http://astmtmc.cmu.edu>



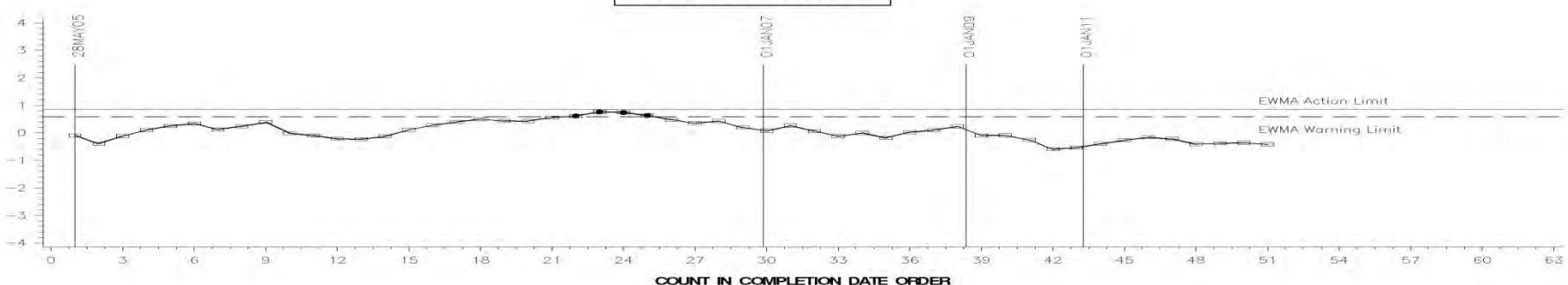
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TOP LAND CARBON AVG. — FINAL RESULT

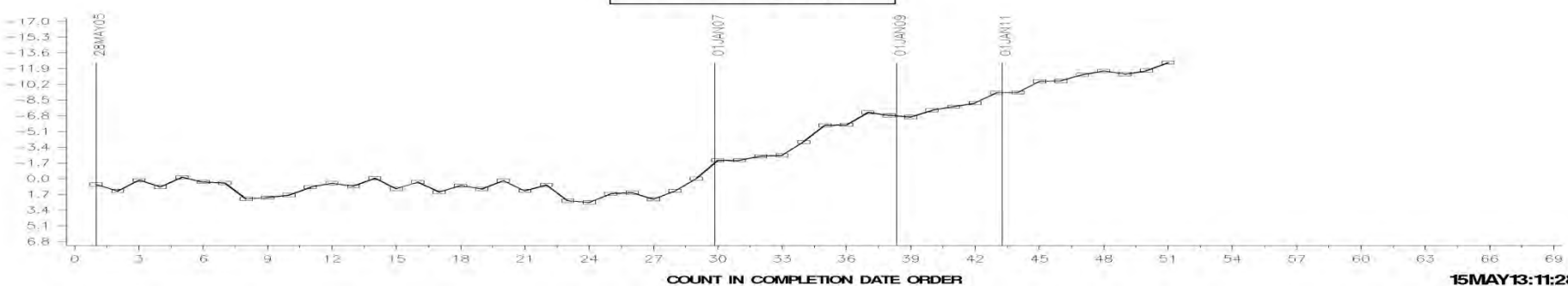
LTMS Severity Analysis



LTMS Precision Analysis



CUSUM Severity Analysis



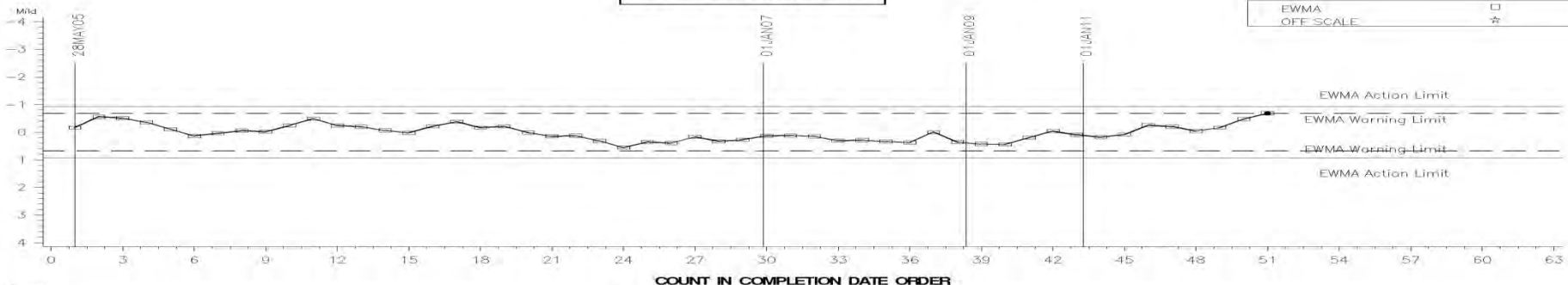
15MAY13:11:28



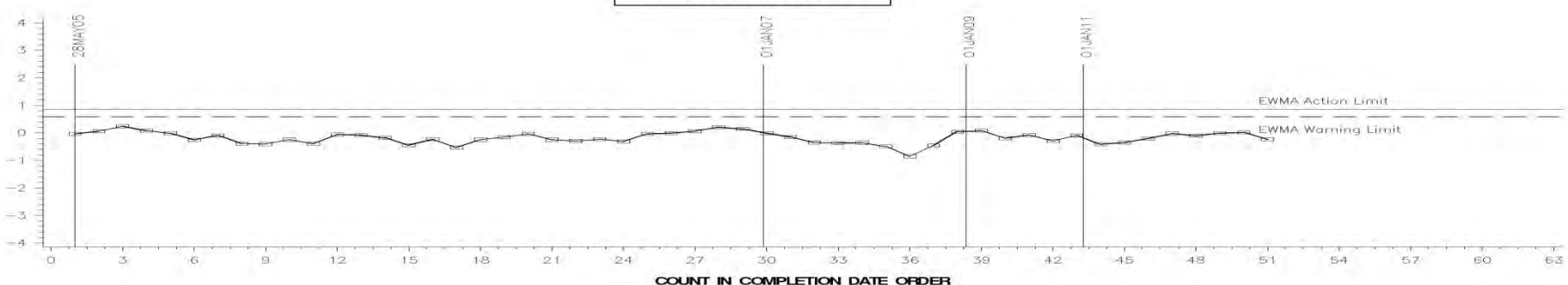
# C13 INDUSTRY OPERATIONALLY VALID DATA

## TOP GROOVE CARBON AVG — FINAL RESULT

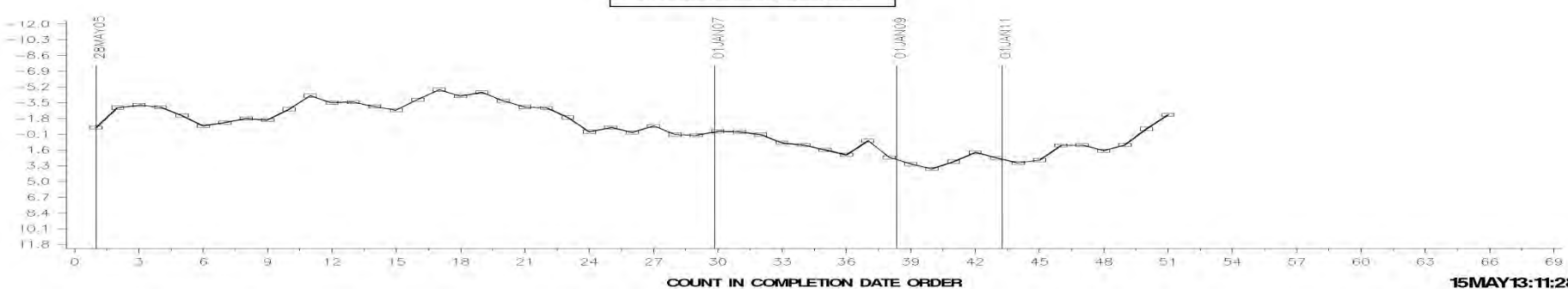
LTMS Severity Analysis



LTMS Precision Analysis



CUSUM Severity Analysis

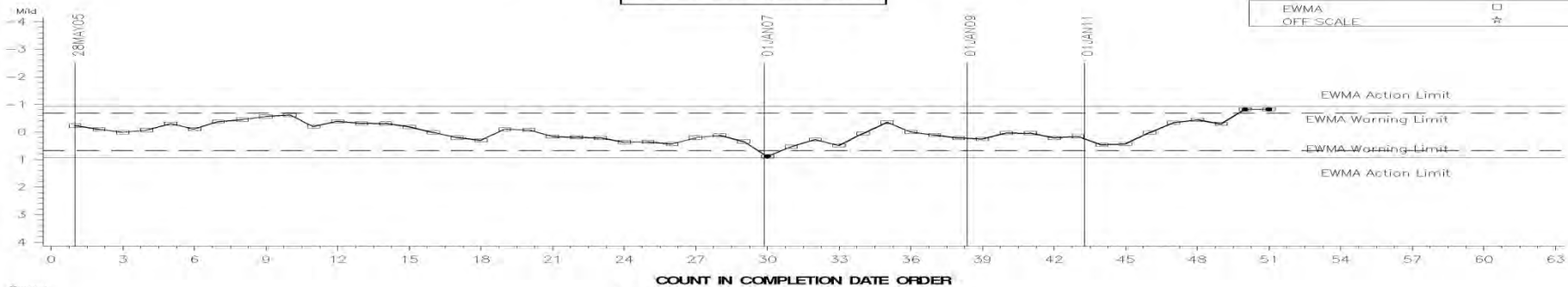


15MAY13:11:28

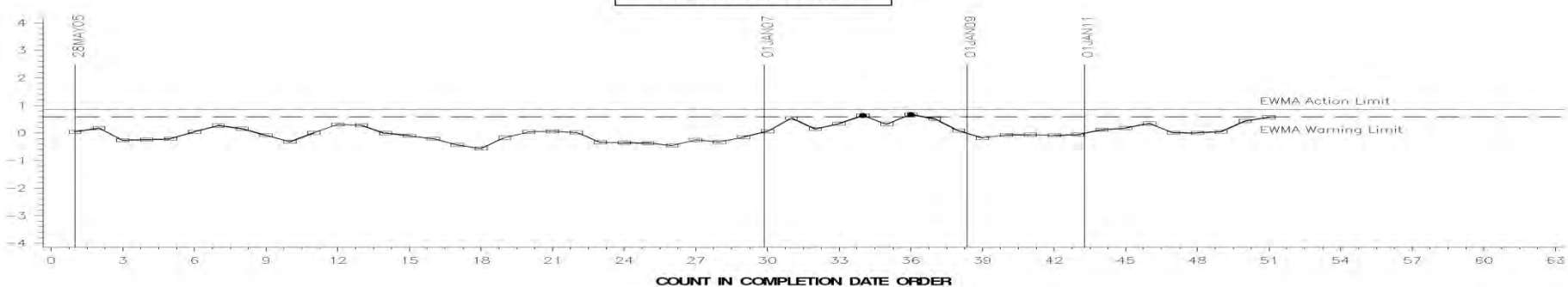
# C13 INDUSTRY OPERATIONALLY VALID DATA

## 2ND RING TOP CARBON AVG. — FINAL RESULT

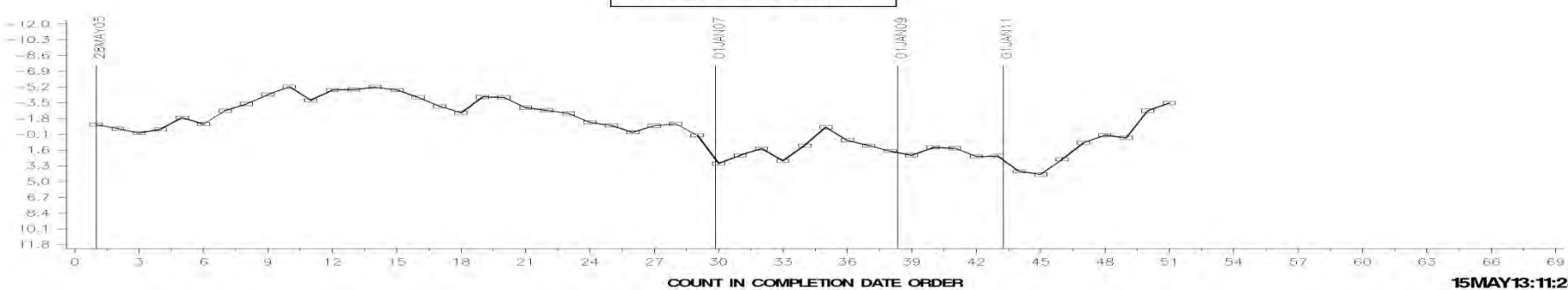
LTMS Severity Analysis



LTMS Precision Analysis



CUSUM Severity Analysis

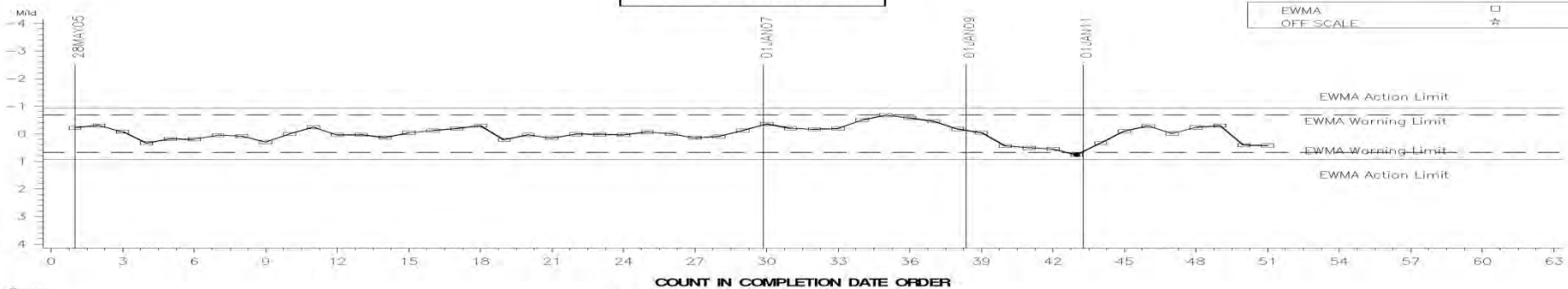


15MAY13:11:28

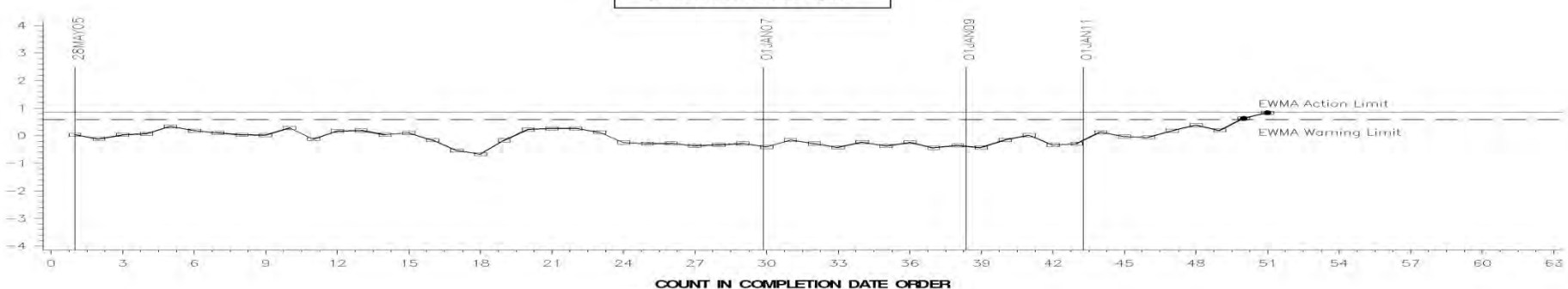
# C13 INDUSTRY OPERATIONALLY VALID DATA

## OIL CONS. DELTA — FINAL RESULT

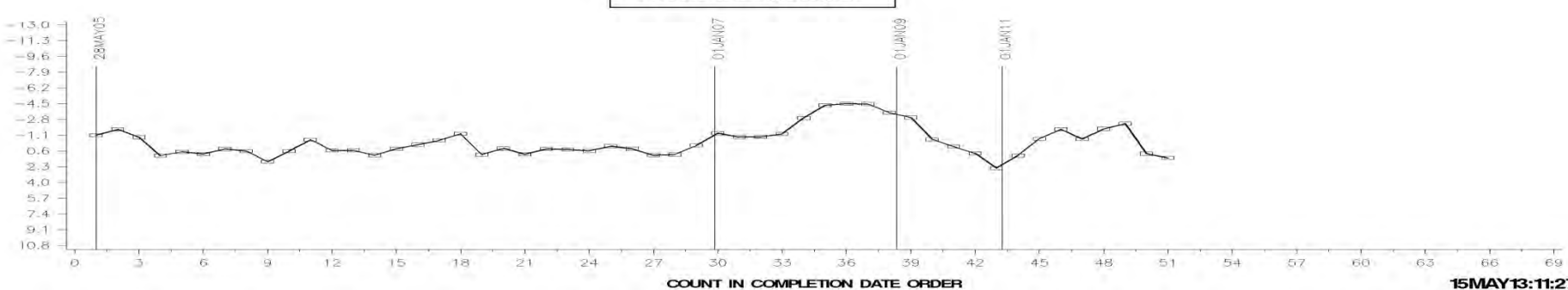
LTMS Severity Analysis



LTMS Precision Analysis



CUSUM Severity Analysis



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# Appendix 1.g

## ISB Control Charts

» Severity and CuSum

Test Monitoring Center

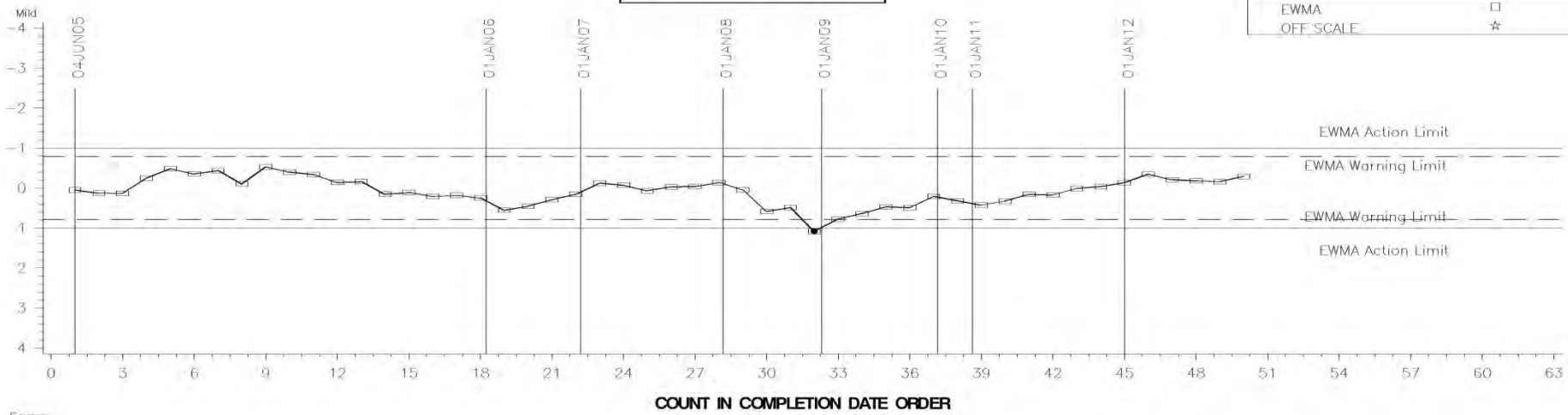
<http://astmtmc.cmu.edu>



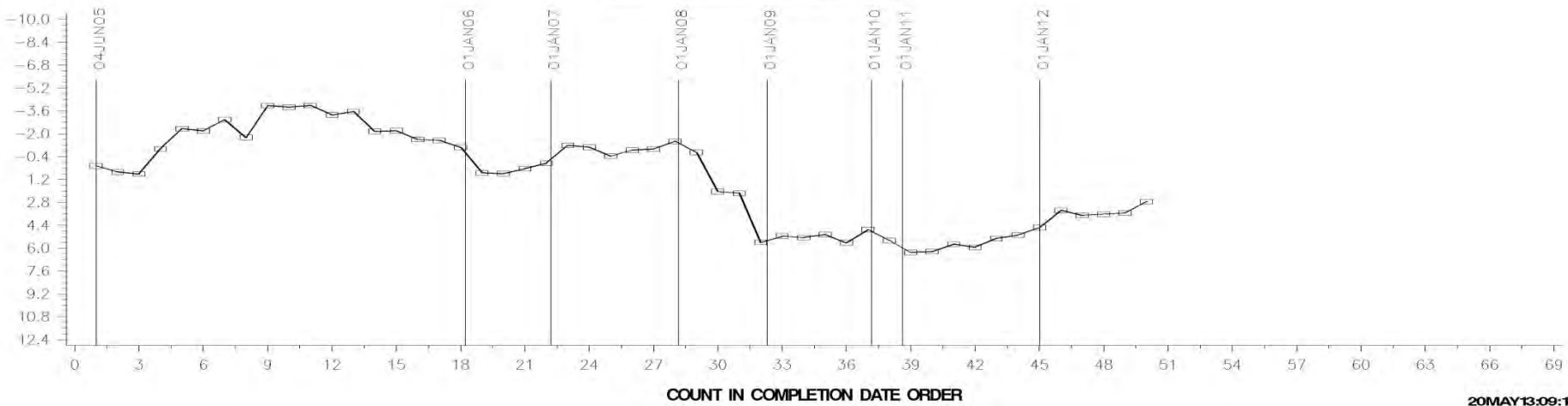
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AVERAGE CAMSHAFT WEAR

LTMS Severity Analysis



CUSUM Severity Analysis

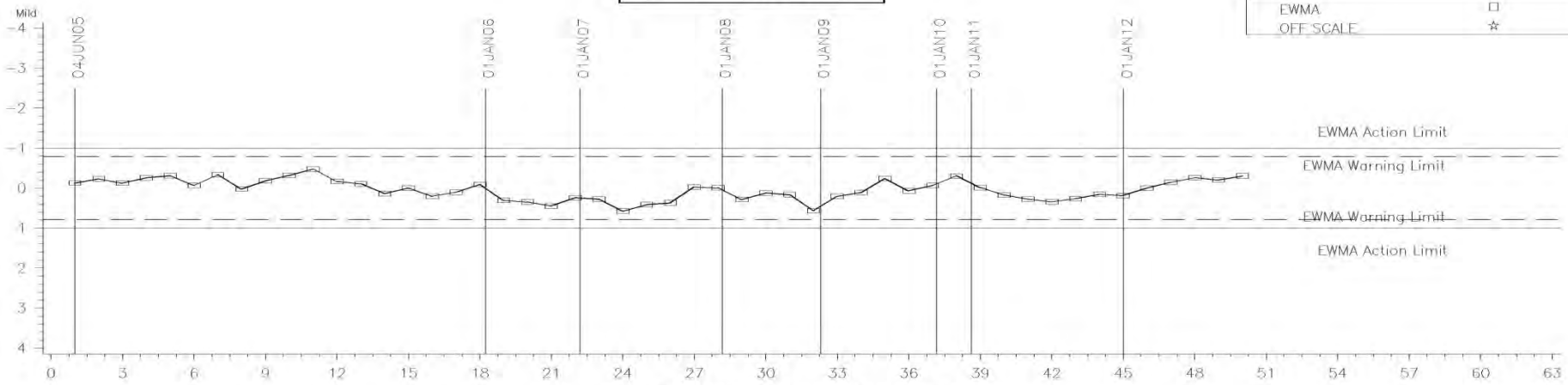


20MAY13:09:18

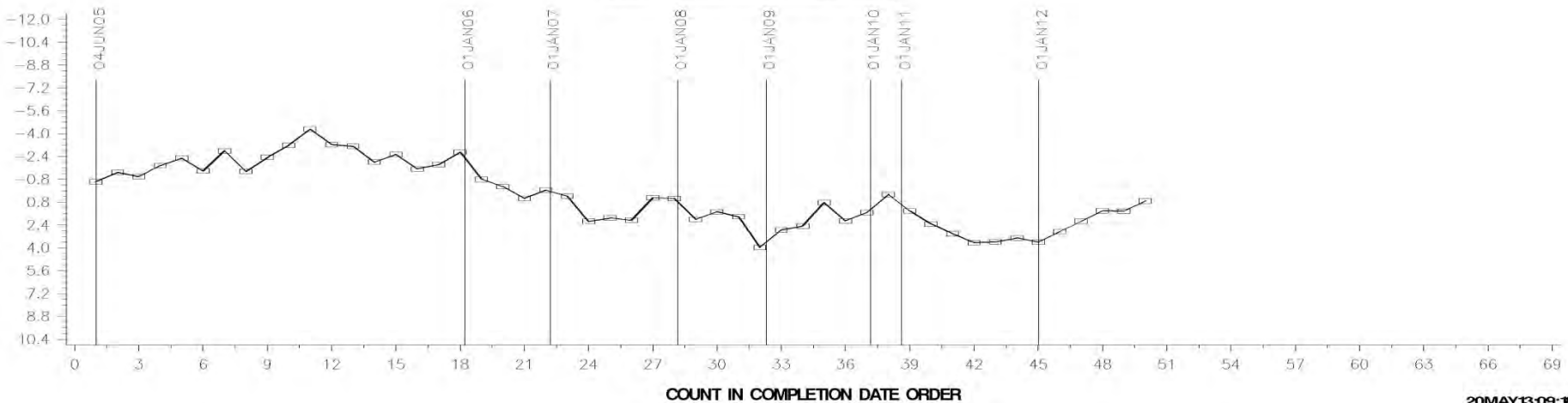


AVERAGE TAPPET WEIGHT LOSS

LTMS Severity Analysis



CUSUM Severity Analysis



20MAY13:09:18

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# Appendix 1.h

## ISM Control Charts

» Severity and CuSum

Test Monitoring Center

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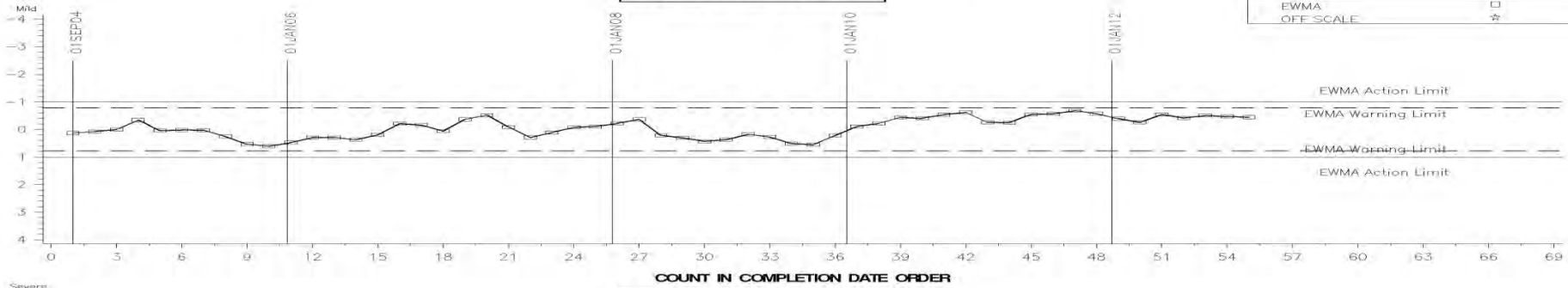


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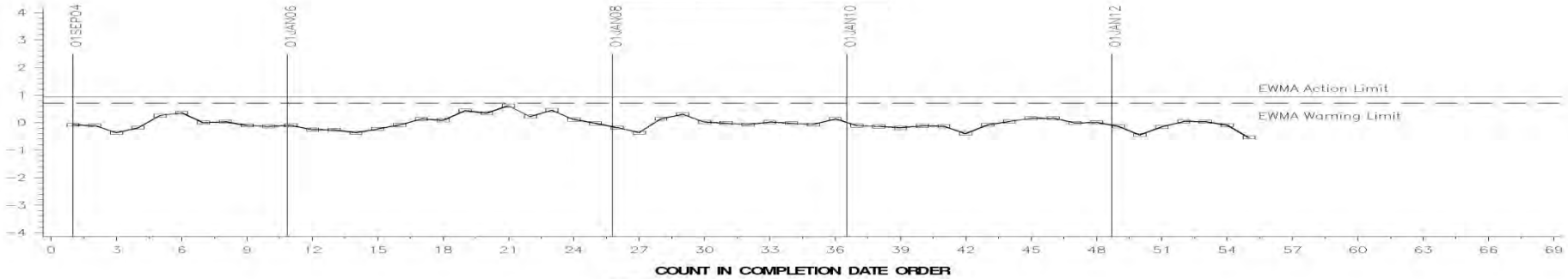
# ISM INDUSTRY OPERATIONALLY VALID DATA

## CROSSHEAD WEIGHT LOSS ADJUSTED TO 3.9 % SOOT

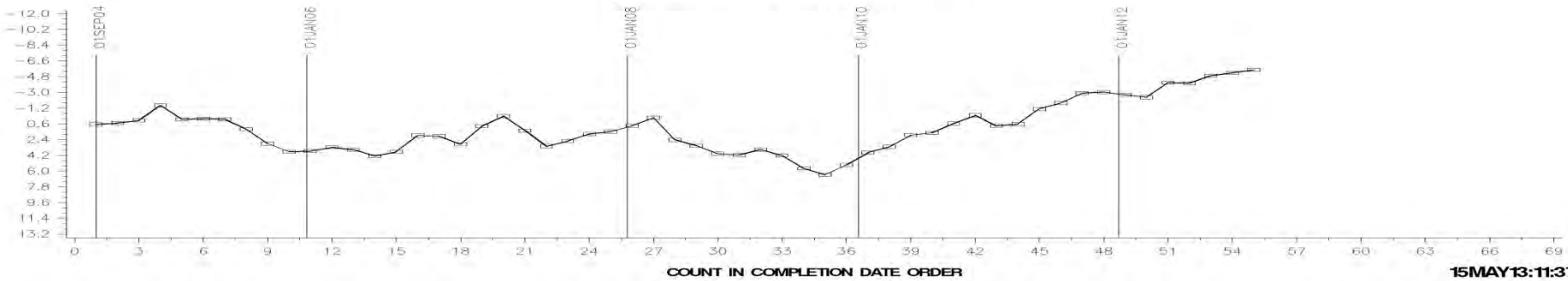
LTMS Severity Analysis



LTMS Precision Analysis



CUSUM Severity Analysis

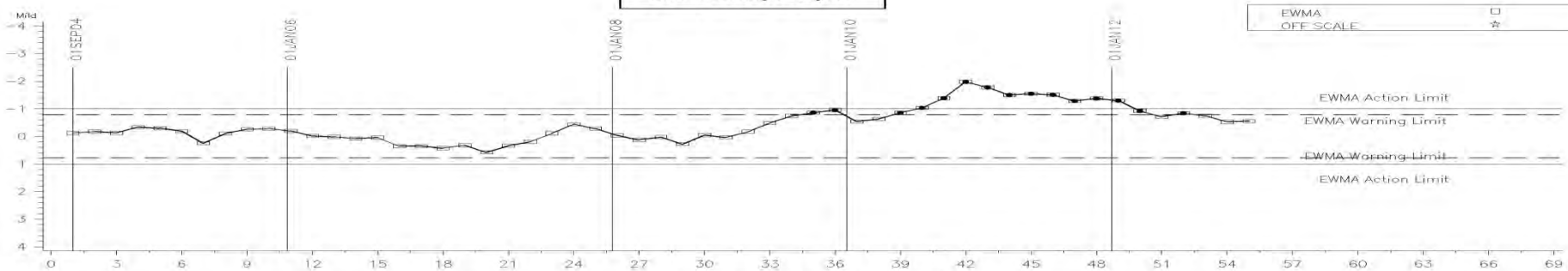


15MAY13:11:37



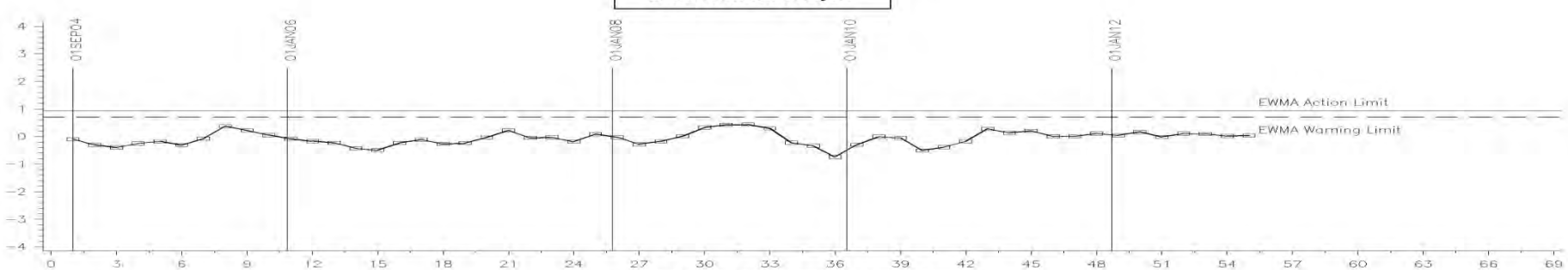
## FILTER PLUGGING DELTA P

### LTMS Severity Analysis



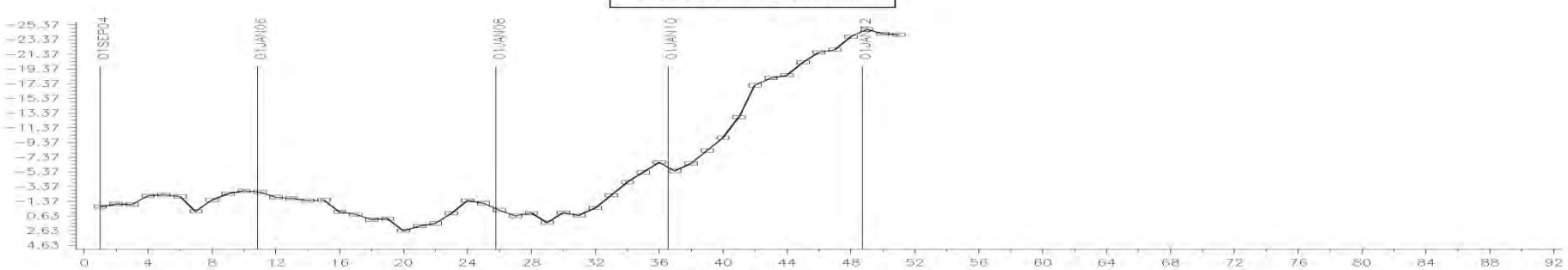
### COUNT IN COMPLETION DATE ORDER

### LTMS Precision Analysis



### COUNT IN COMPLETION DATE ORDER

### CUSUM Severity Analysis



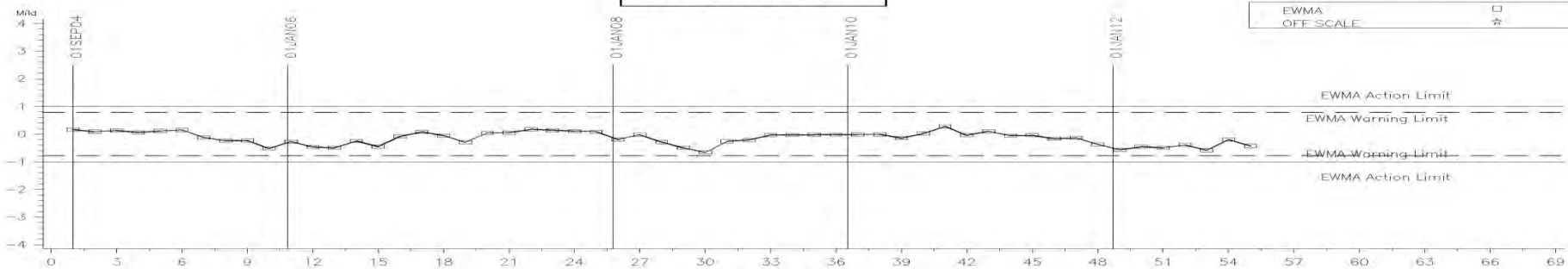
### COUNT IN COMPLETION DATE ORDER

15MAY13:11:38

# ISM INDUSTRY OPERATIONALLY VALID DATA

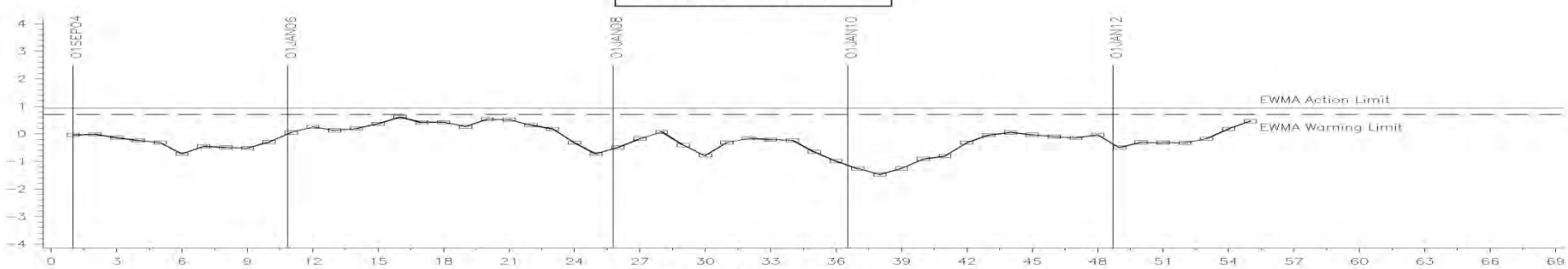
## AVERAGE SLUDGE RATING

LTMS Severity Analysis



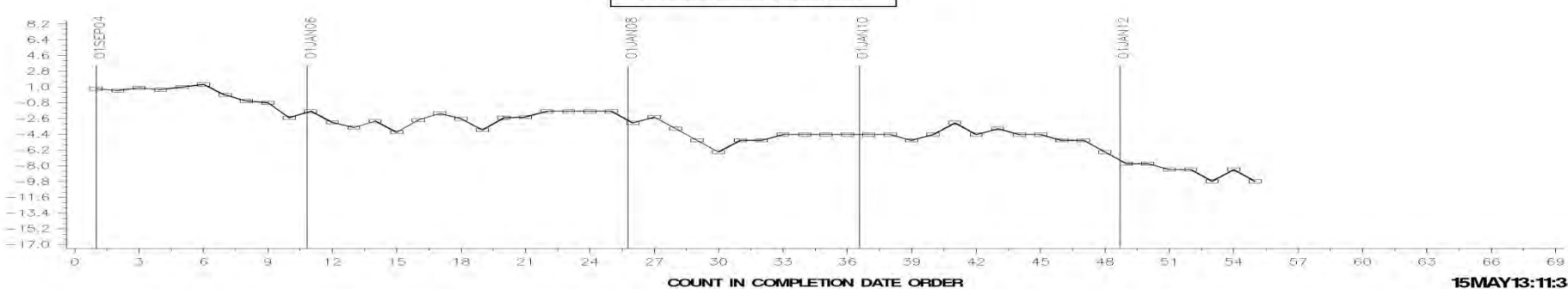
COUNT IN COMPLETION DATE ORDER

LTMS Precision Analysis



COUNT IN COMPLETION DATE ORDER

CUSUM Severity Analysis

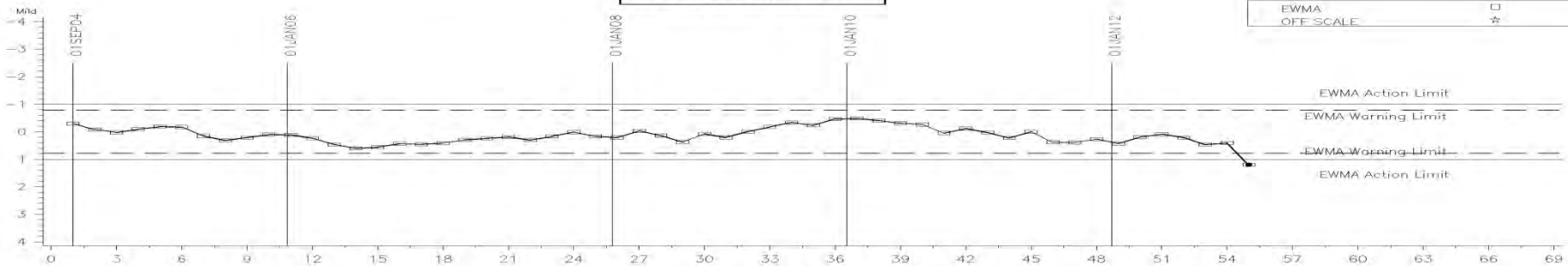


15MAY13:11:38

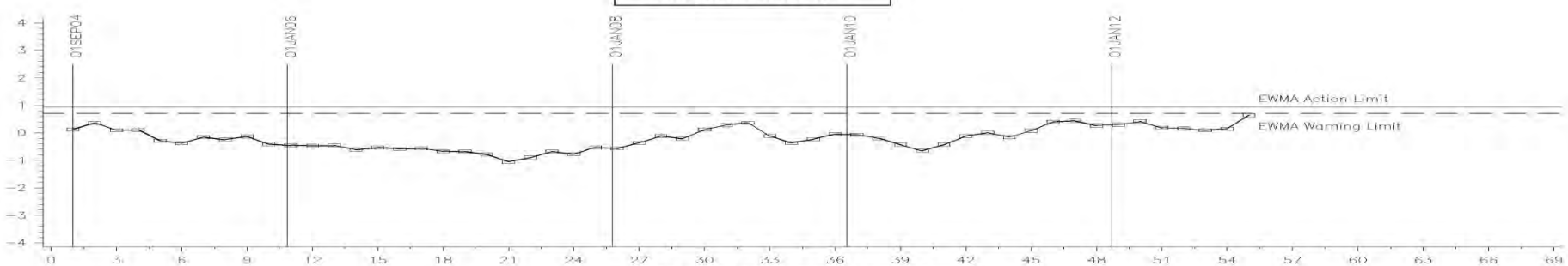
# ISM INDUSTRY OPERATIONALLY VALID DATA

## INJECTOR SCREW WEIGHT LOSS ADJUSTED TO 3.9% SOOT

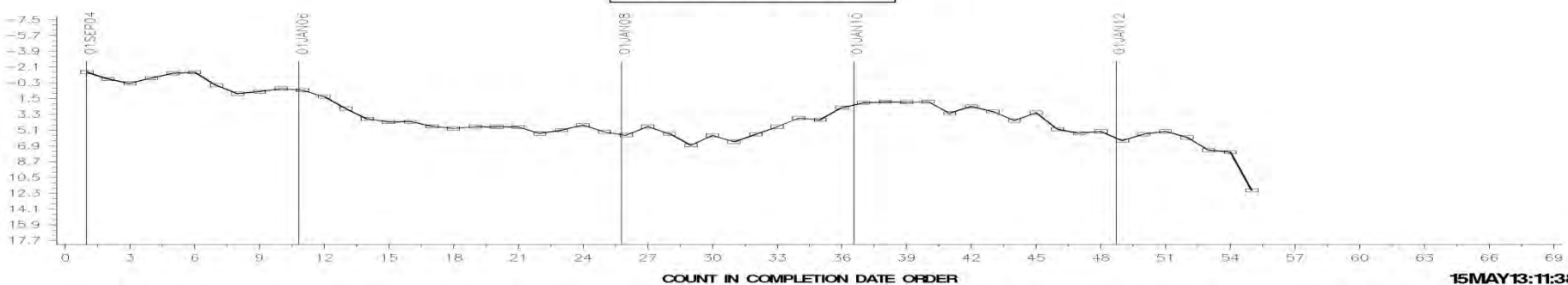
LTMS Severity Analysis



LTMS Precision Analysis



CUSUM Severity Analysis



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# Appendix 1.i

## EOAT Control Charts

» Severity, Precision, and CuSum

Test Monitoring Center

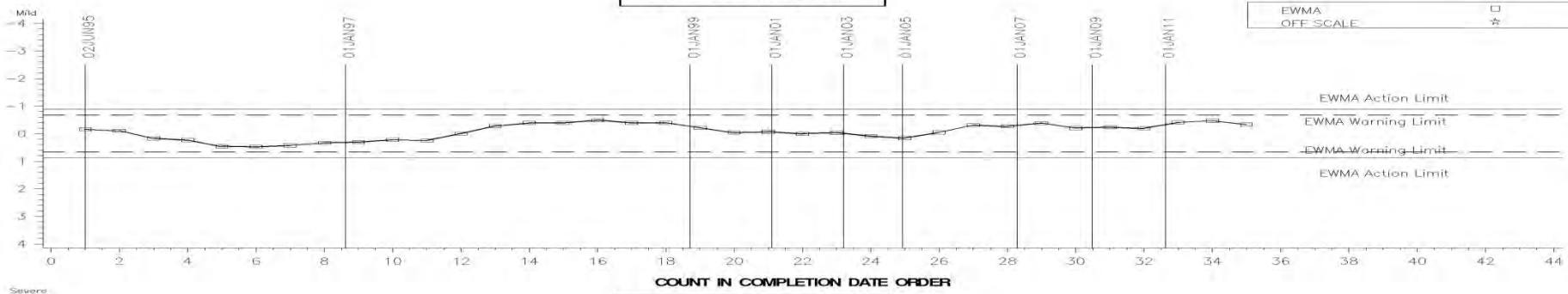
<http://astmtmc.cmu.edu>



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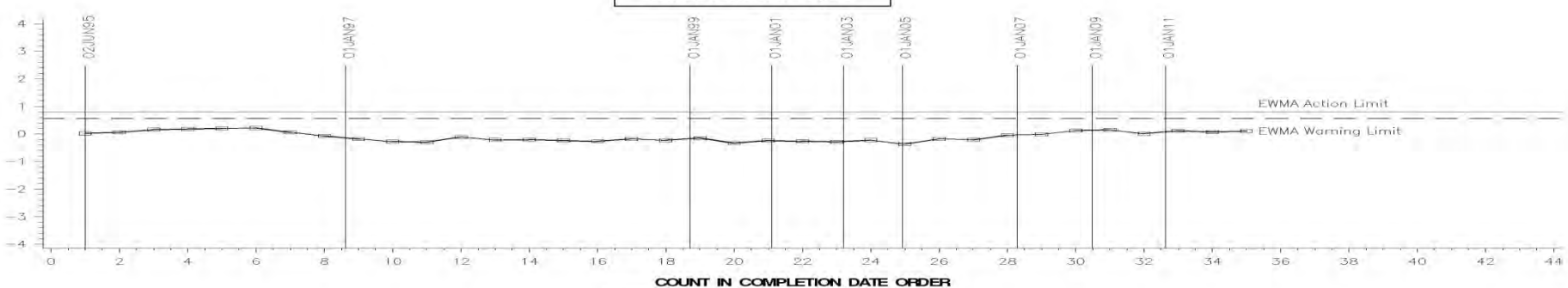
ENGINE OIL AERATION

LTMS Severity Analysis



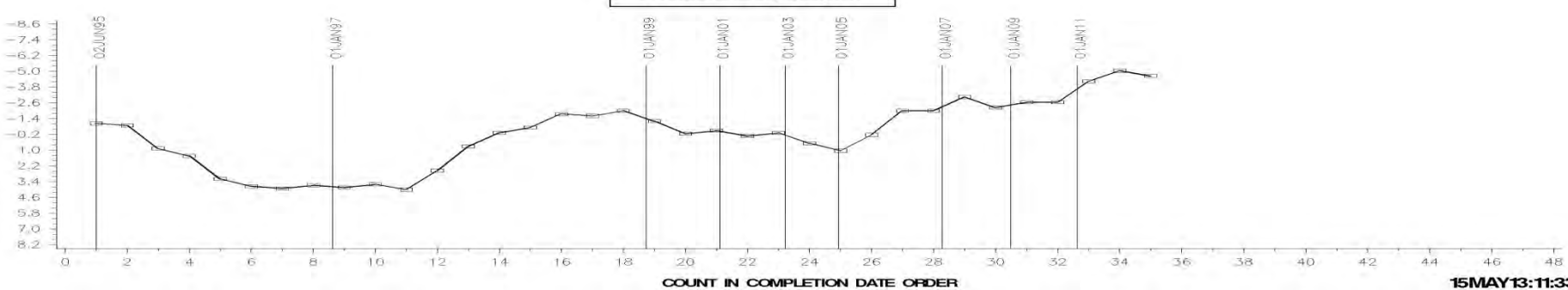
COUNT IN COMPLETION DATE ORDER

LTMS Precision Analysis



COUNT IN COMPLETION DATE ORDER

CUSUM Severity Analysis



COUNT IN COMPLETION DATE ORDER

15MAY13:11:33

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Test Monitoring Center

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# Appendix 1.j

## RFWT Control Charts

» Severity, Precision, and CuSum

Test Monitoring Center

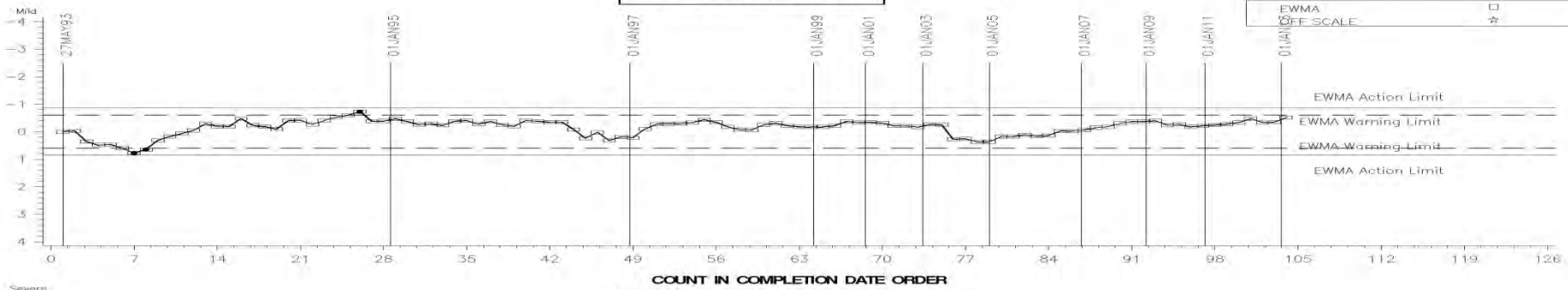
<http://astmtmc.cmu.edu>



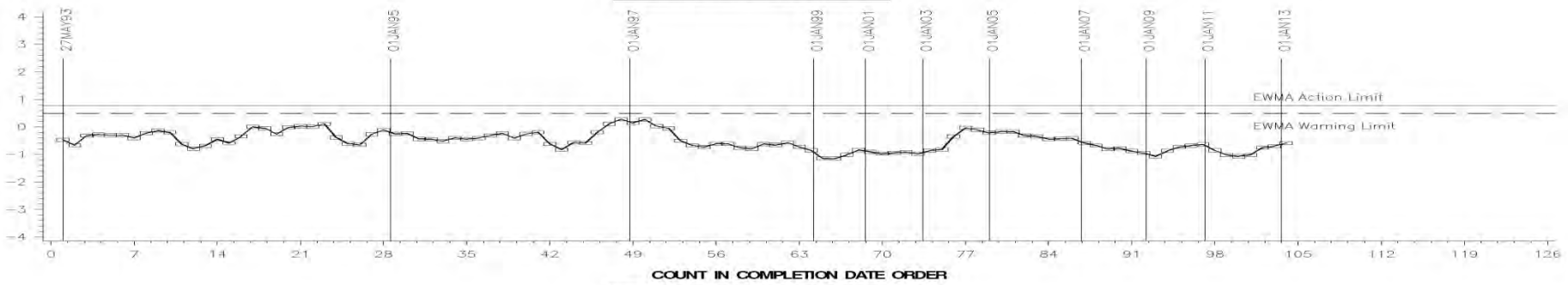
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Average Follower Wear

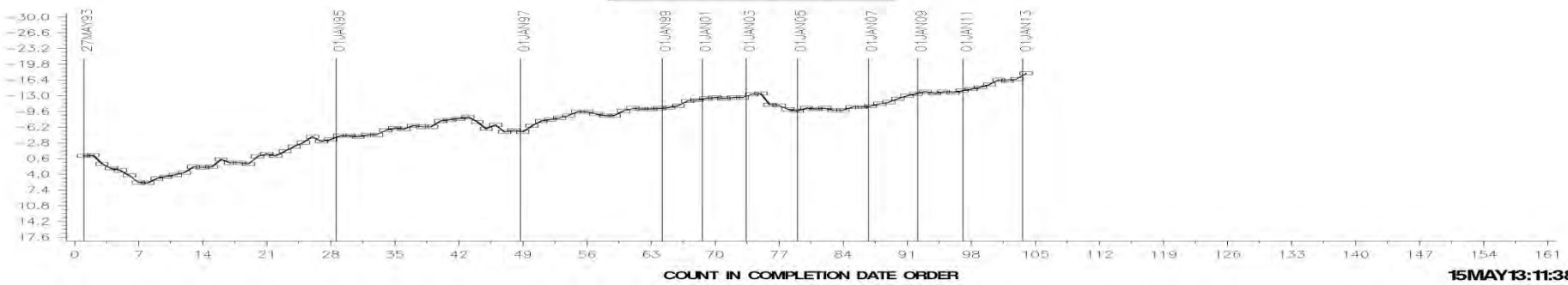
LTMS Severity Analysis



LTMS Precision Analysis



CUSUM Severity Analysis



15MAY13:11:38

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# Appendix 1.k

## T-8/T-8E Control Charts

» Severity, Precision, and CuSum

Test Monitoring Center

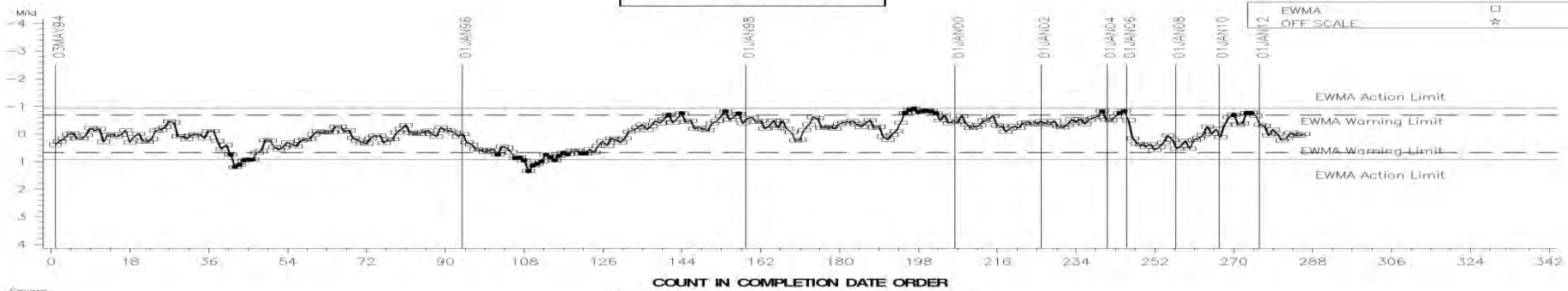
<http://astmtmc.cmu.edu>



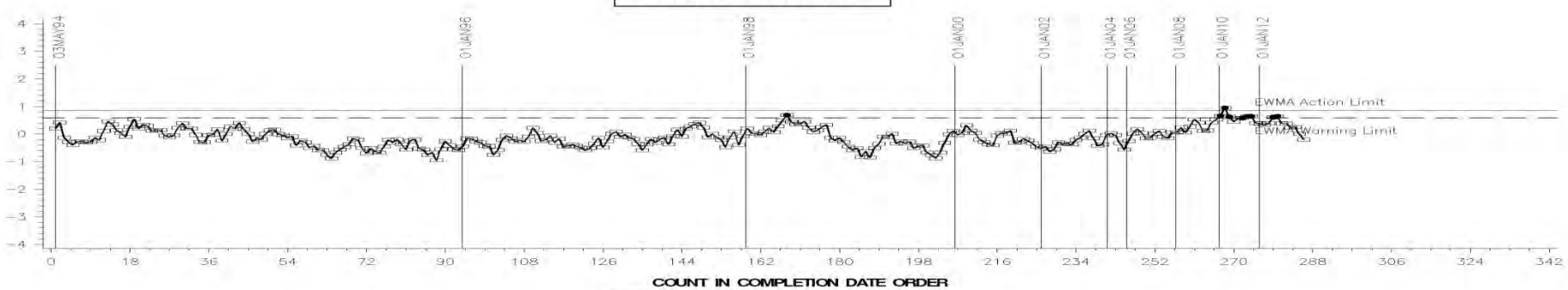
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FINAL REFERENCE VISCOSITY AT 3.8% TGA SOOT LEVEL

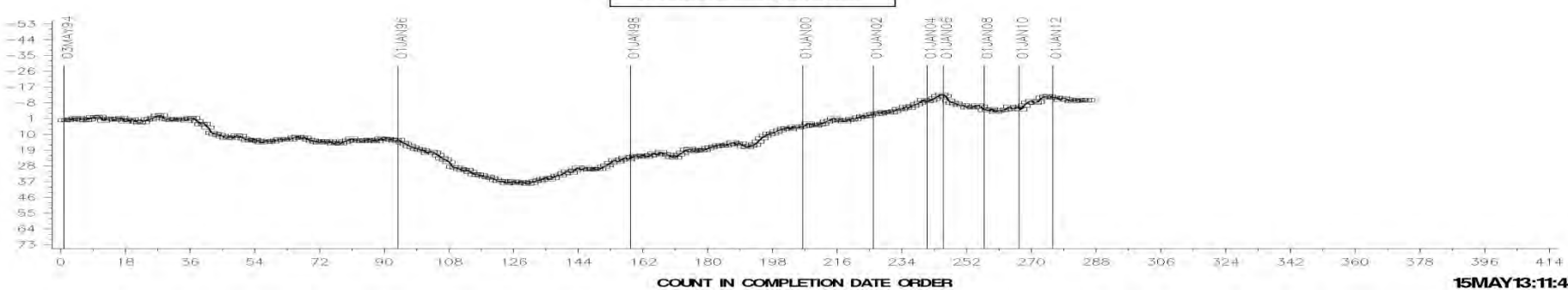
LTMS Severity Analysis



LTMS Precision Analysis



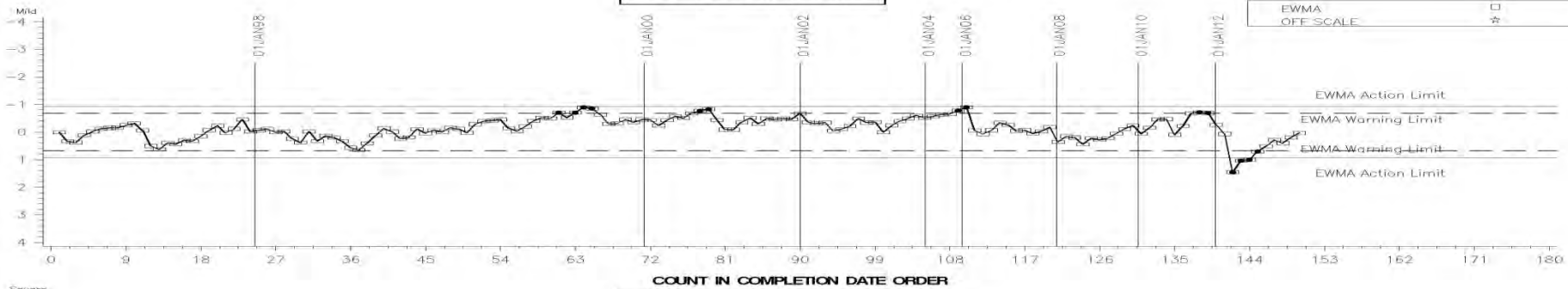
CUSUM Severity Analysis



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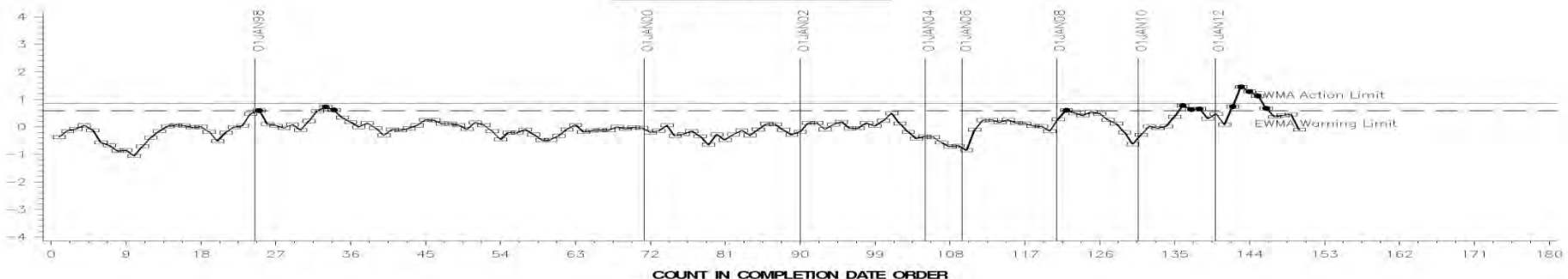
FINAL RELATIVE VISCOSITY (50% LOSS)

LTMS Severity Analysis



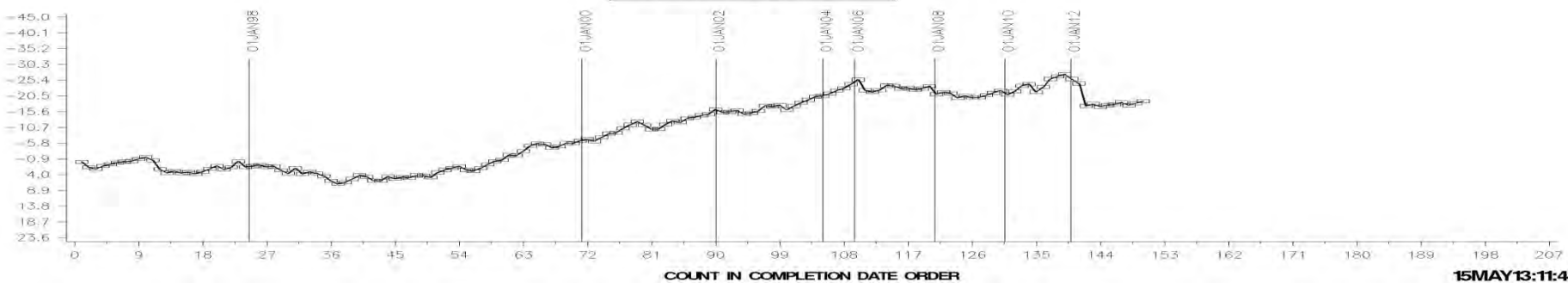
COUNT IN COMPLETION DATE ORDER

LTMS Precision Analysis



COUNT IN COMPLETION DATE ORDER

CUSUM Severity Analysis

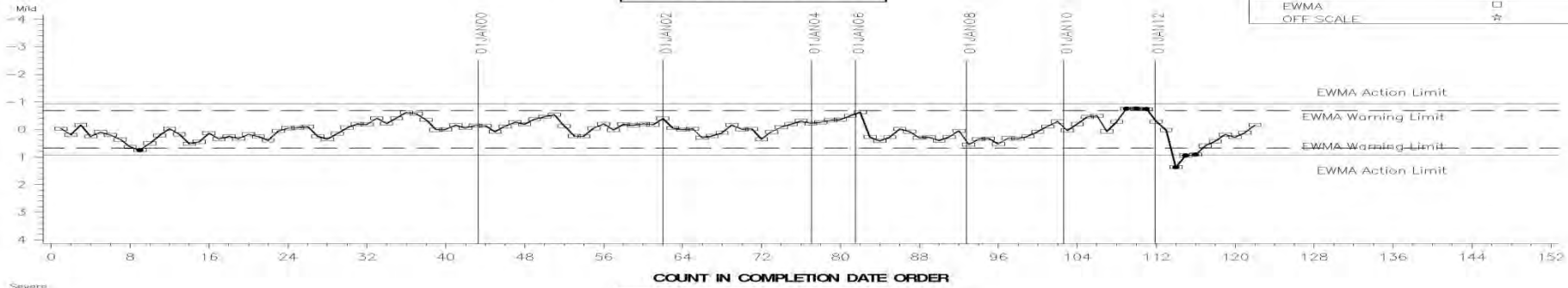


COUNT IN COMPLETION DATE ORDER

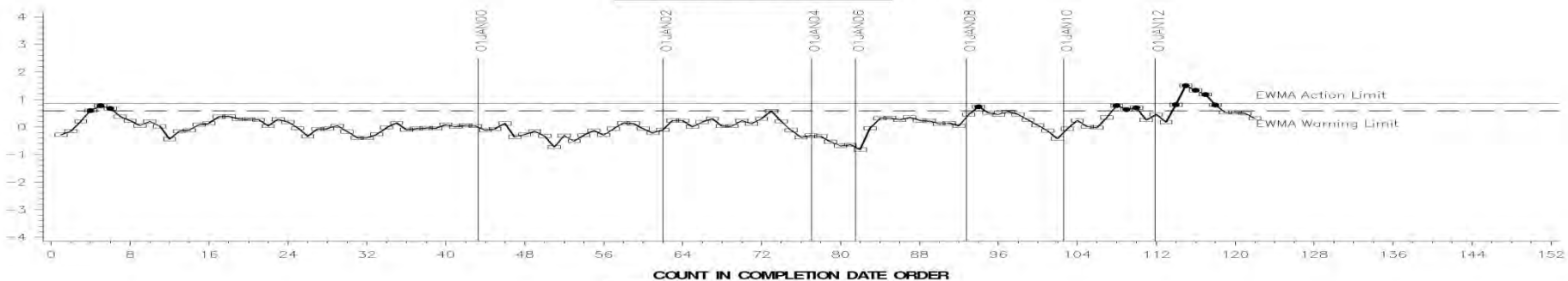
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FINAL RELATIVE VISCOSITY (100% LOSS)

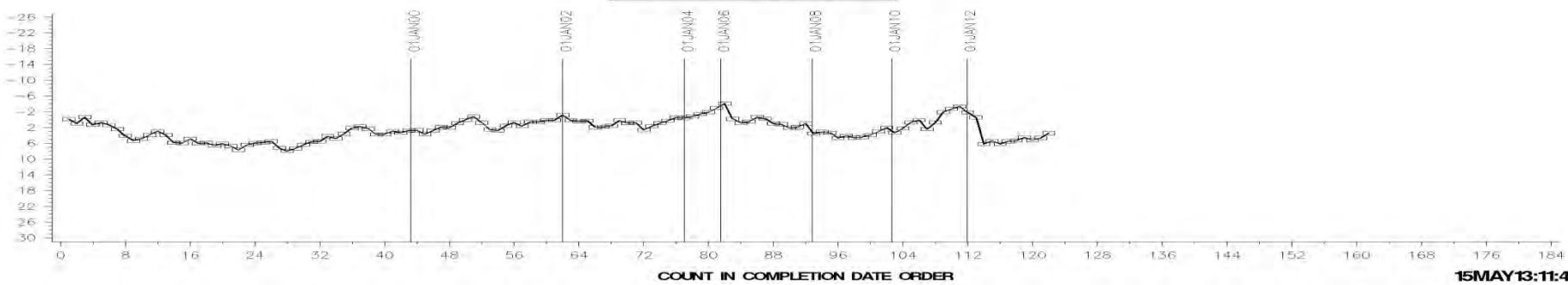
LTMS Severity Analysis



LTMS Precision Analysis



CUSUM Severity Analysis



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# Appendix 1.1

## T-10A Control Charts

» Severity, Precision, and CuSum

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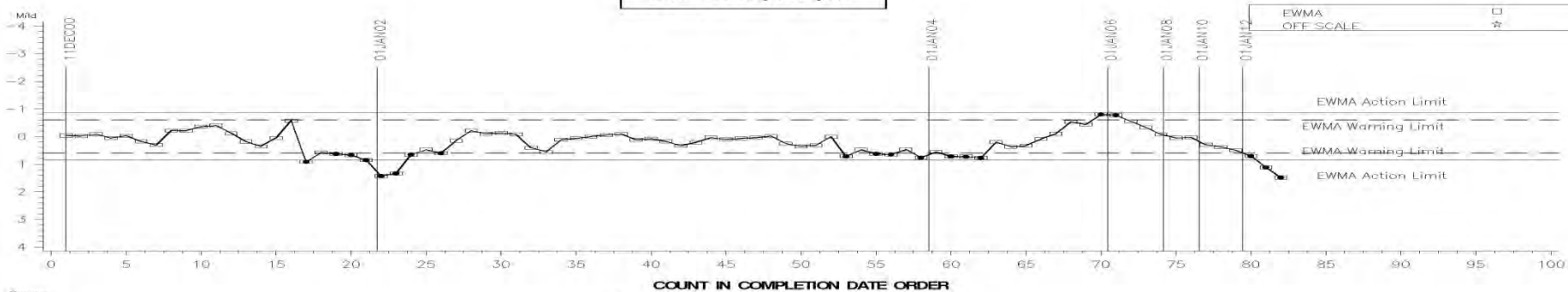
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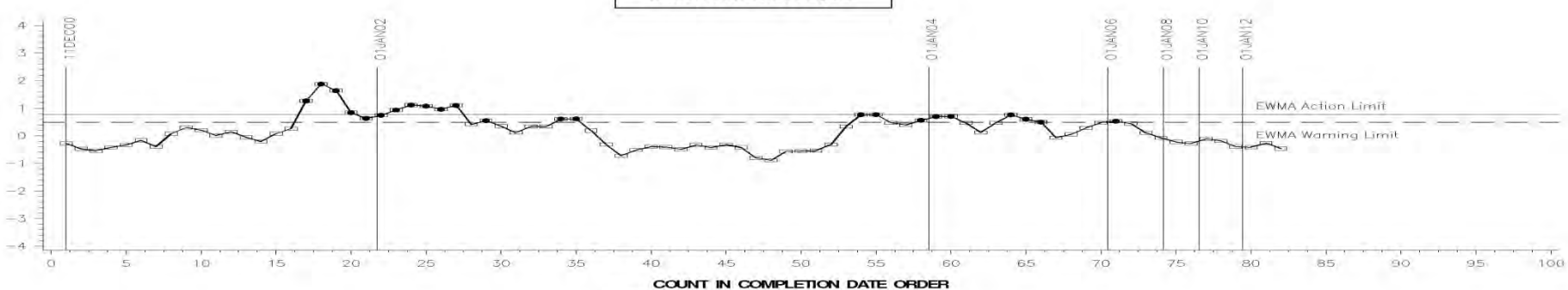
# T10A INDUSTRY OPERATIONALY VALID DATA

## MRV VISCOSITY @ 75H

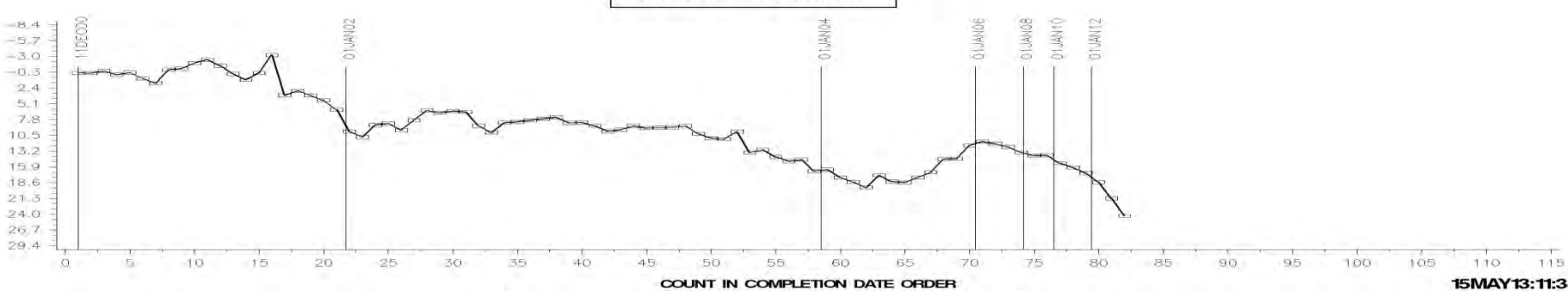
### LTMS Severity Analysis



### LTMS Precision Analysis



### CUSUM Severity Analysis



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# Appendix 1.m

## T-11 Control Charts

» Severity, Precision, and CuSum

Test Monitoring Center

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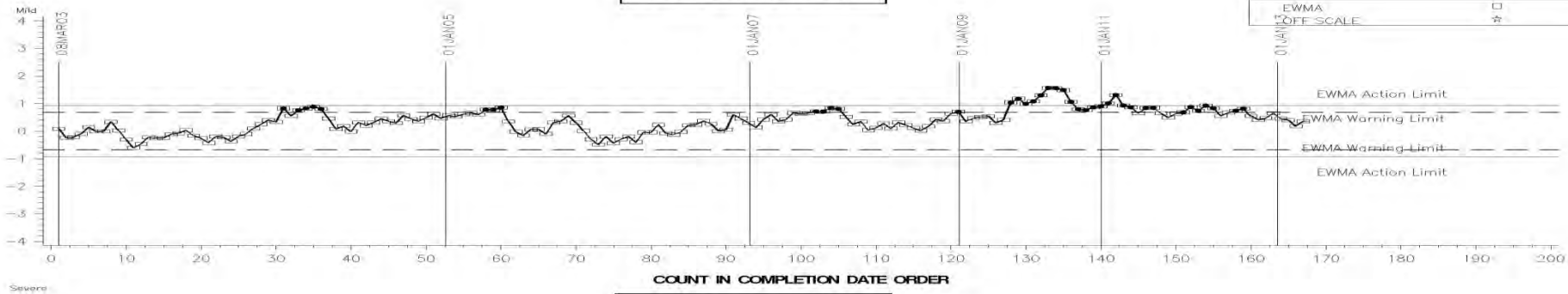


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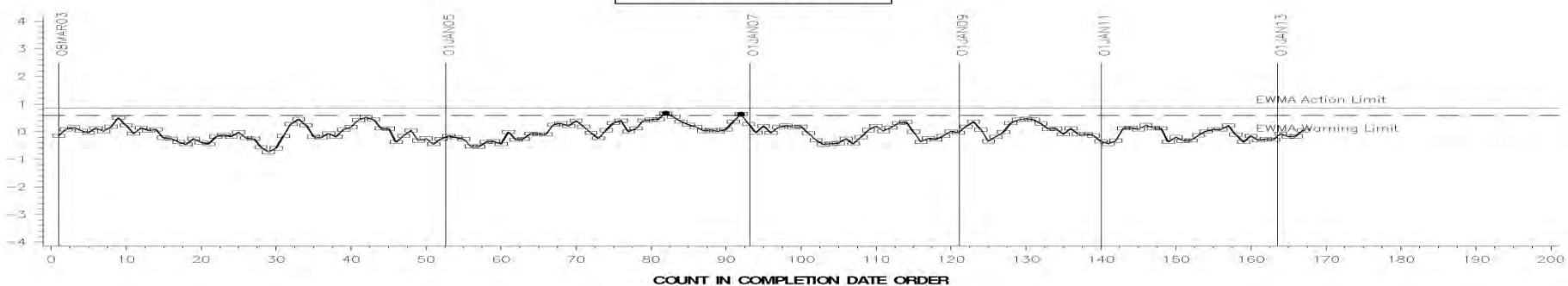
# T-11 INDUSTRY OPERATIONAL VALID DATA

## SOOT AT 12 cSt

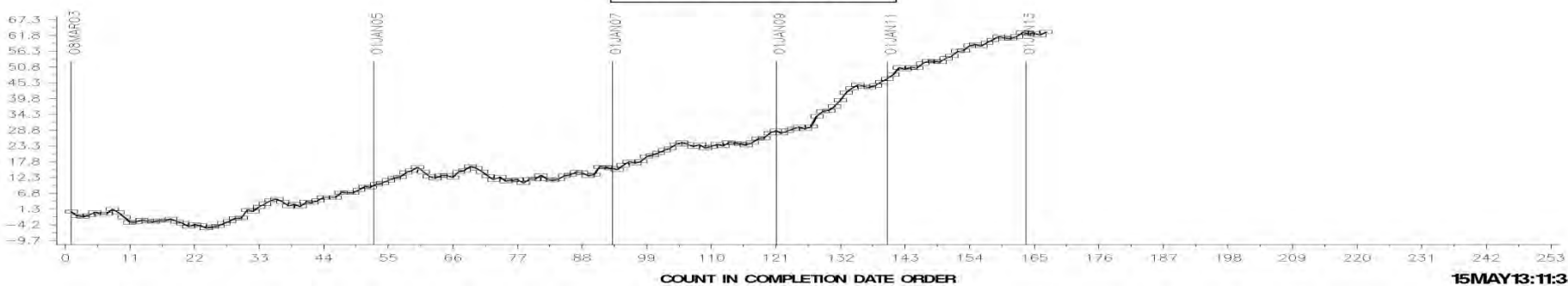
### LTMS Severity Analysis



### LTMS Precision Analysis



### CUSUM Severity Analysis

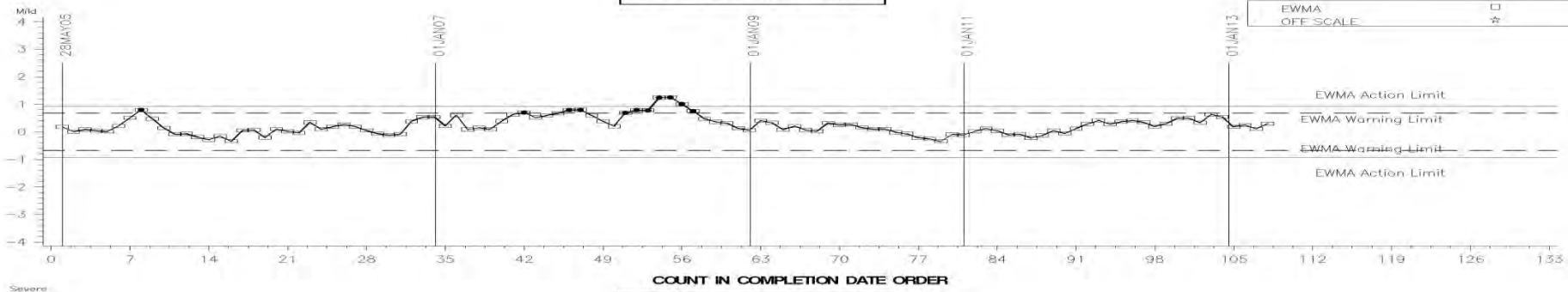


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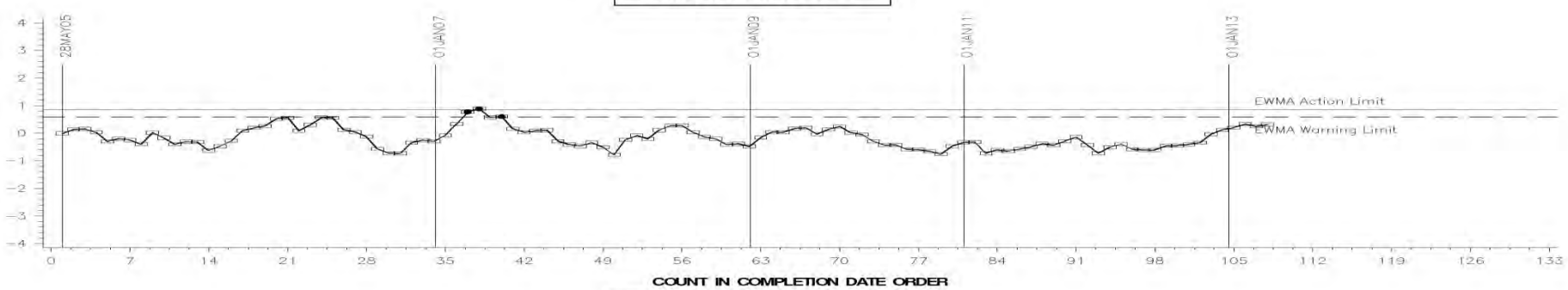
# T-11 INDUSTRY OPERATIONALLY VALID DATA

## SOOT @ 4 cSt - FINAL RESULT

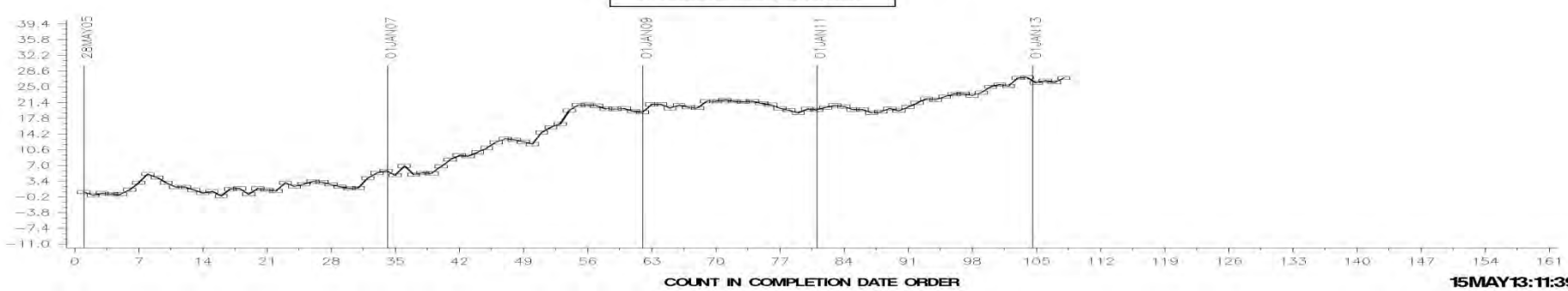
### LTMS Severity Analysis



### LTMS Precision Analysis



### CUSUM Severity Analysis

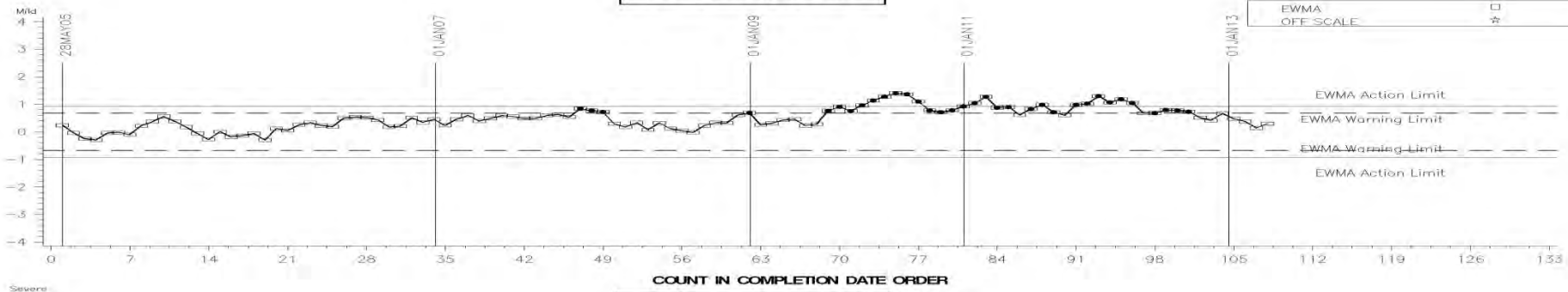


15MAY13:11:39

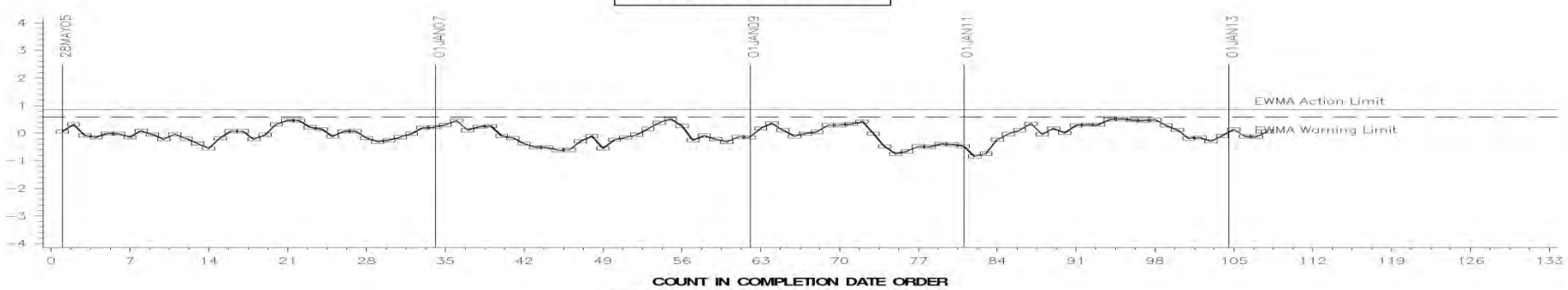
# T-11 INDUSTRY OPERATIONALLY VALID DATA

## SOOT @ 15 cSt - FINAL RESULT

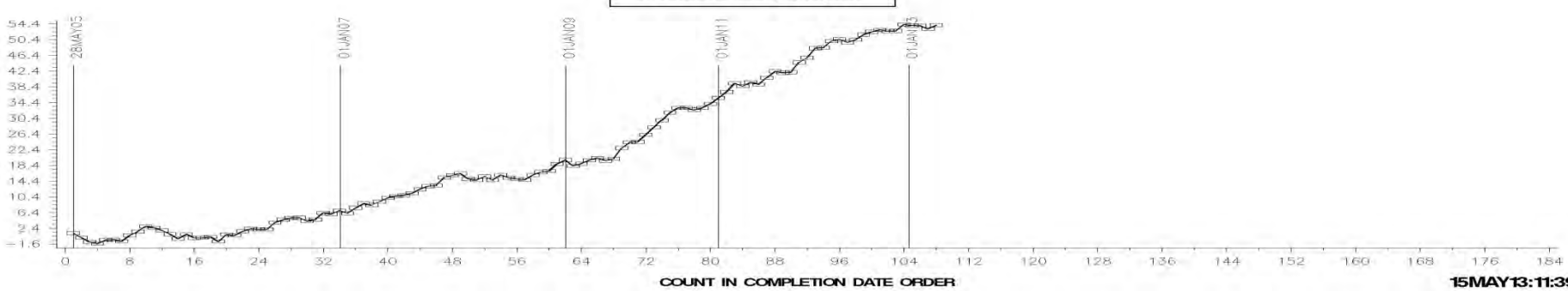
LTMS Severity Analysis



LTMS Precision Analysis



CUSUM Severity Analysis

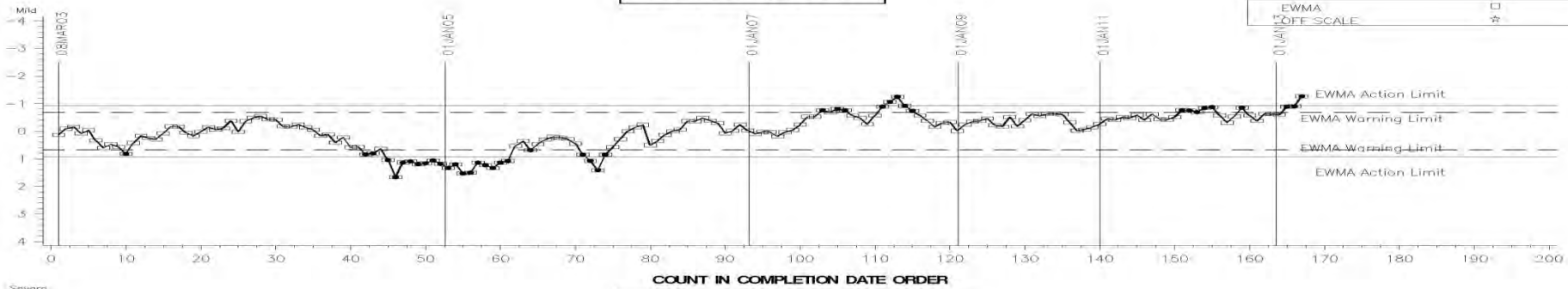


15MAY13:11:39

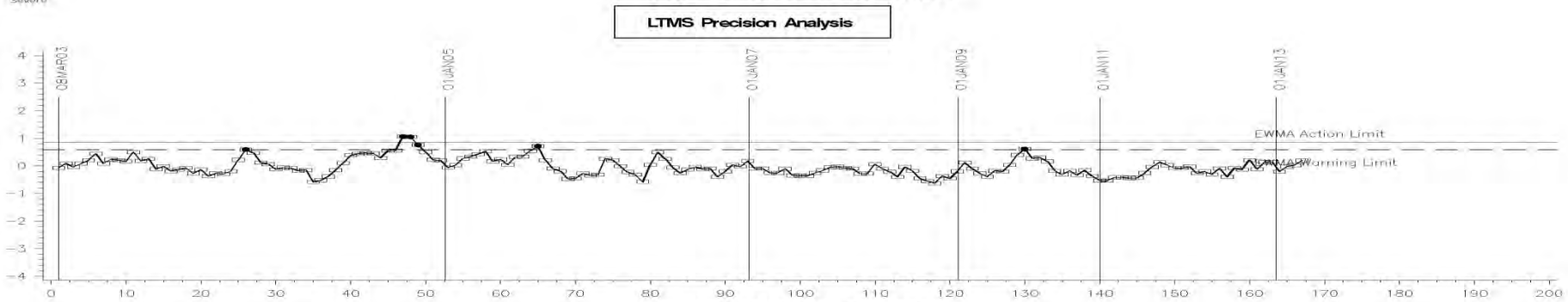


MRV VISCOSITY

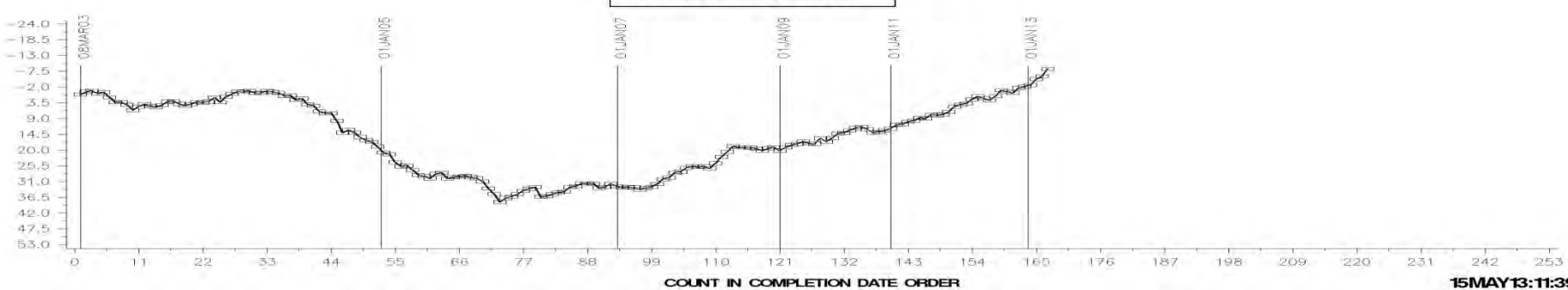
LTMS Severity Analysis



LTMS Precision Analysis



CUSUM Severity Analysis



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# Appendix 1.n

## T-12 Control Charts

» Severity, Precision, and CuSum

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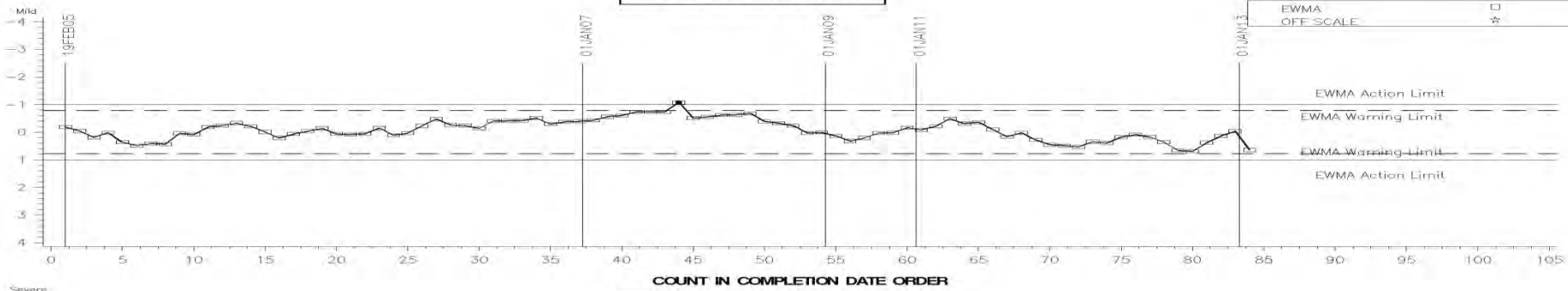


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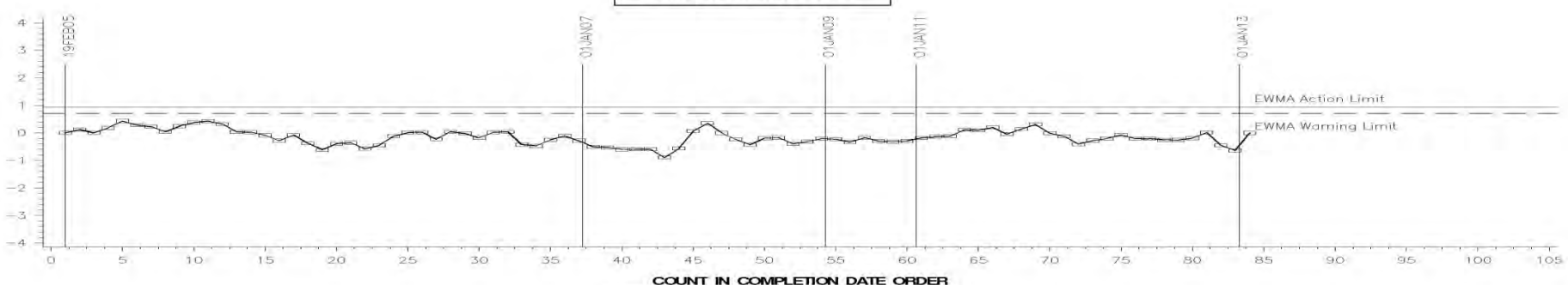


FINAL TRANS. RES. DELTA PB @ EOT

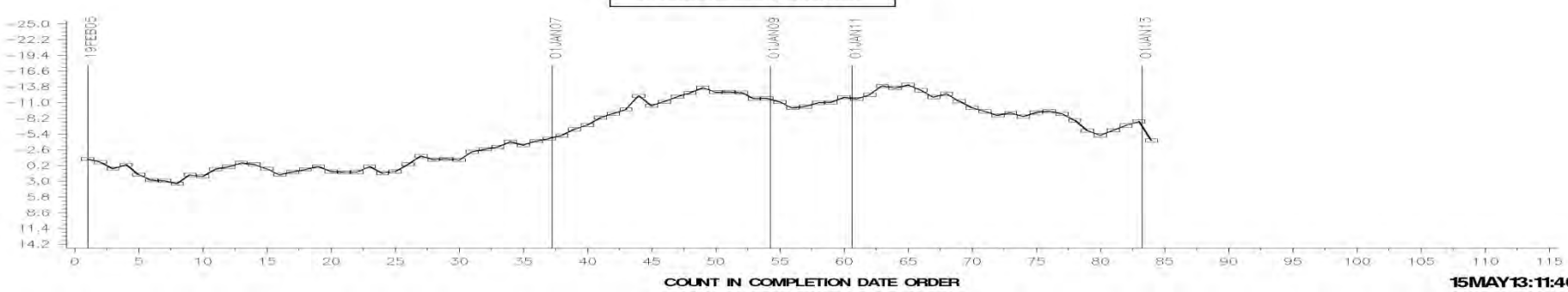
LTMS Severity Analysis



LTMS Precision Analysis



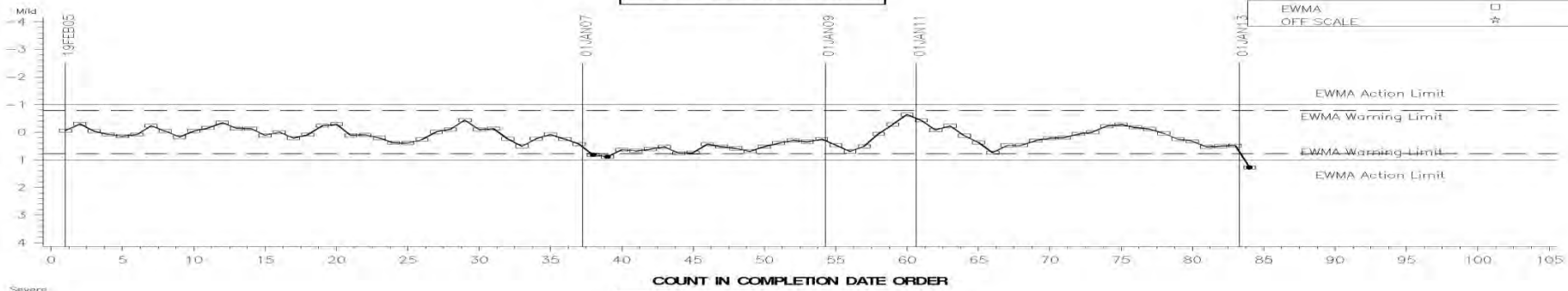
CUSUM Severity Analysis



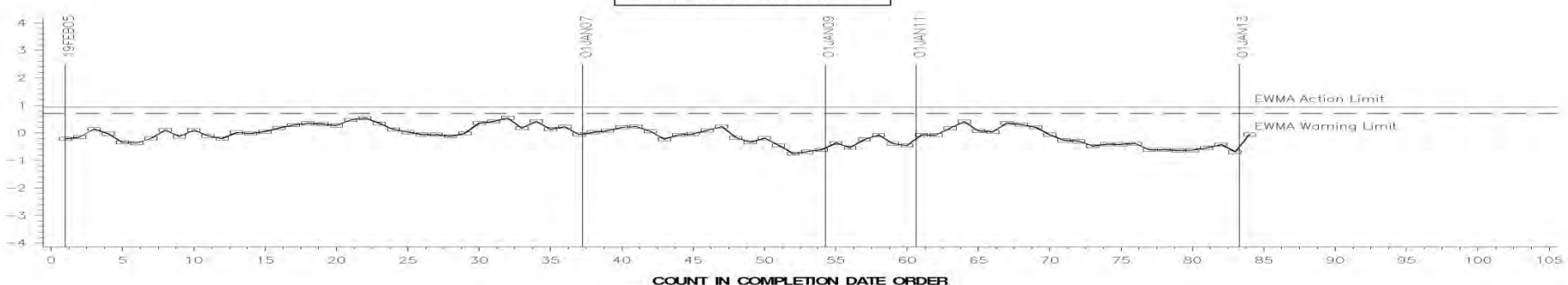
15MAY13:11:40

AVG. CYLINDER LINER WEAR (CLW)

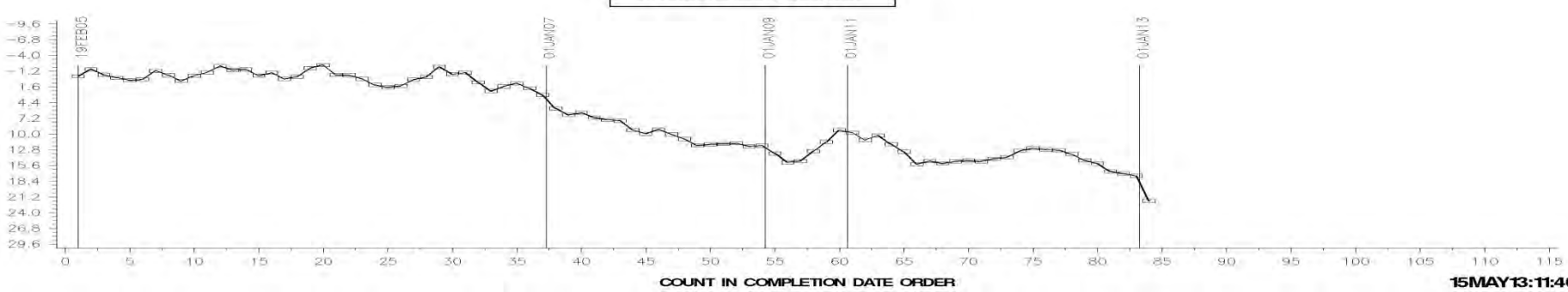
LTMS Severity Analysis



LTMS Precision Analysis



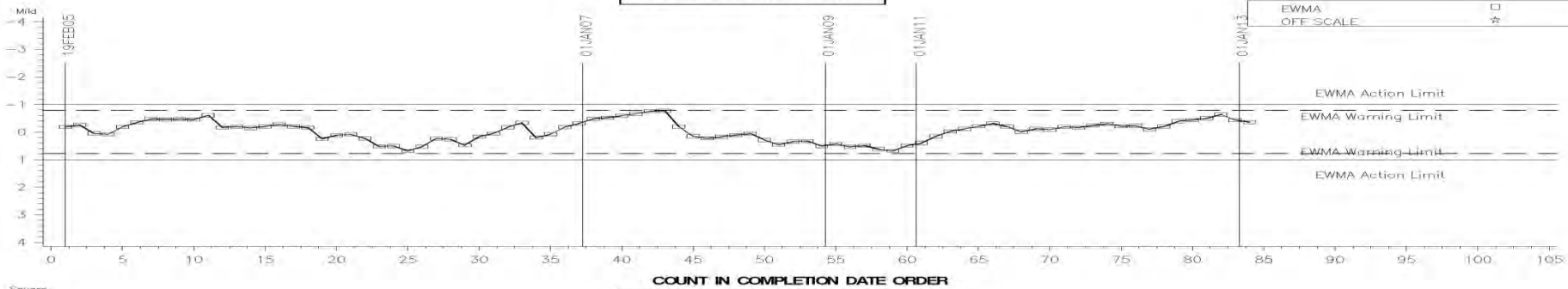
CUSUM Severity Analysis



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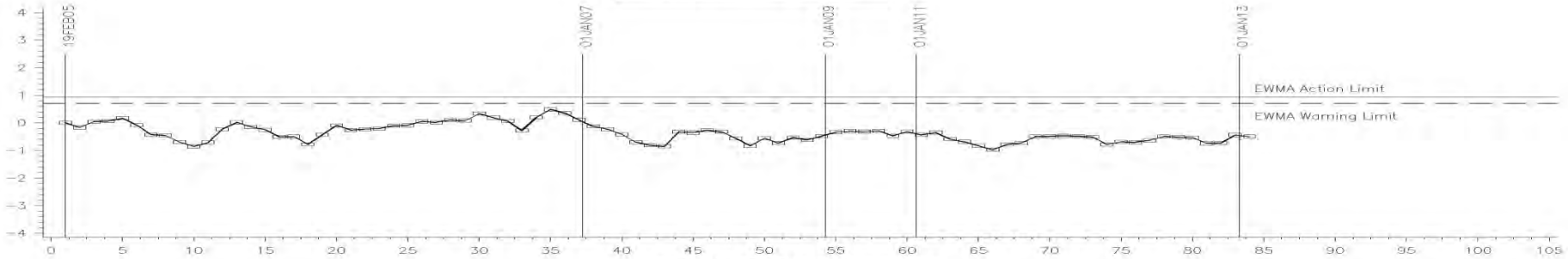
AVG. TOP RING WEIGHT LOSS (TRWL)

LTMS Severity Analysis



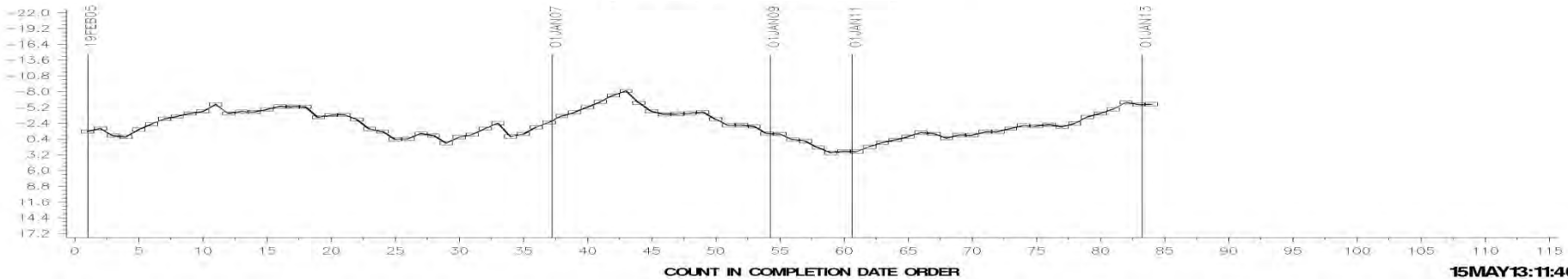
COUNT IN COMPLETION DATE ORDER

LTMS Precision Analysis



COUNT IN COMPLETION DATE ORDER

CUSUM Severity Analysis

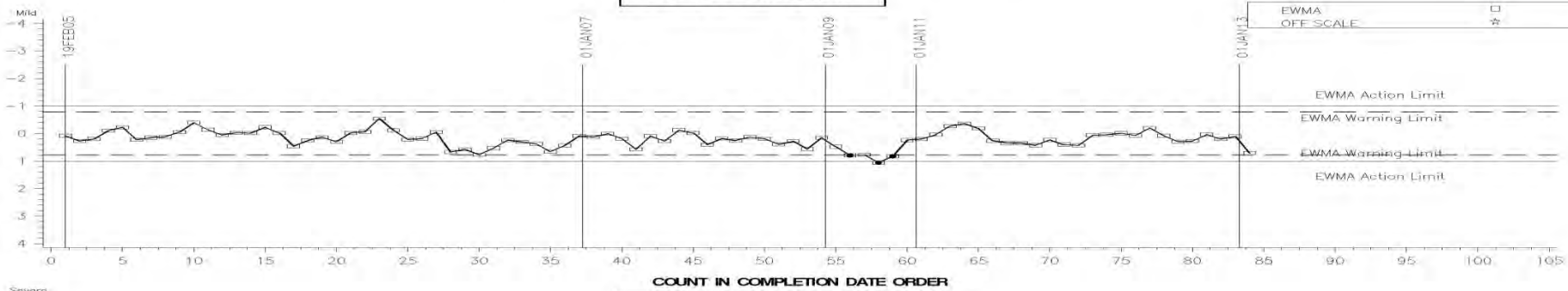


COUNT IN COMPLETION DATE ORDER

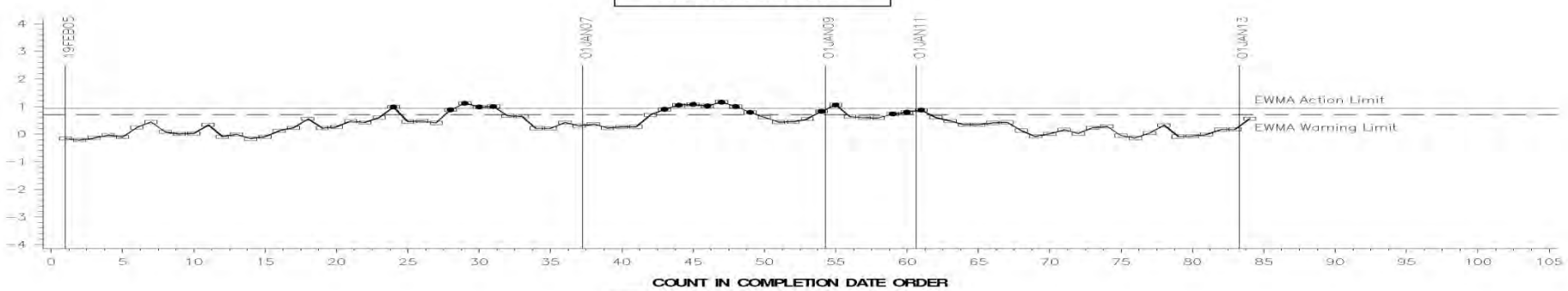
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FINAL TRANS. RES. OIL CONSUMPTION

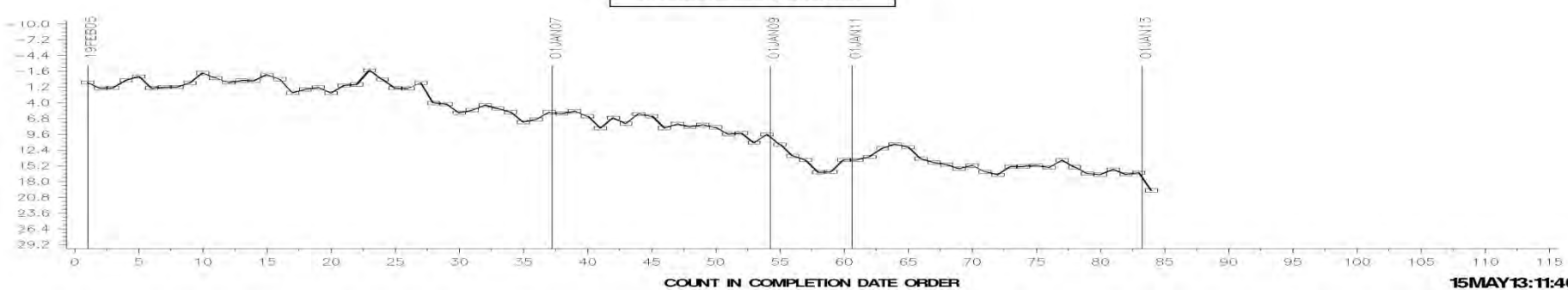
LTMS Severity Analysis



LTMS Precision Analysis



CUSUM Severity Analysis

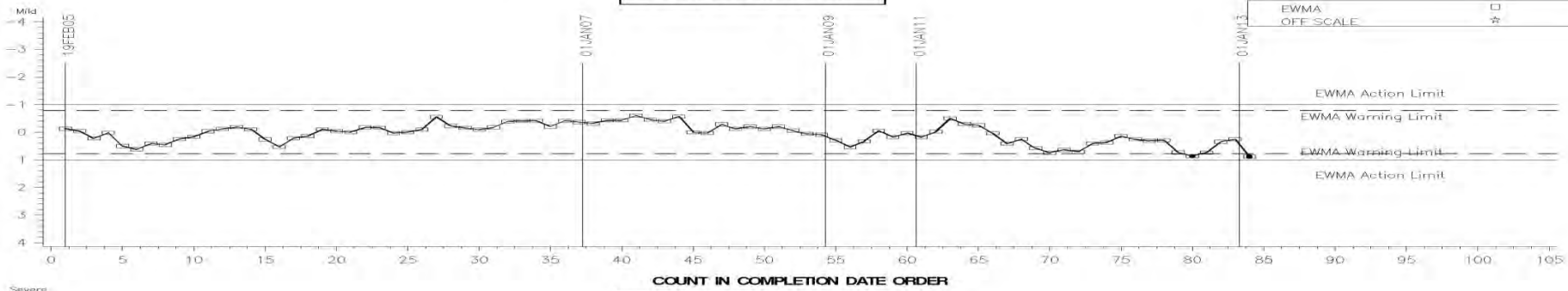


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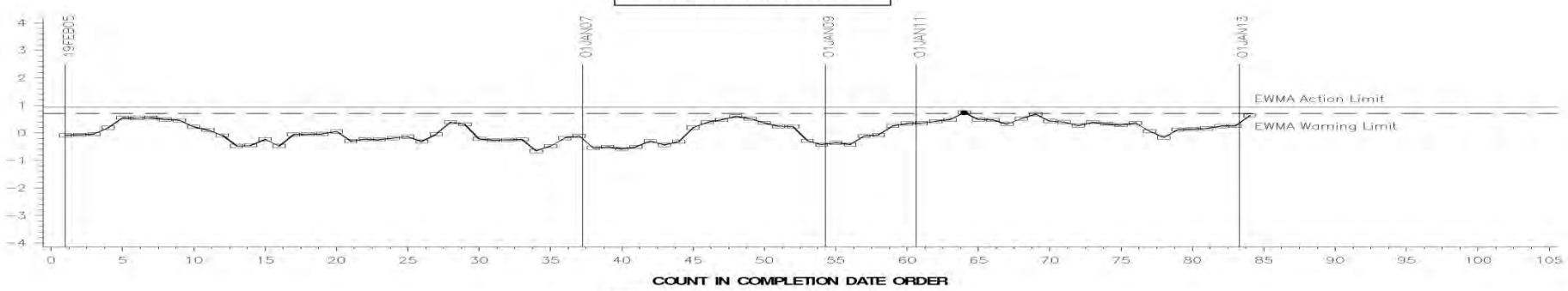


FINAL TRANS. RES. DELTA PB 250-300H

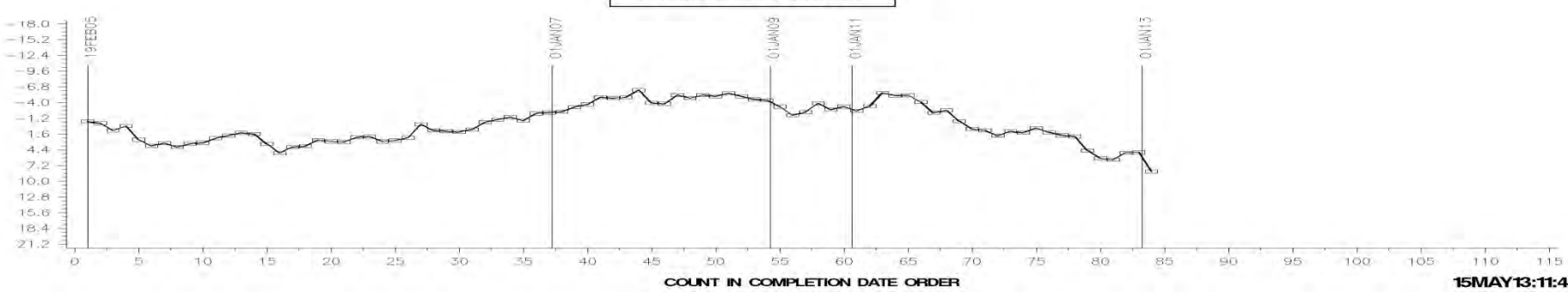
LTMS Severity Analysis



LTMS Precision Analysis



CUSUM Severity Analysis



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# Appendix 1.0

## T-12A Control Charts

» Severity, Precision, and CuSum

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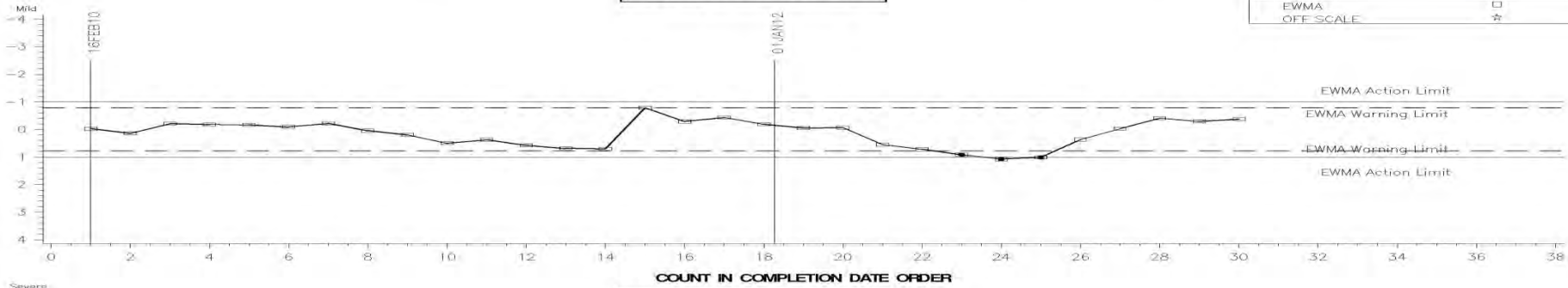
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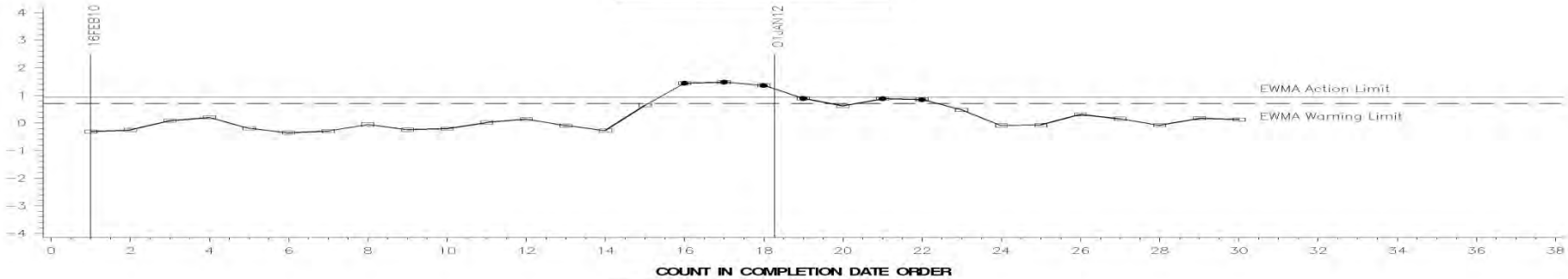
# MACK T-12A INDUSTRY OPERATIONALLY VALID DATA

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

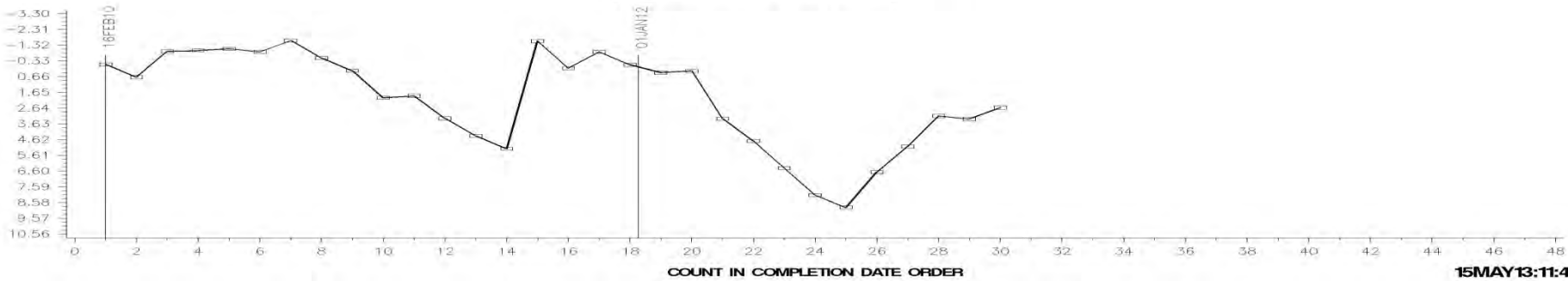
LTMS Severity Analysis



LTMS Precision Analysis



CUSUM Severity Analysis



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