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# **Test Monitoring Center**

<http://astmtmc.cmu.edu>

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

October 2013

# Heavy Duty Testing

## Executive Summary

- ▶ Reference Oils
  - 822-1 reblend
    - Large batch of 822 blended as 822-2.
  - 821-3 Supply being rapidly depleted
    - Reblend of 821 expected January 2014
- ▶ T10A End of Life
  - Test has reached end of life. Hardware no longer available.
- ▶ T12 UUXO Hardware approval
  - New hardware approved with updated industry correction factors. Severity adjustments frozen at pre-UUXO hardware values.
- ▶ T11 Suspension of first in first out hardware use
  - Requirement suspended to conserve limited UUXO hardware.

# Calibrated Labs and Stands\*

Test	Labs	Stands
1K	4	4
1N	3	7
1M-PC	2	2
1P	3	3
1R	1	3
C13	2	3
ISB	3	4
ISM	4	5
EOAT	1	1
RFWT	2	2
T-8/E	2	5
T-10A	0	0
T-11	4	5
T-12	4	4
T-12A	4	4

\*As of 9/30/2013

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# Test Activity Levels

»» April 1, 2013 –

September 30, 2013

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# CAT – SCOTE Tests

Test Status	Validity Code	1K	1N	1M-PC	1P	1R
Acceptable Calibration Test	AC	3	4	2	1	2
Failed Calibration Test	OC	0	0	0	0	0
Operationally Invalid	LC	1	0	0	2	1
Aborted	XC	0	0	0	2	0
<b>Total</b>		<b>4</b>	<b>4</b>	<b>2</b>	<b>5</b>	<b>3</b>

# CAT - C13 Test

Test Status	Validity Code	C13
Acceptable Calibration Test	AC	2
Failed Calibration Test	OC	3
Operationally Invalid	LC	0
Aborted	XC	0
<b>Total</b>		<b>5</b>

# Cummins Tests

Test Status	Validity Code	ISB	ISM
Acceptable Calibration Test	AC	2	4
Failed Calibration Test	OC	0	1
Operationally Invalid	LC	0	0
Aborted	XC	0	0
<b>Total</b>		<b>2</b>	<b>5</b>

# Light Duty Diesel Tests

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



# Mack Tests

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

# Failed Tests

Test	Failed Parameter	Number of Tests
C13	Mild R2TC	3
ISM	Severe FPD	1
Total		4

# Lost Tests\*

\*Invalid and aborted tests

Test	Status	Cause
1K	Invalid	Scuffed Piston and High OC
1P	Invalid	Fuel Flow Out of Spec
1P	Invalid	High Copper
1P	Aborted	Scuffed Piston
1P	Aborted	Scuffed Piston
1R	Invalid	High Copper - Rod Bearing Failure
T11	Invalid	Injector Failure
T11	Invalid	Injector Failure
T12	Invalid	Incorrect Oil Added
T12	Aborted	Improper Oil Add Procedure
T12	Aborted	Safety Concerns due to High OC

# Lost Tests\*

\*Invalid and aborted tests

Test	Status	Cause
T8/T8E	Aborted	No Viscosity Increase
T8/T8E	Aborted	Unstable Soot Generation

# Test Severity

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# CAT Test Severity

## ▶ 1K

- WDK, TLHC, ETOC are in control. WDK near warning limit.
- TGF
  - Within Chart Limits
  - Long-term mild trend continuing
- BSOC in Warning Limit in the mild direction
  - Long-term mild trend continuing

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

## ▶ 1N

- WDN in control near warning limit
- TGF, WDN, TLHC, and BSOC trending mild
- TGF, 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

- EOTOC is in warning limit (severe direction)
- OC, TGC, TLC and WD are in control.

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

# CAT Test Severity

## ▶ 1R

- BTOC and TLC are in control.
- TOC in severity alarm, severe direction
- WD, TGC and ETOC in precision alarm

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

## ▶ C13

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

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



# Cummins Test Severity

## ▶ ISB

- ACSW is in control.
- ATWL in Warning alarm in the mild direction

- 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 and near warning alarm.

- 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
  - Test has reached end-of-life.
  - Test will not be included in future reports.
- Charts shown in [Appendix 1.l.](#)

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# Mack Test Severity

## ▶ T-11

- SOOT, SOOT4 and SOOT5 in control chart limits.
  - SOOT and MRV mild trend ending.

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

## ▶ T-12

- All parameters are in control.
  - TRWL long-term mild trend ended.
  - OC and CLW trending severe..

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

# Mack Test Severity

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

# Test Precision

»» October 1, 2012 –  
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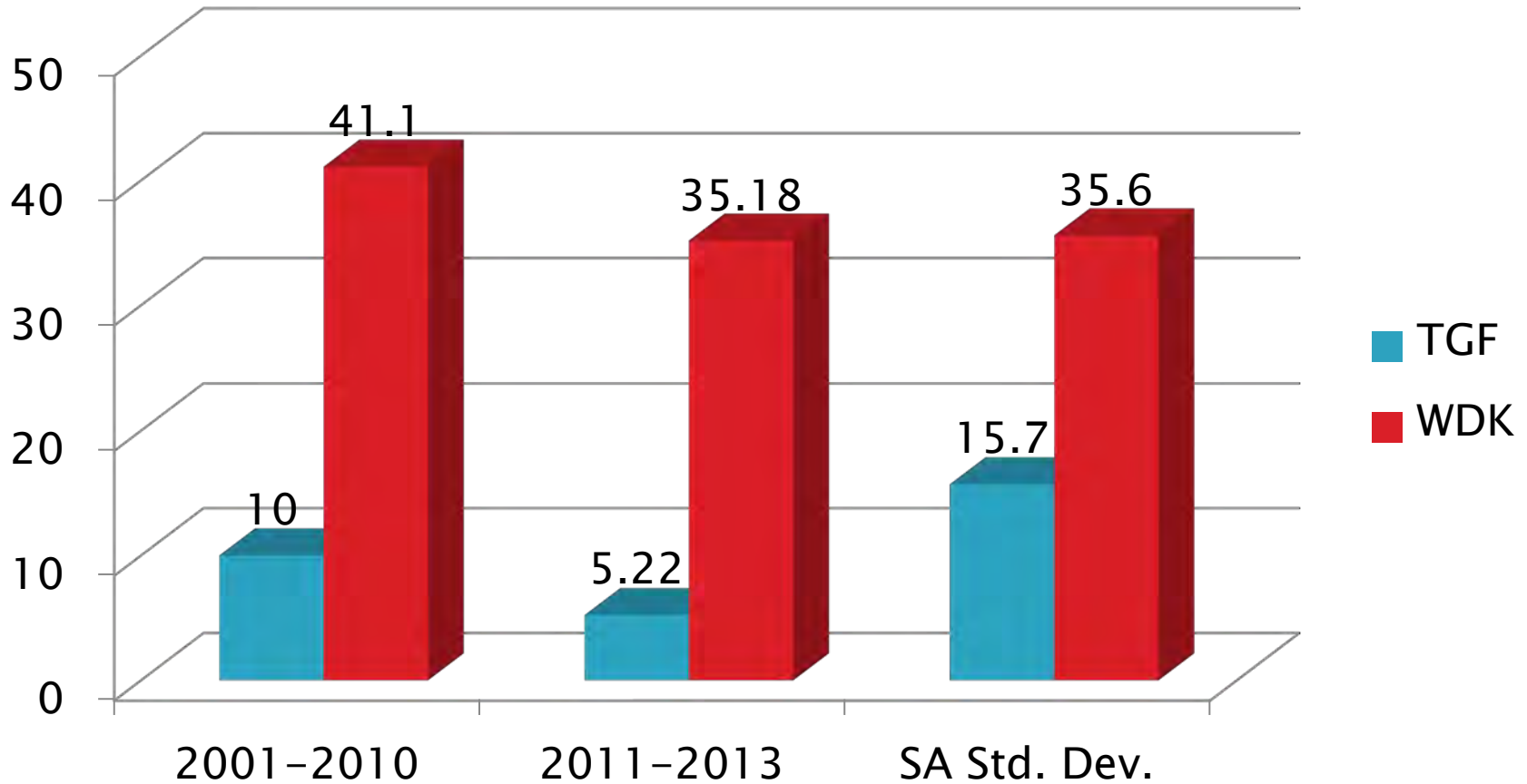


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# Test Precision Estimates

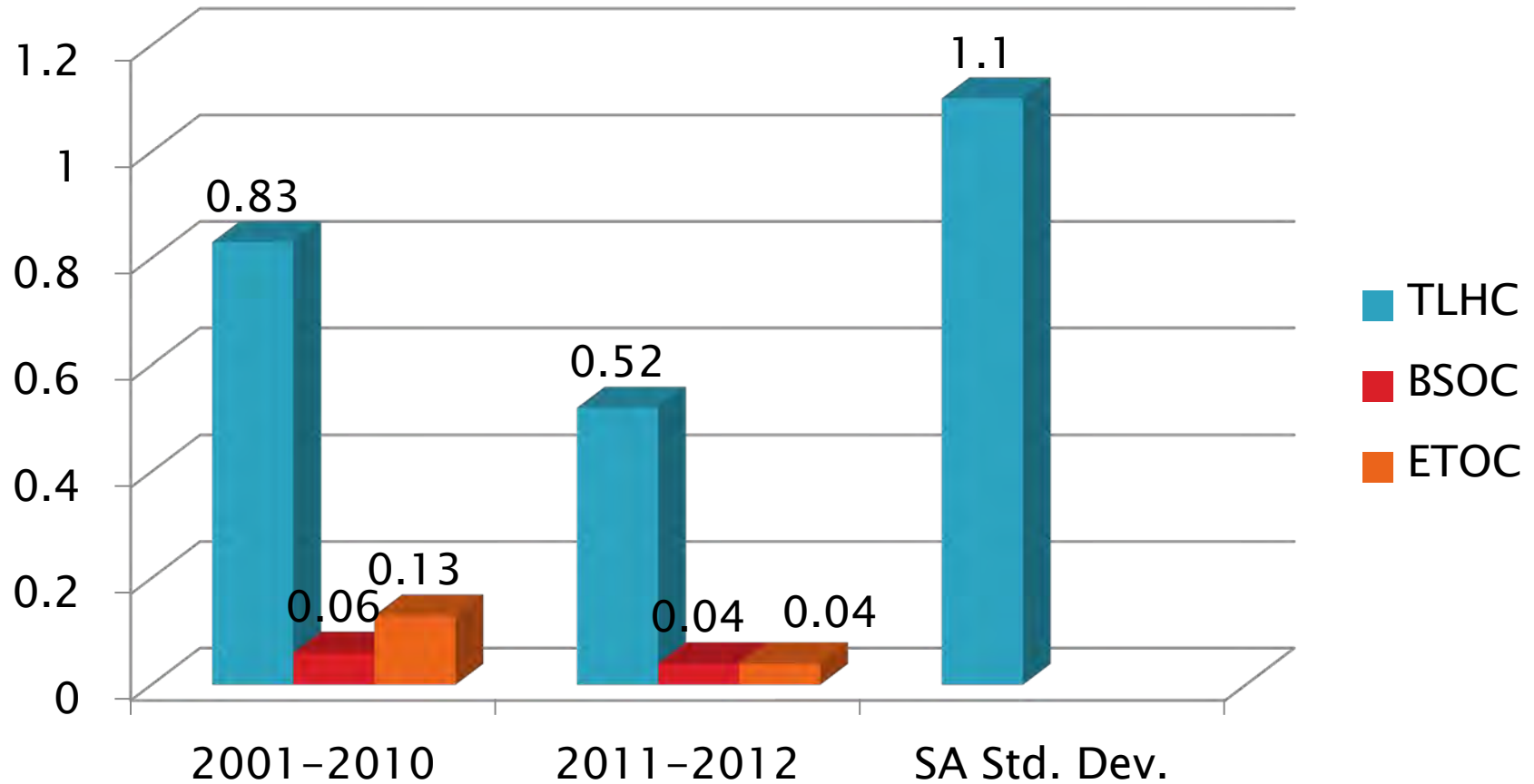
- ▶ Presented for years where sufficient data exist
- ▶ Precision estimates are shown with reference oil std. deviations, or where applicable, with Severity Adjustment std. deviations
- ▶ For several test types, precision estimates are not available due to low activity levels

# 1 K Precision Estimates

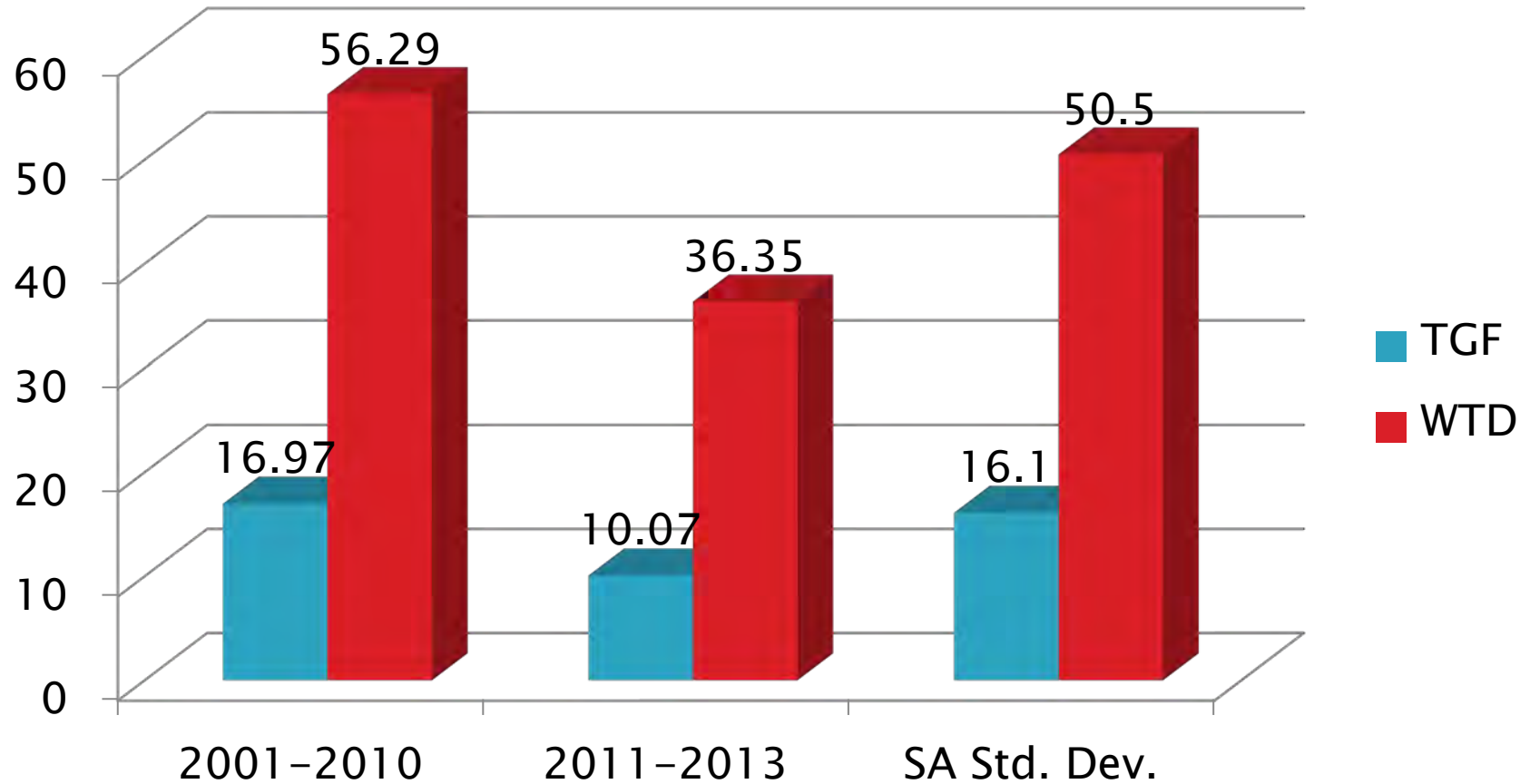




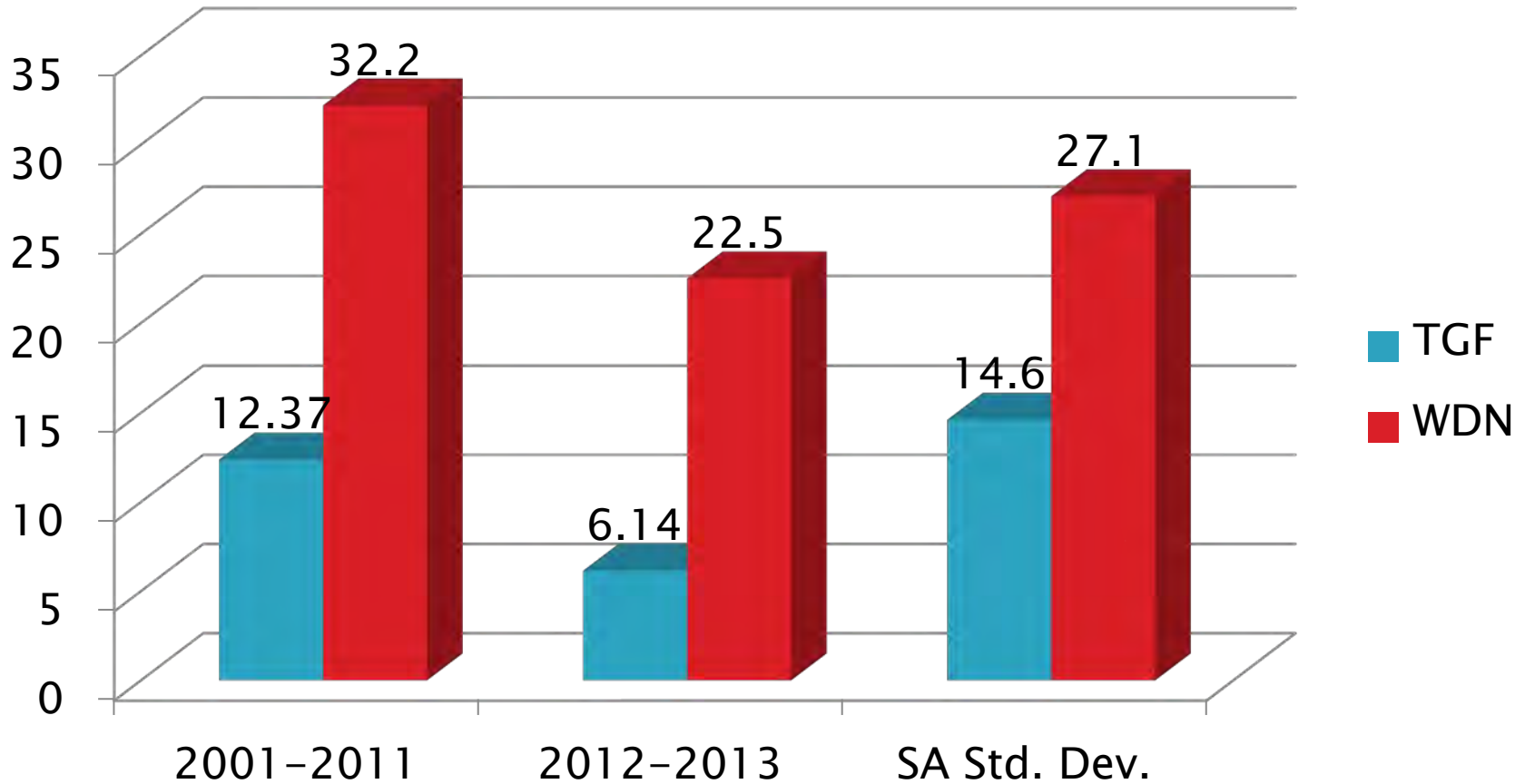
# 1 K Precision Estimates



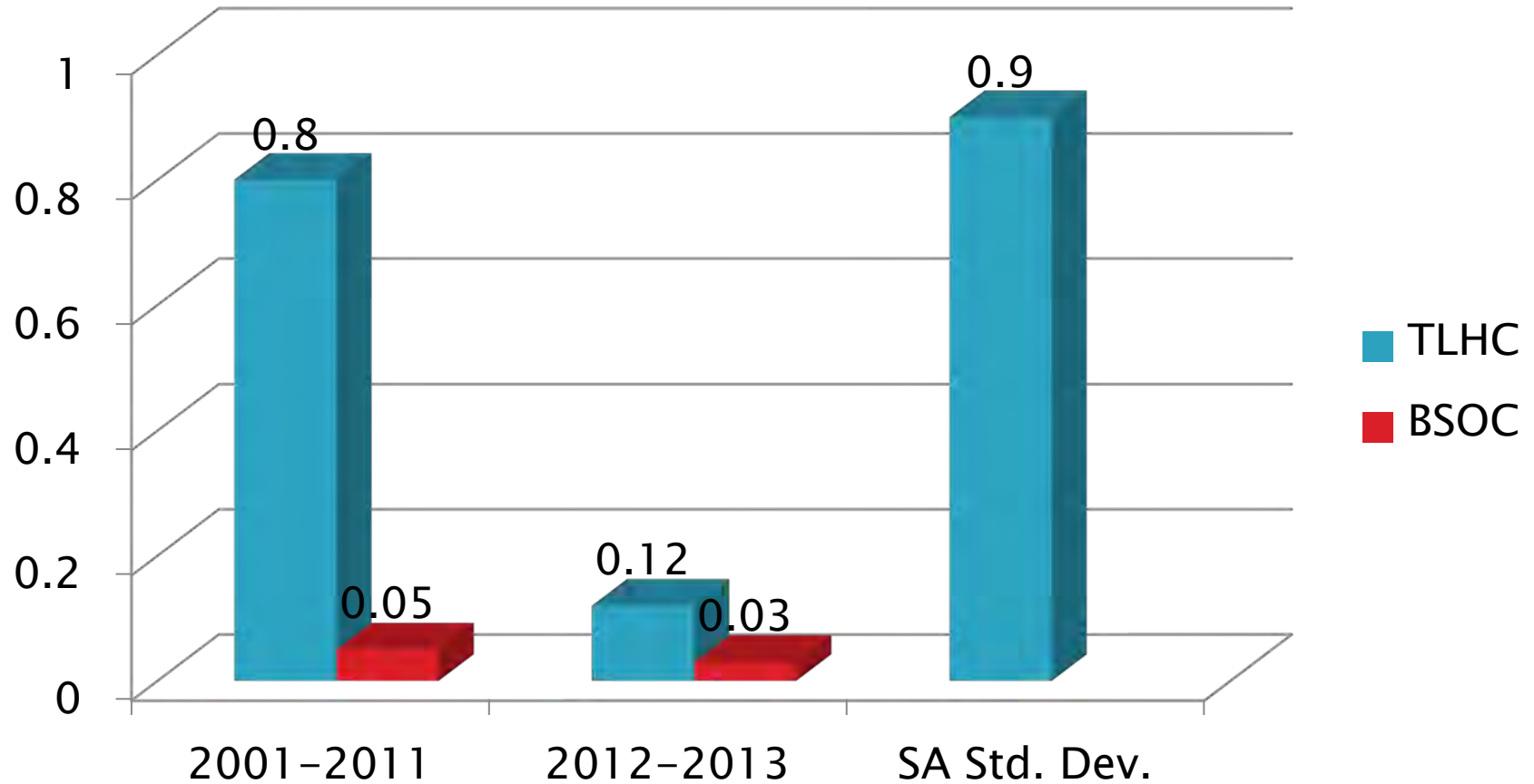
# 1 MPC Precision Estimates



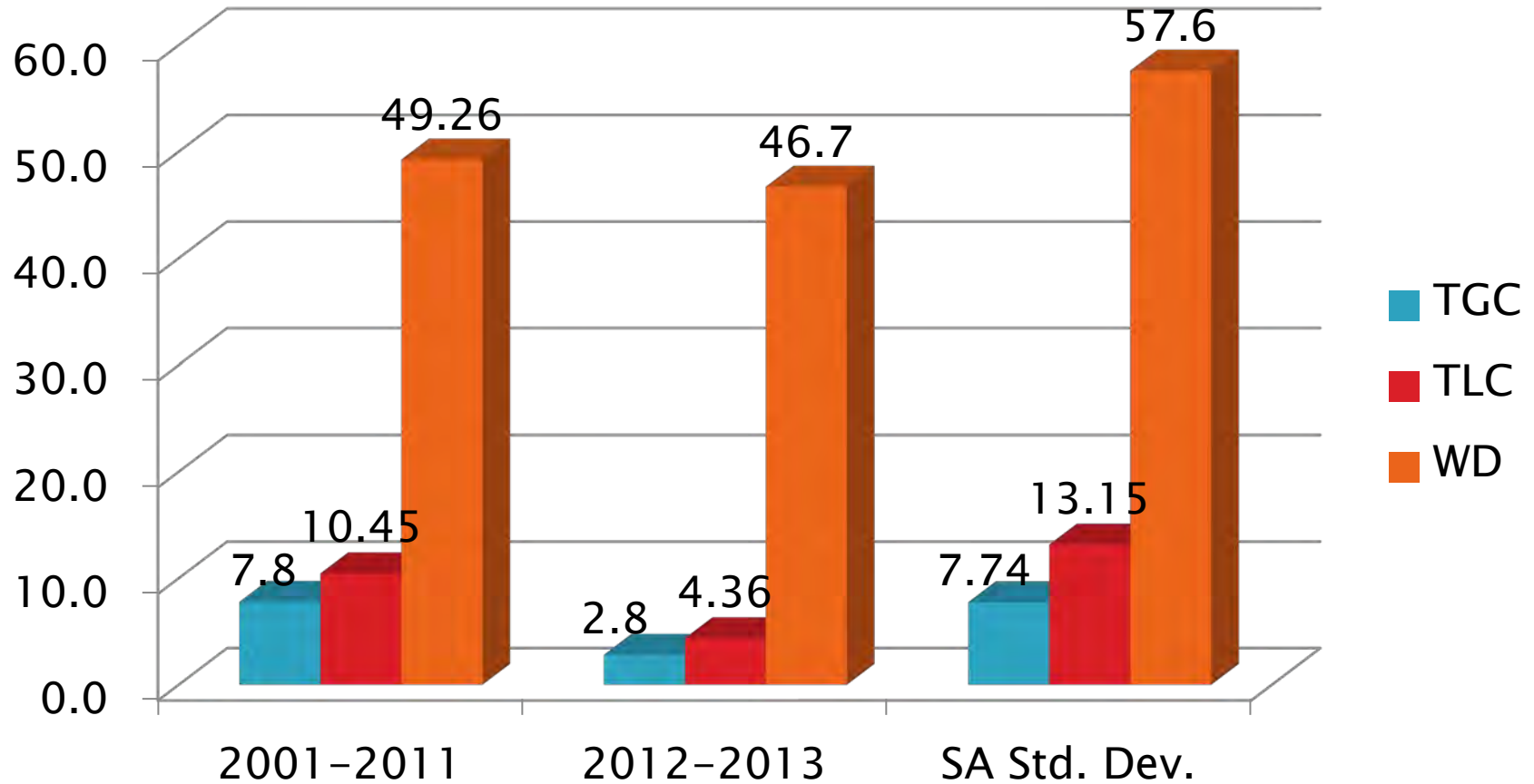
# 1 N Precision Estimates



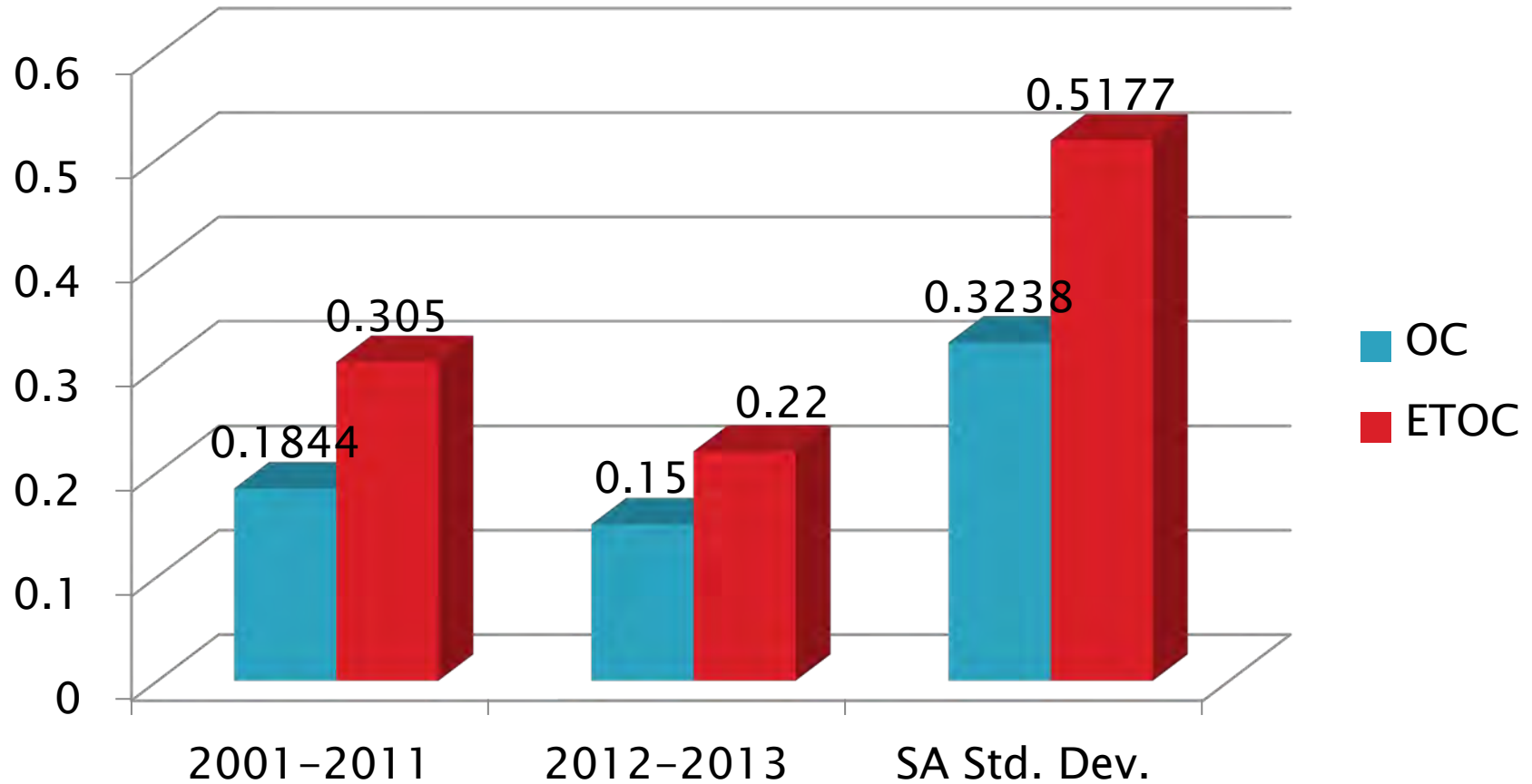
# 1 N Precision Estimates



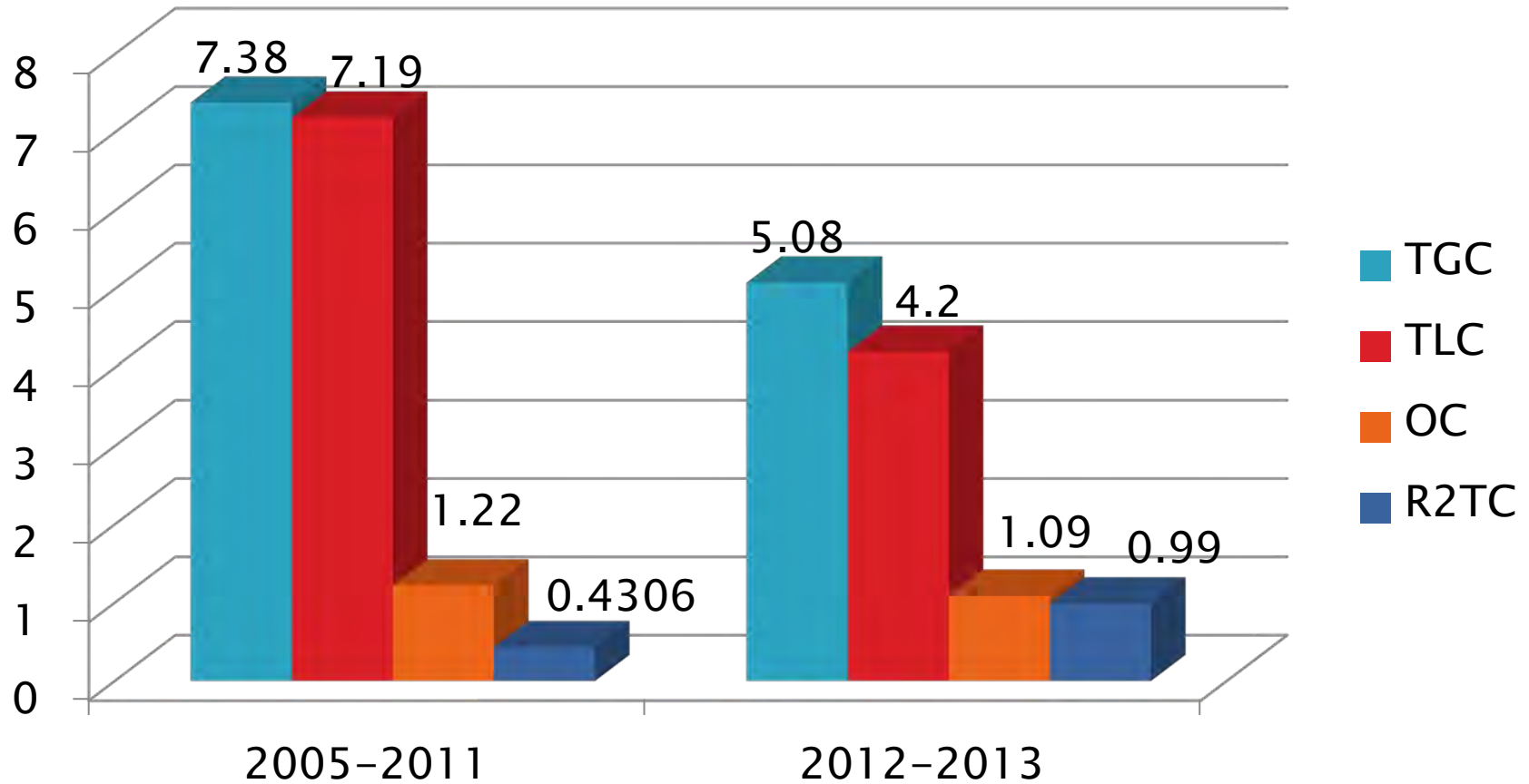
# 1P Precision Estimates



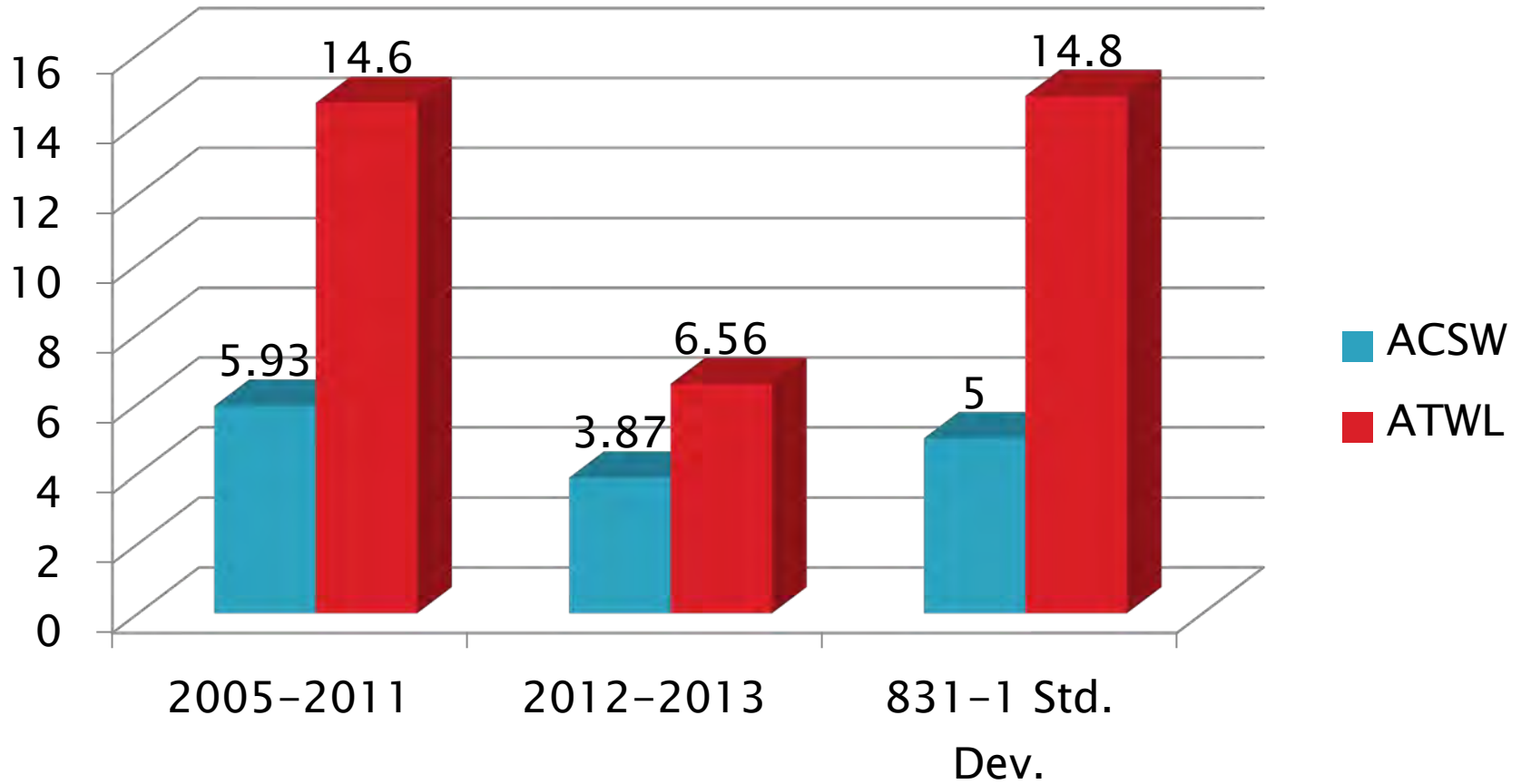
# 1 P Precision Estimates



# C13 Precision Estimates

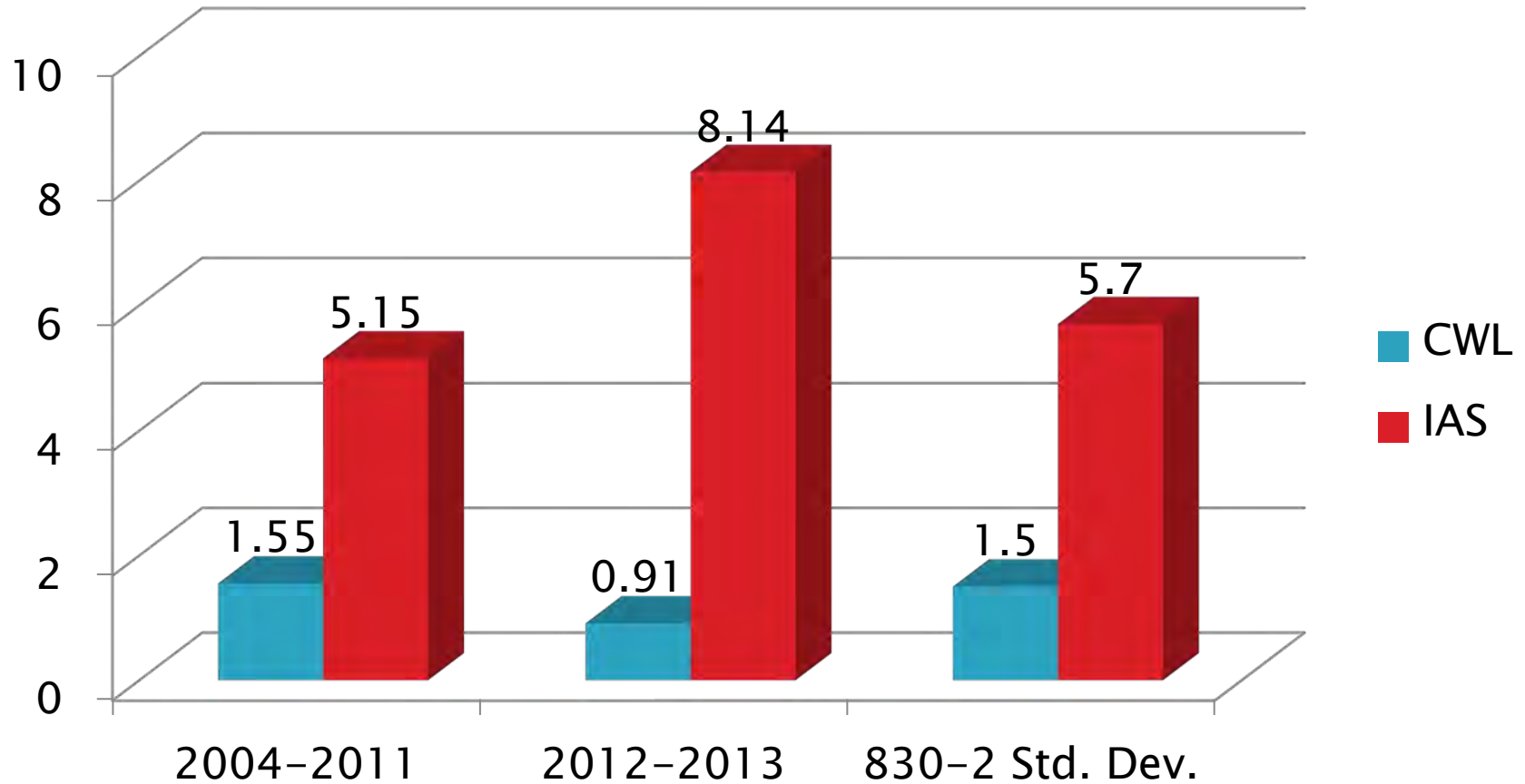


# ISB Precision Estimates

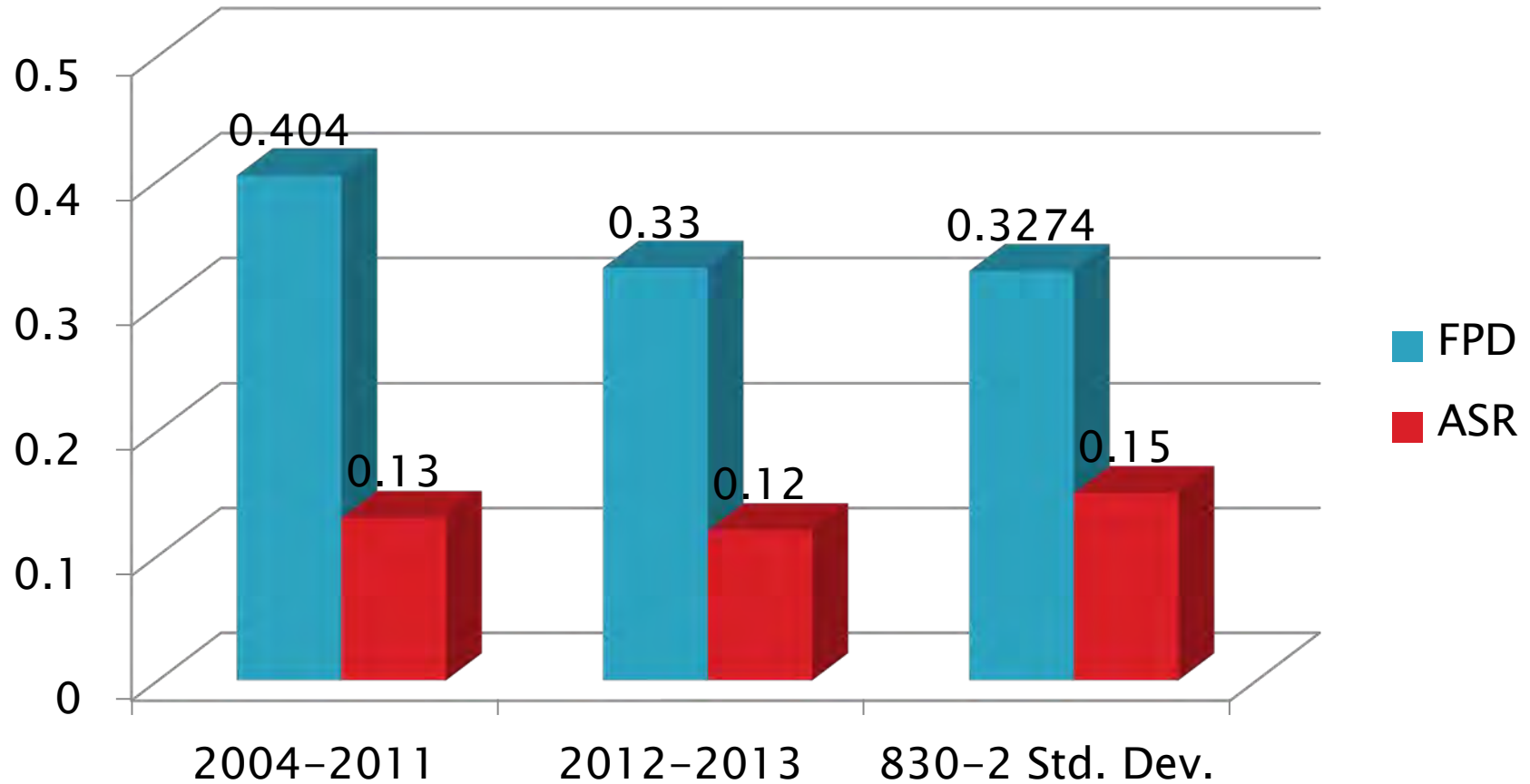




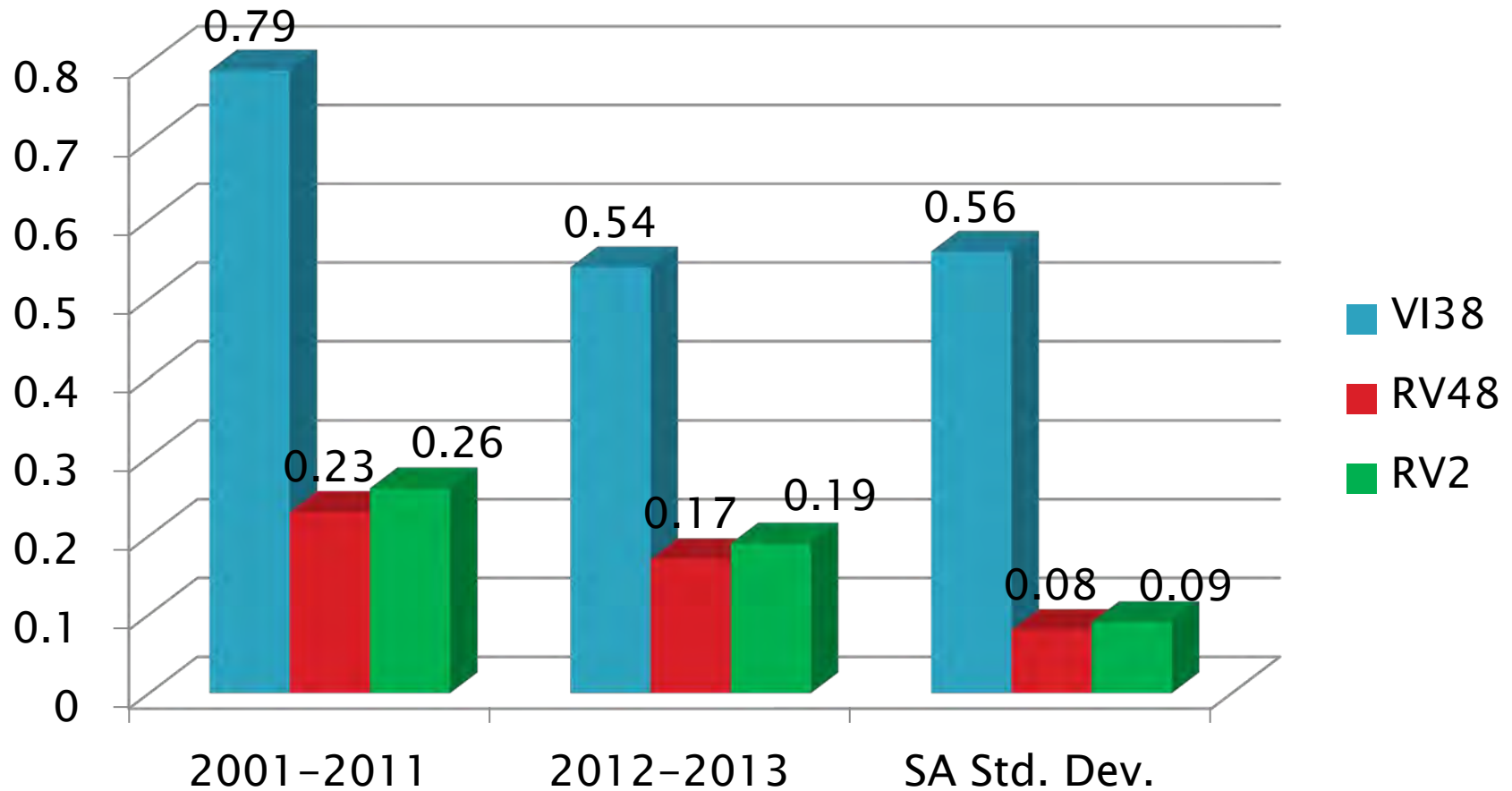
# ISM Precision Estimates



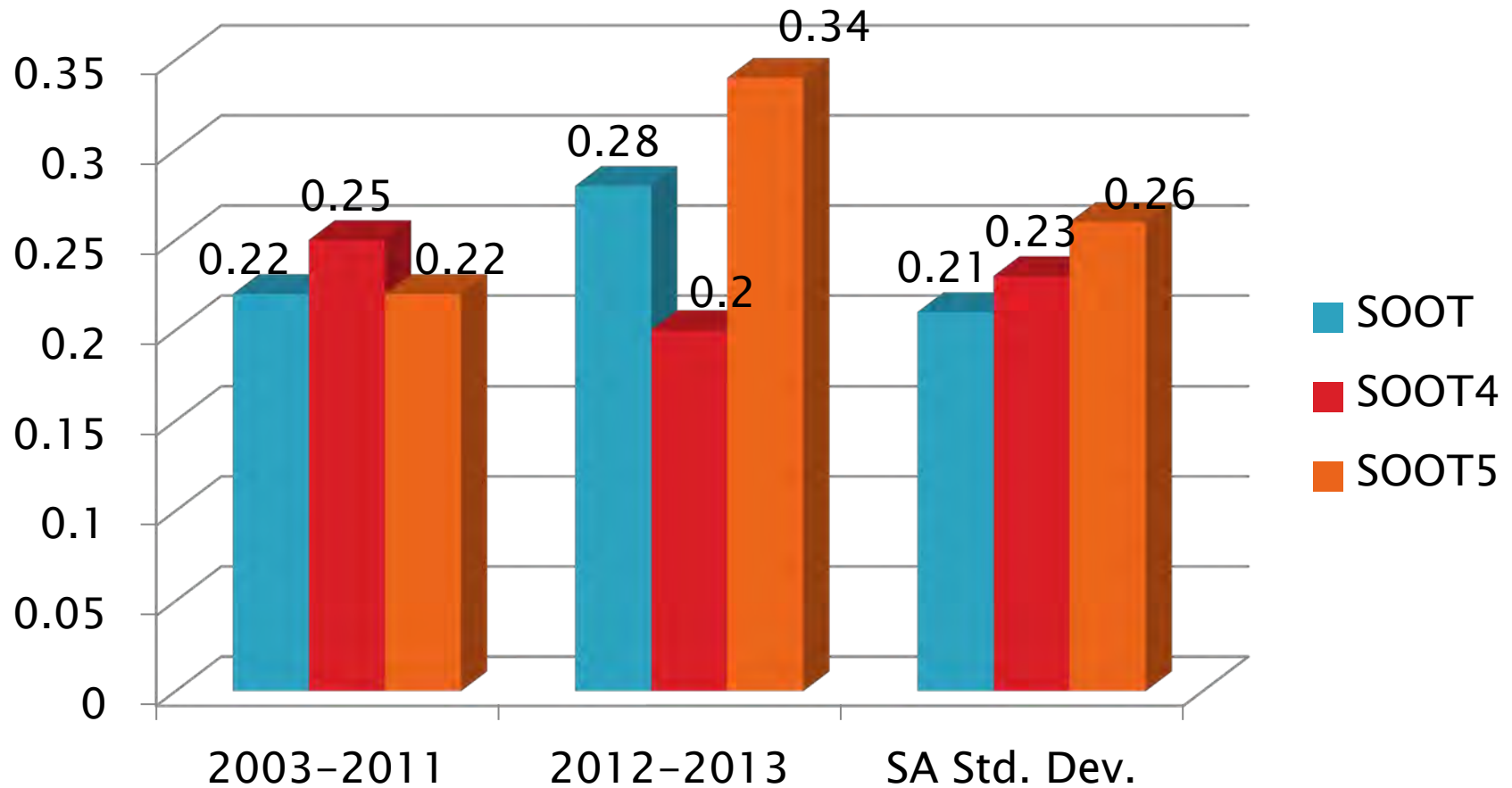
# ISM Precision Estimates



# T-8/E Precision Estimates

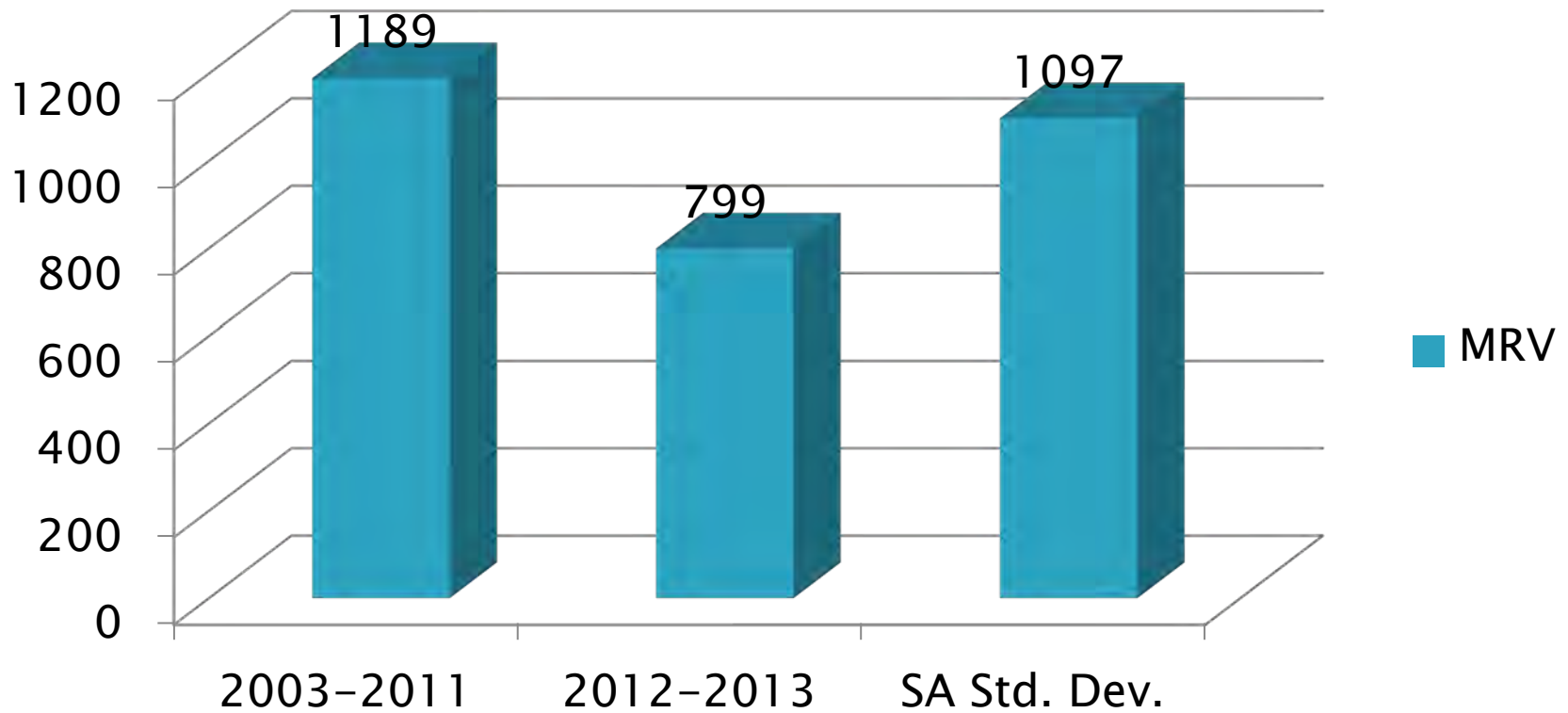


# T-11 Precision Estimates

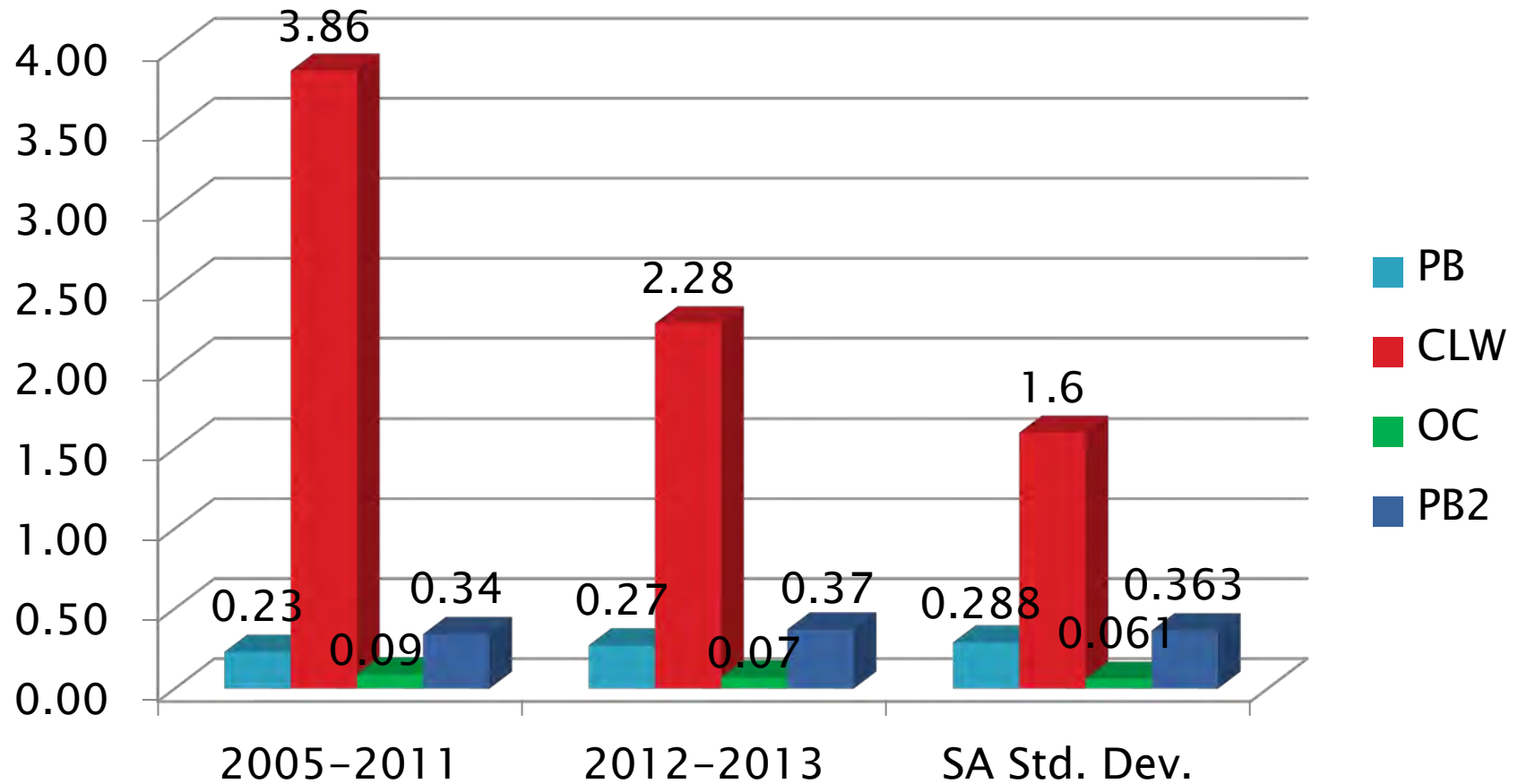


# T-11 Precision Estimates

## MRV

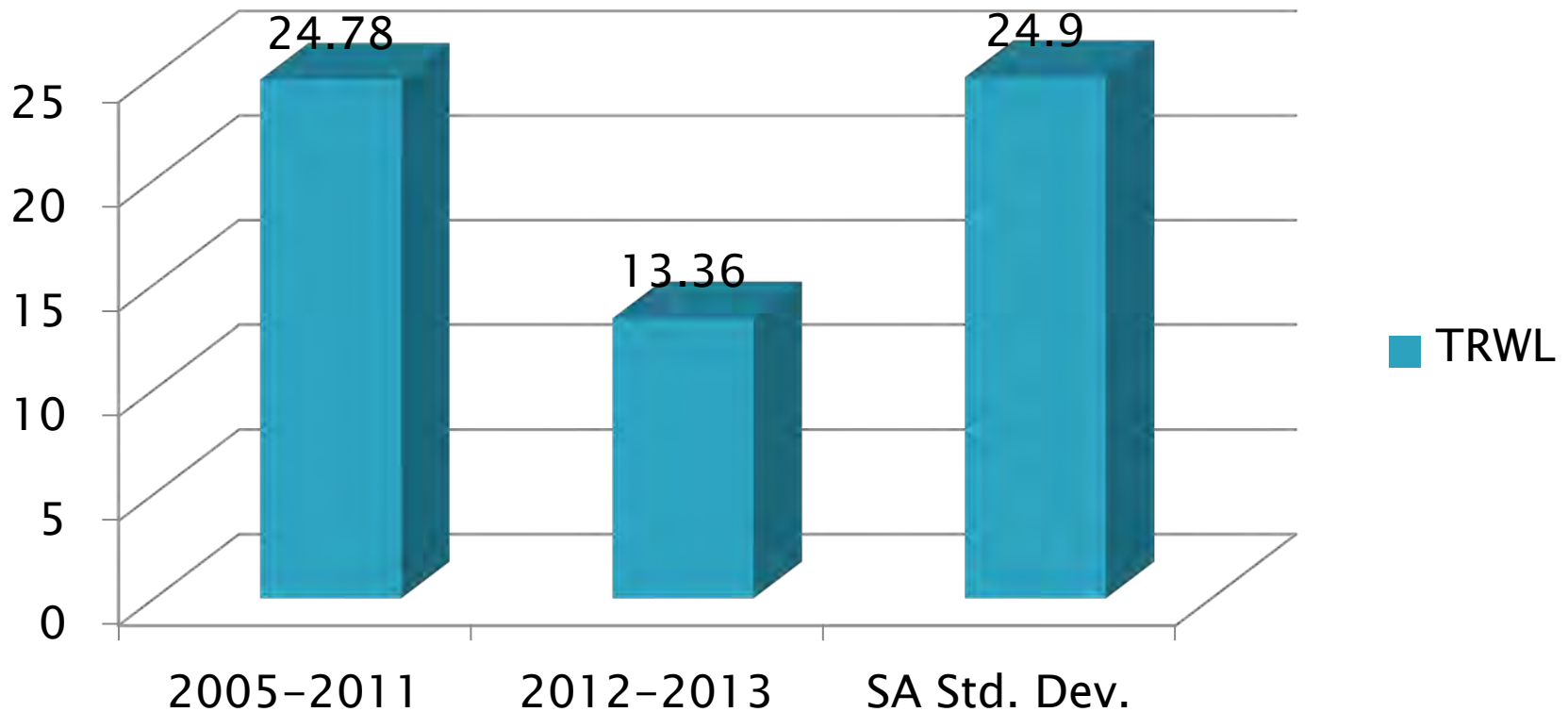


# T-12 Precision Estimates



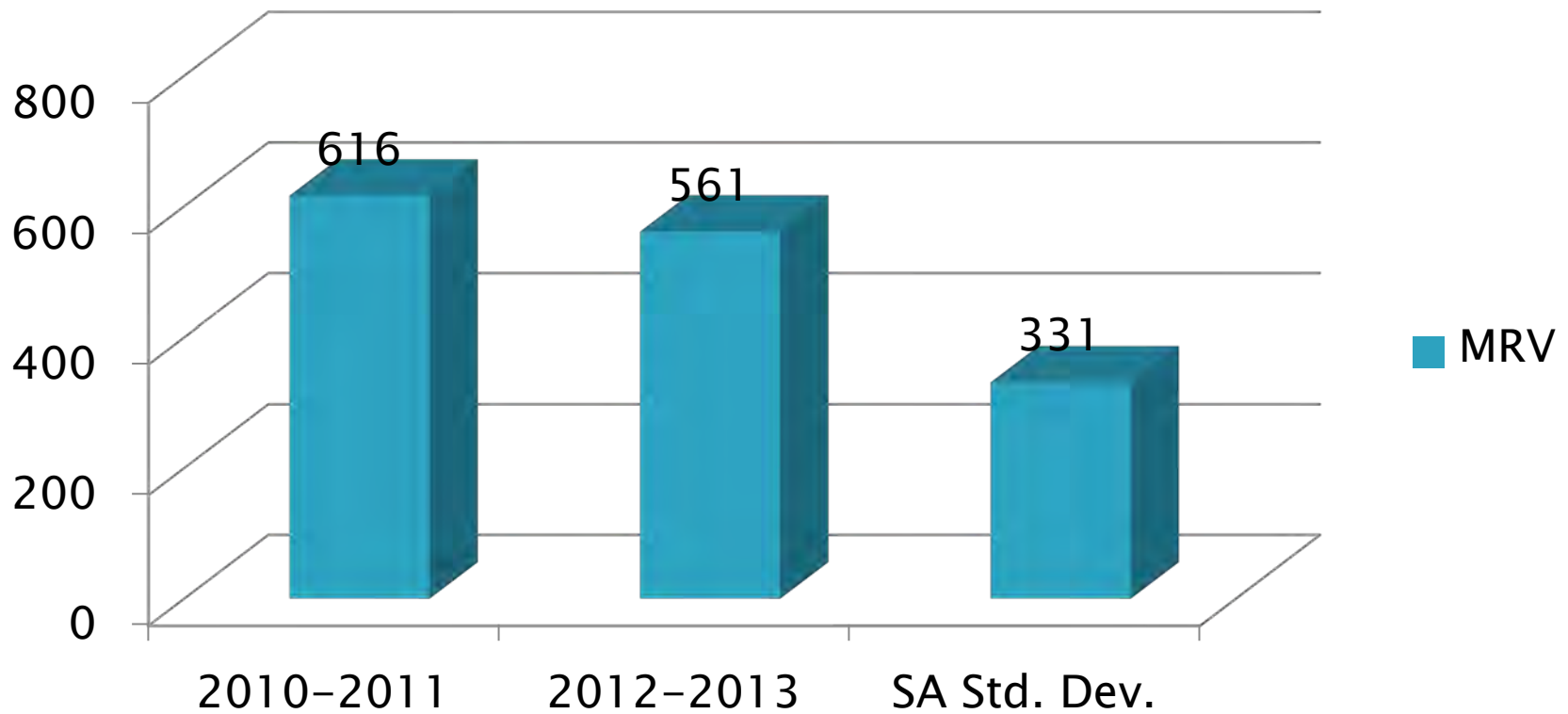
# T-12 Precision Estimates

## TRWL



# T-12A Precision Estimates

## MRV





# Information Letters

»» April 1, 2013 –  
September 30, 2013

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# Information Letters\*

Test	Date	IL	Topic
C13	5/29/2013	13-1	Corrected References for Rating Manual
1MPC	5/29/2013	13-1	Corrected References for Rating Manual
1P	5/29/2013	13-1	Corrected References for Rating Manuals and Workshop
1R	5/29/2013	13-1	Corrected References for Rating Manuals and Workshop
1K/1N	5/28/2013	13-1	Corrected References for Rating Manuals and Workshop
T12	7/22/2013	13-1	UUXO Hardware Correction Factors

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\*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

- ▶ T11 Re-blend
  - Re-blend of 822 completed and designated as 822-2. Ready for shipment from TMC.
- ▶ T12 Re-blend
  - Re-blend process started. Expected to be available early 2014.

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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	50	2448	126	5+ years
811-2	1K, 1N	1732	30	1245	60	5+ years
820-3	1R, T-10A, T-11	2750	0	0	56	~ 1 year
822-1	1R, T-10A, T-11	560	196	16	84	~.25 years
822-2	1R, T-10A, T-11	4386	0	4286	0	5+ years
821-3	T-12	1500	425	435	225	~.75 years
830-2	ISM	3786	75	757	276	3.4 years
831-1	C13, ISB	1300	100	0	91	~ .5years
831-2	C13, ISB	880	215	612	195	5+ years
873-2	1M-PC	1650	30	177	50	5+ years
1005-3	1P, 1R, EOAT, RFWT, T-8/E	2000	265	15	182	~ 1 year
1005-4	1P, 1R, EOAT, RFWT, T-8/E	2000	477	1224	427	4.5 years

# LTMS Deviations

»» April 1, 2013 –  
September 30, 2013

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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

»» April 1, 2013 –

September 30, 2013

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# Quality Index Deviations

- ▶ No deviations during this reporting period.

# 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

»» April 1, 2013 –

September 30, 2013

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# TMC Lab Visits

- ▶ No HD lab visits during the reporting period.

# Test Area Timelines

»» April 1, 2013 –  
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# Test Area Timeline Additions\*

Test	Date	Topic	IL/Memo
T-11	20130725	Temporary Suspension of T-11 FIFO Parts Usage Requirement	13-044
T-12	20130722	T12 Severity Adjustment Freeze	13-043
T-11	20130705	Updated Targets for Reference Oil 822-1	13-042

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\*As of 9/30/2013

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# Additional Information

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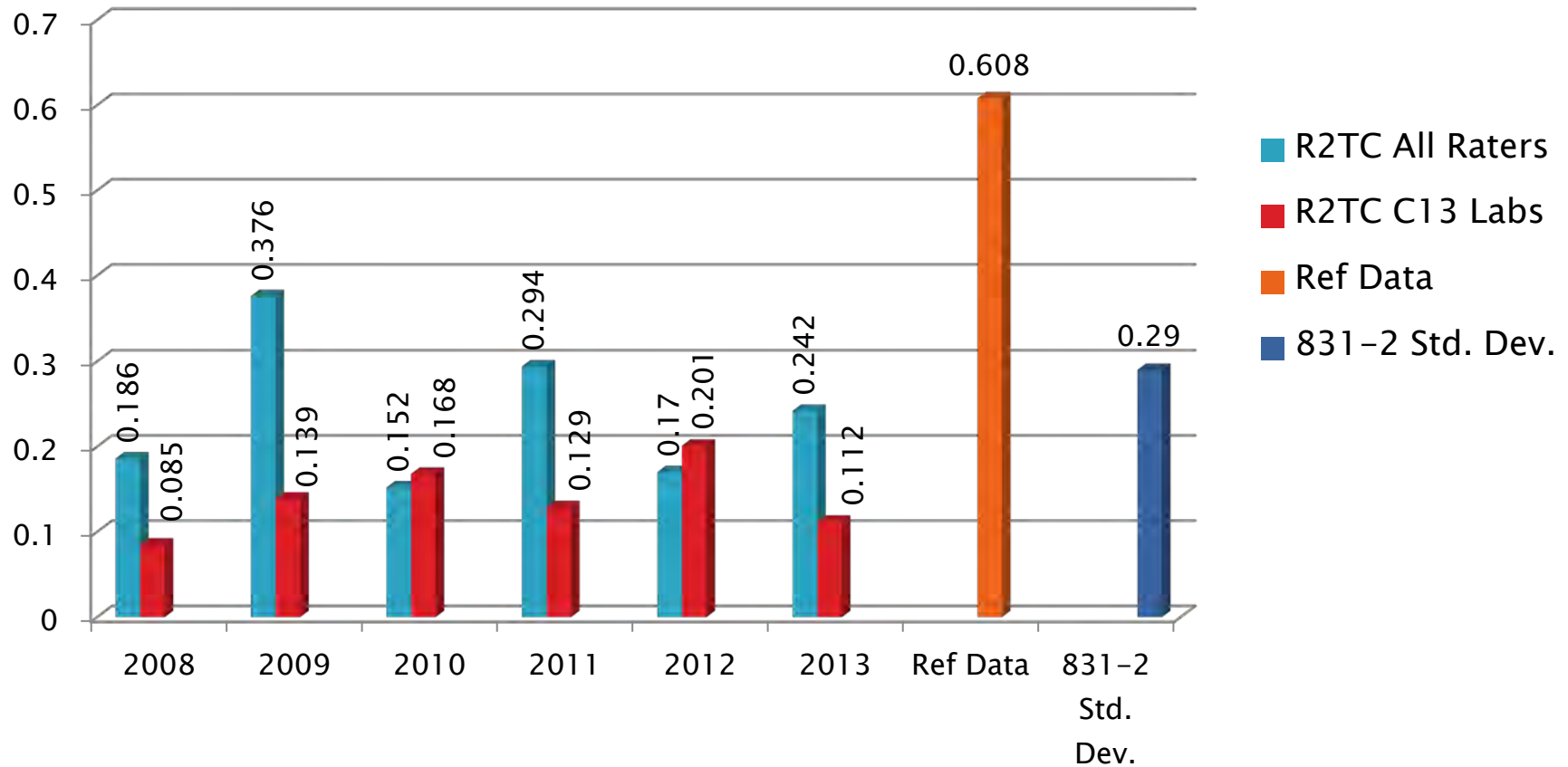
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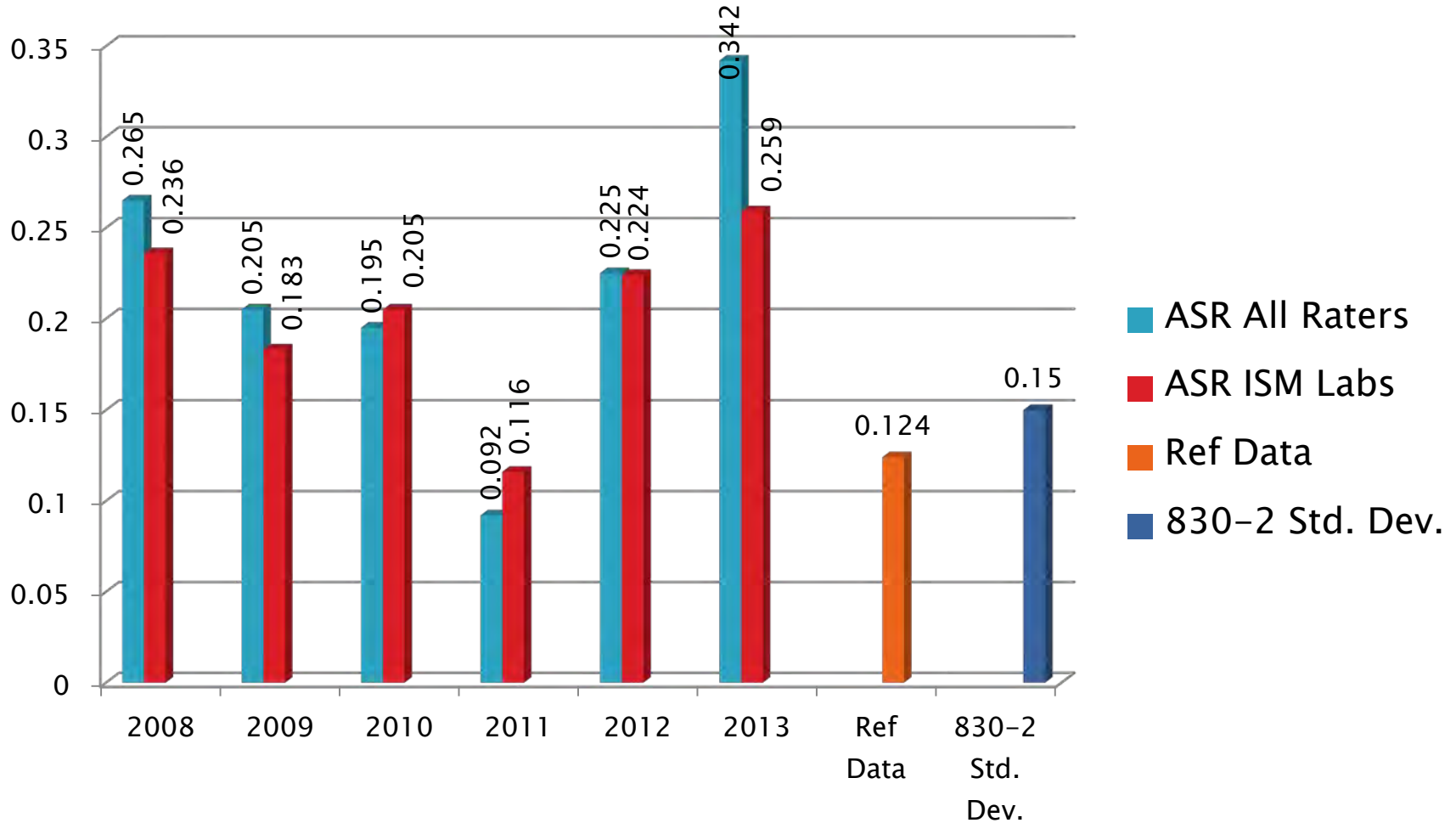
# C13 2<sup>nd</sup> Ring Carbon Rating Precision Estimates

R2TC

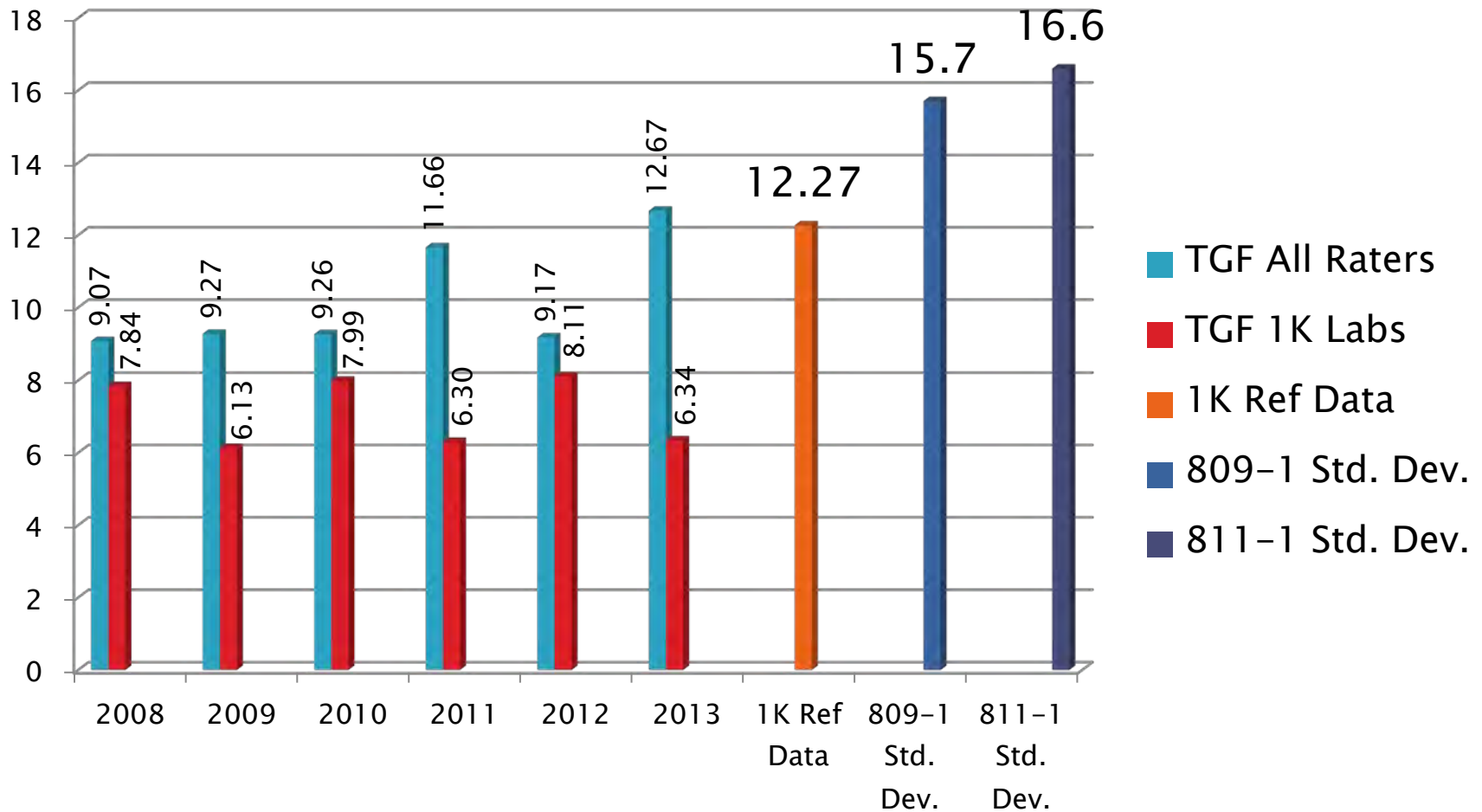




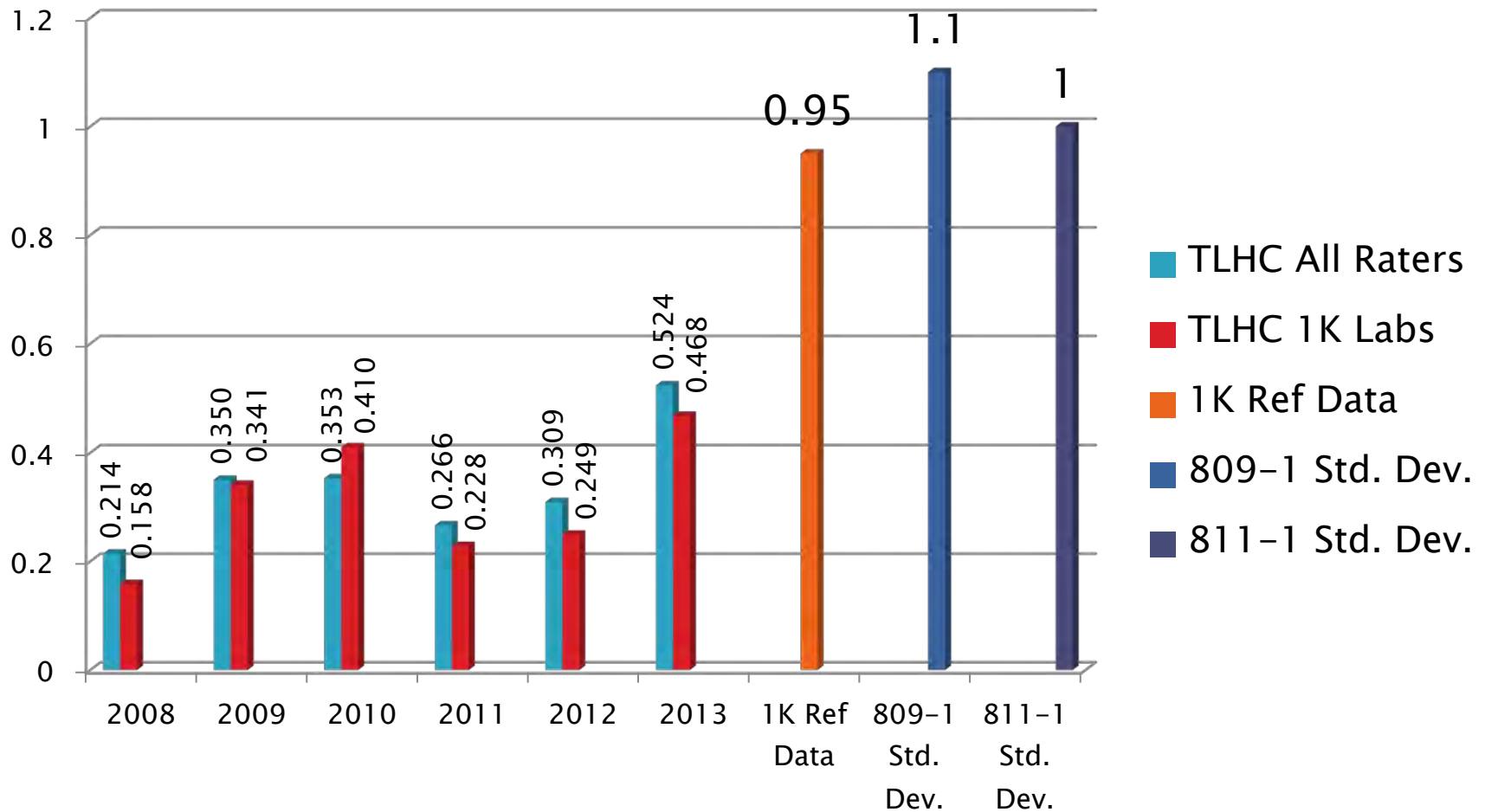
# ISM Sludge Rating Precision Estimates



# Deposit Rating Precision Estimates



# Deposit Rating Precision Estimates



# 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 2013

# Appendix 1.a

# 1 K Control Charts

» Severity, Precision, and CuSum

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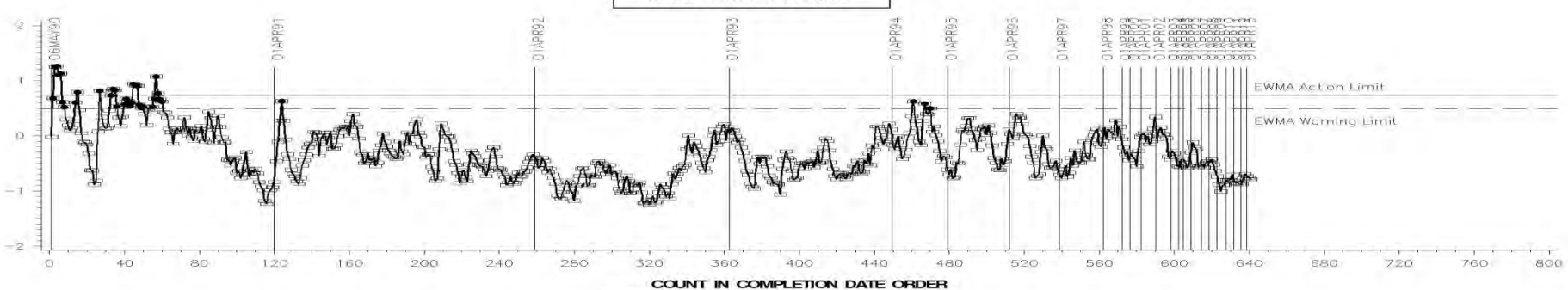


Top Groove Fill

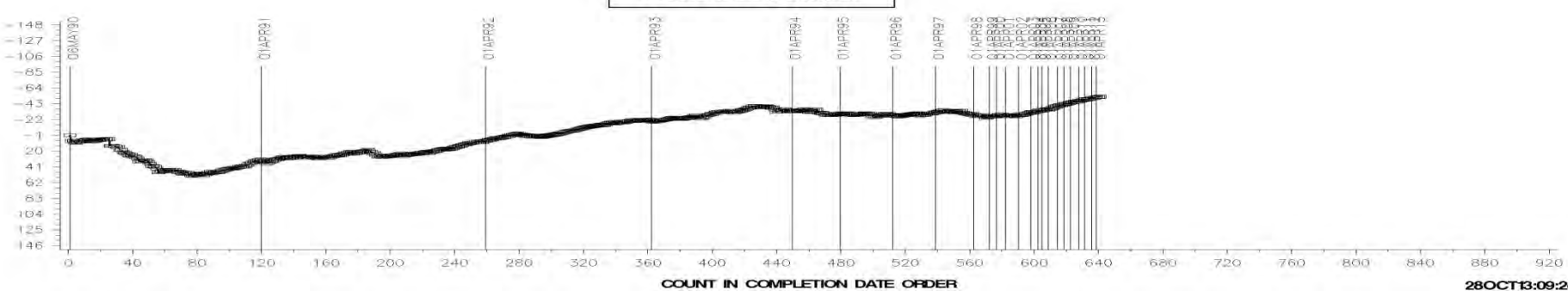
LTMS Severity Analysis



LTMS Precision Analysis



CUSUM Severity Analysis



28OCT13:09:24

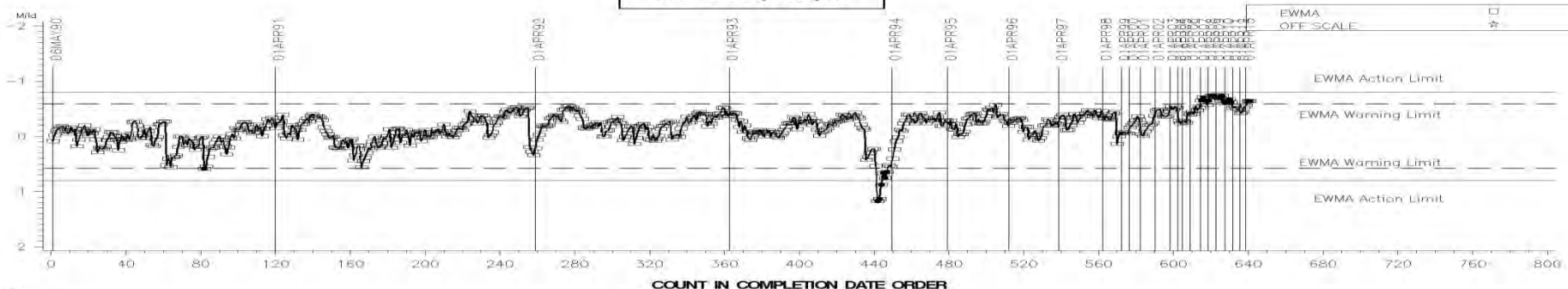




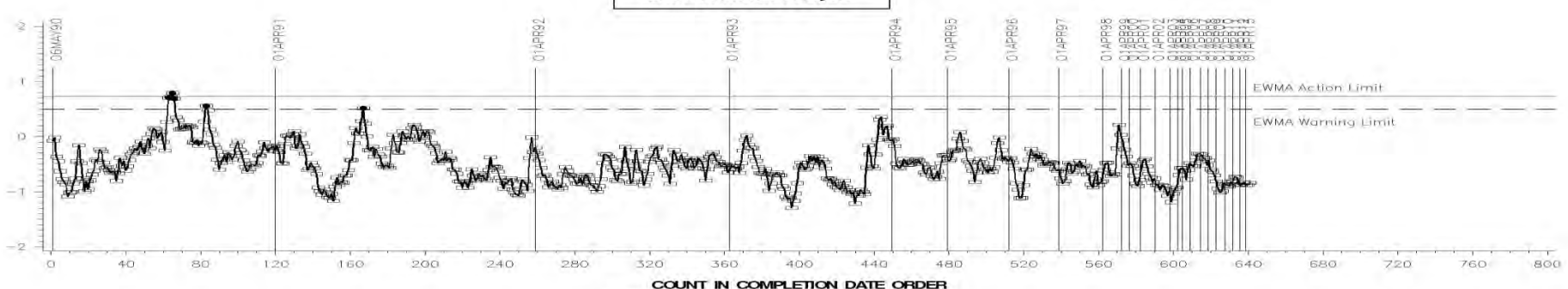


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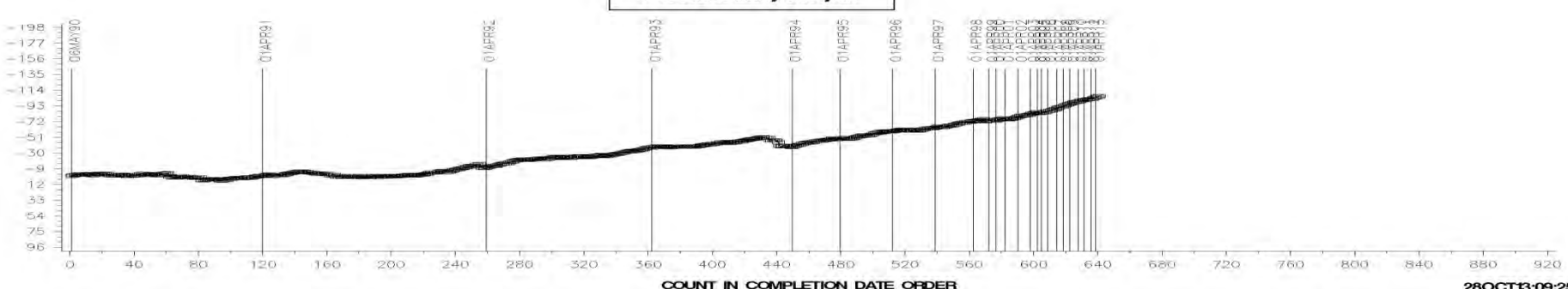
LTMS Severity Analysis



LTMS Precision Analysis



CUSUM Severity Analysis

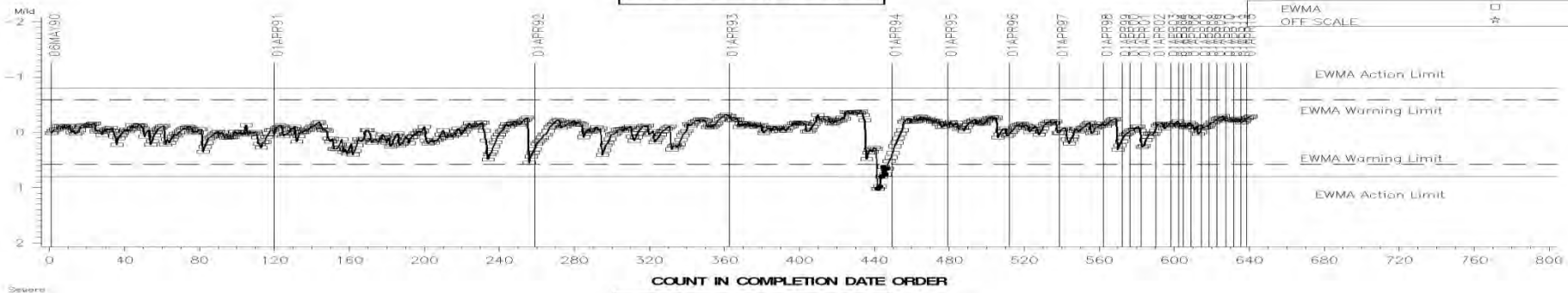


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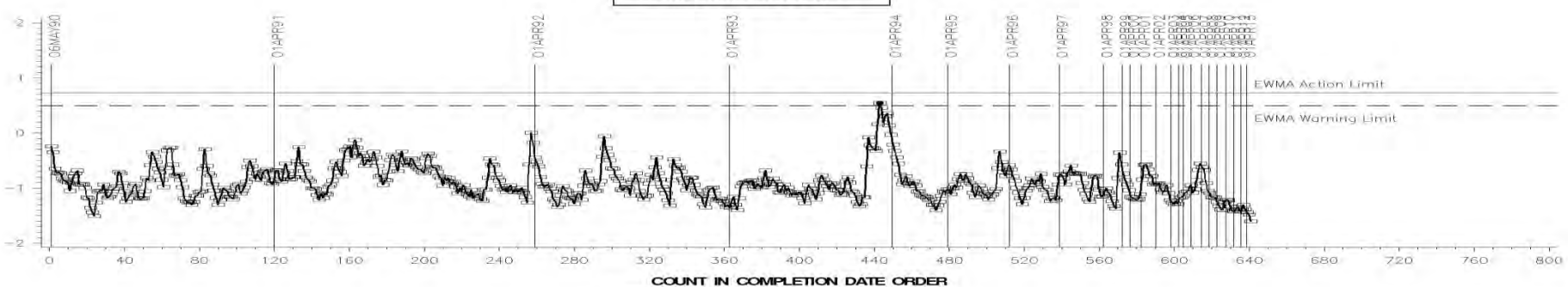


EOTOC

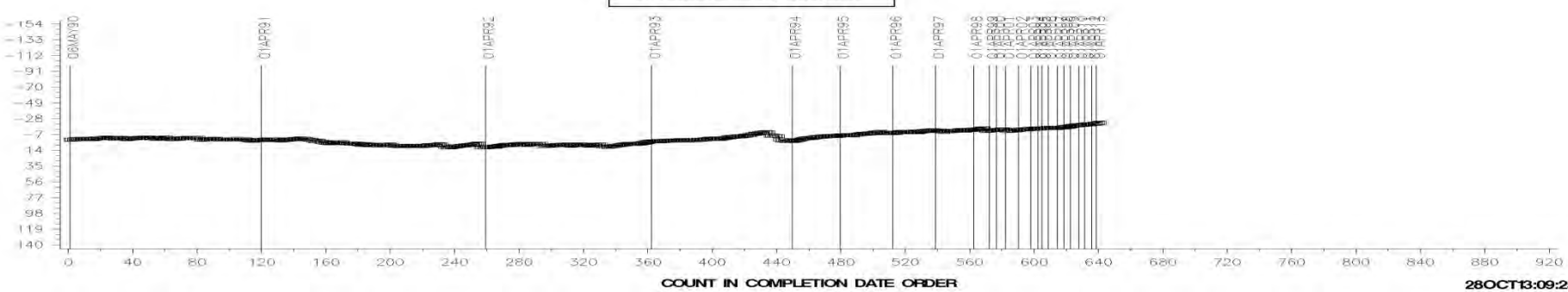
LTMS Severity Analysis



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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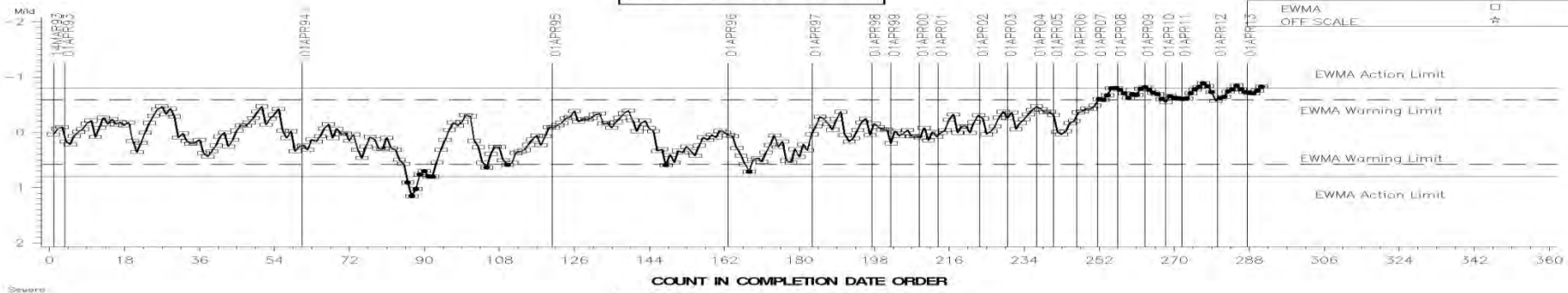
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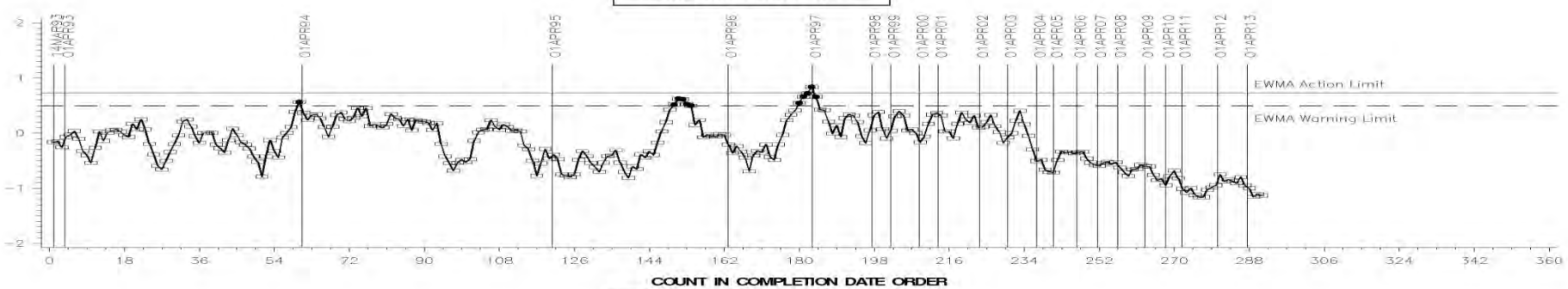
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Top Groove Fill

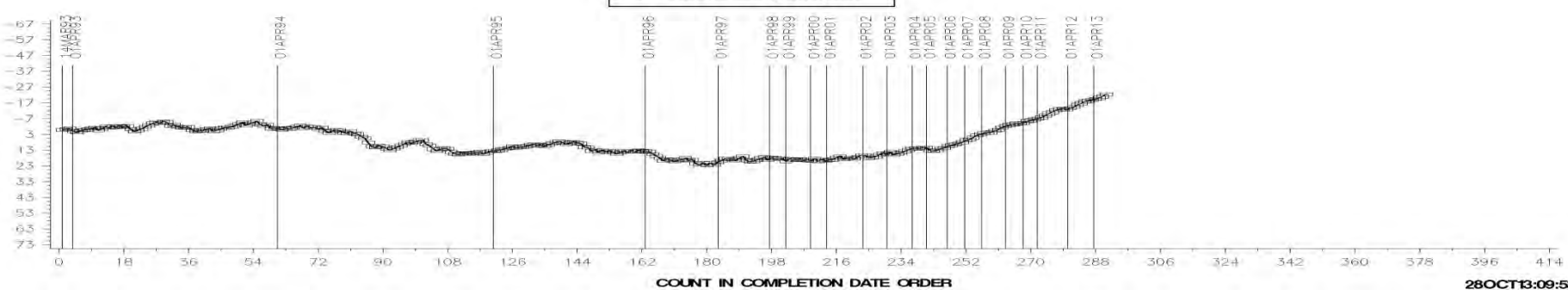
LTMS Severity Analysis



LTMS Precision Analysis



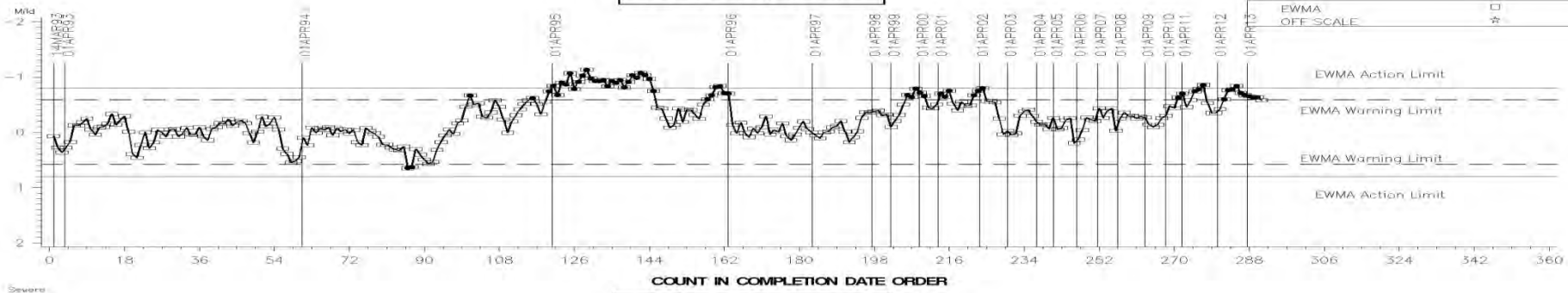
CUSUM Severity Analysis



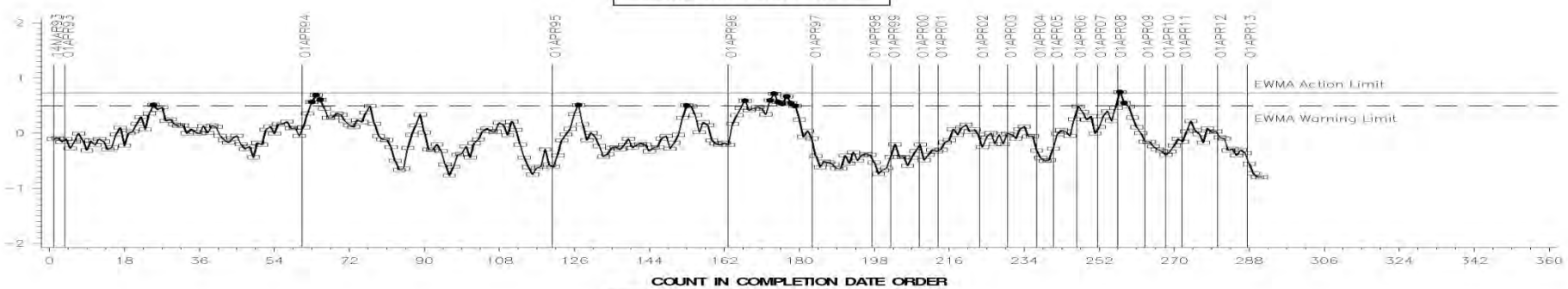
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Weighted Total Demerits

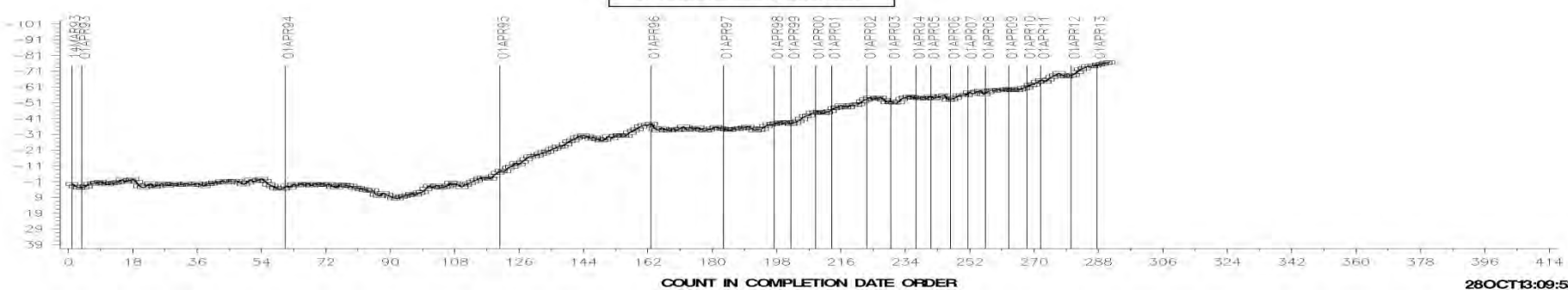
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LTMS Precision Analysis



CUSUM Severity Analysis

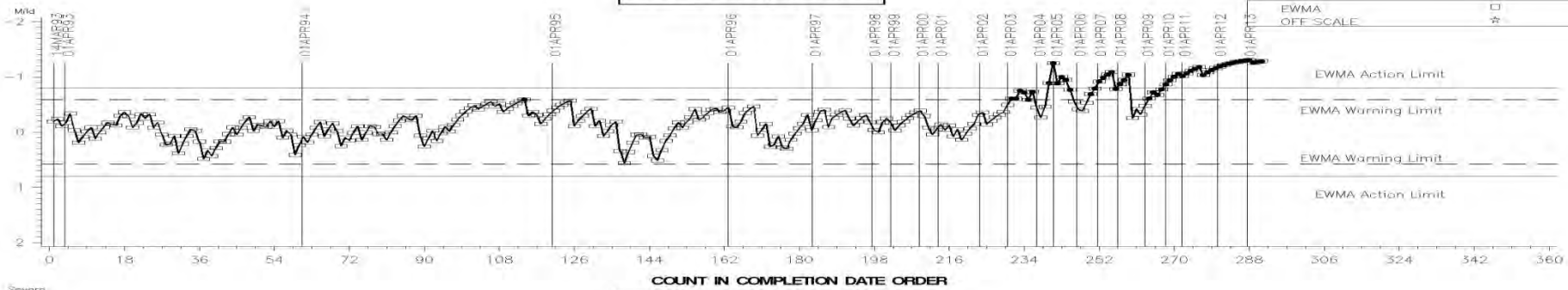


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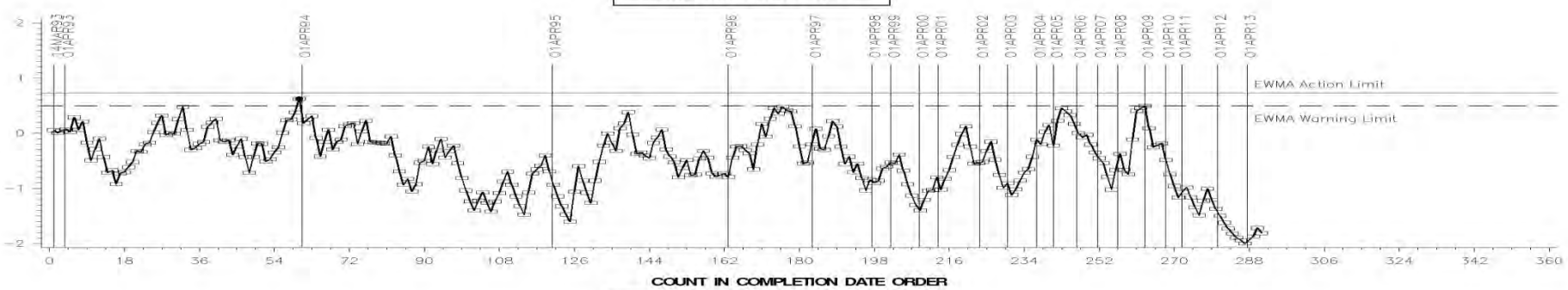


FINAL TRANS. TOP LAND HEAVY CARBON

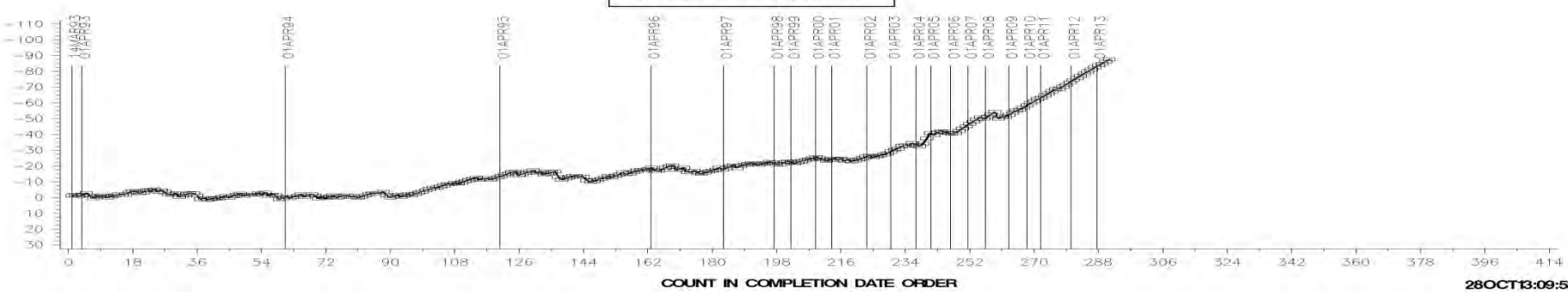
LTMS Severity Analysis



LTMS Precision Analysis



CUSUM Severity Analysis

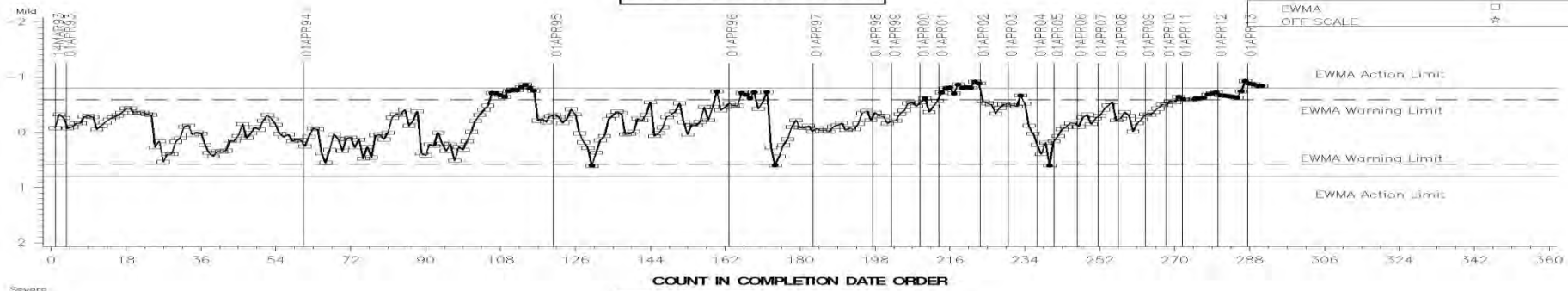


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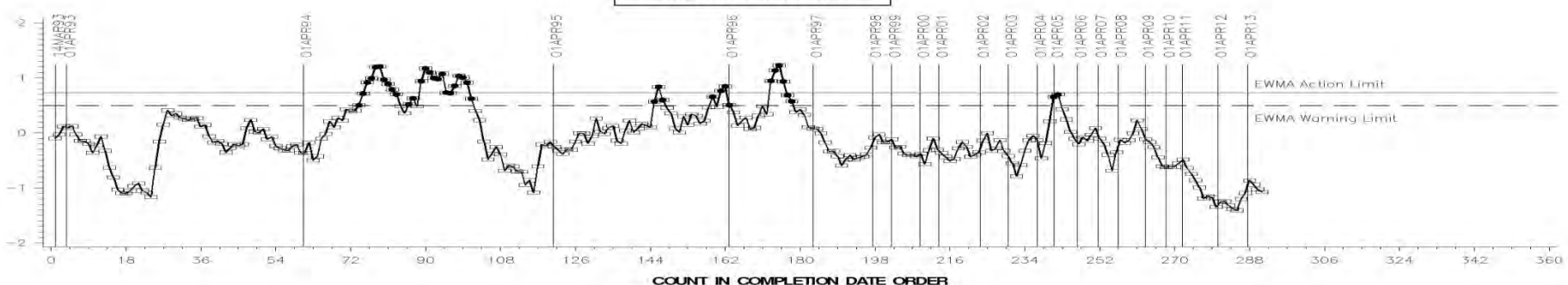


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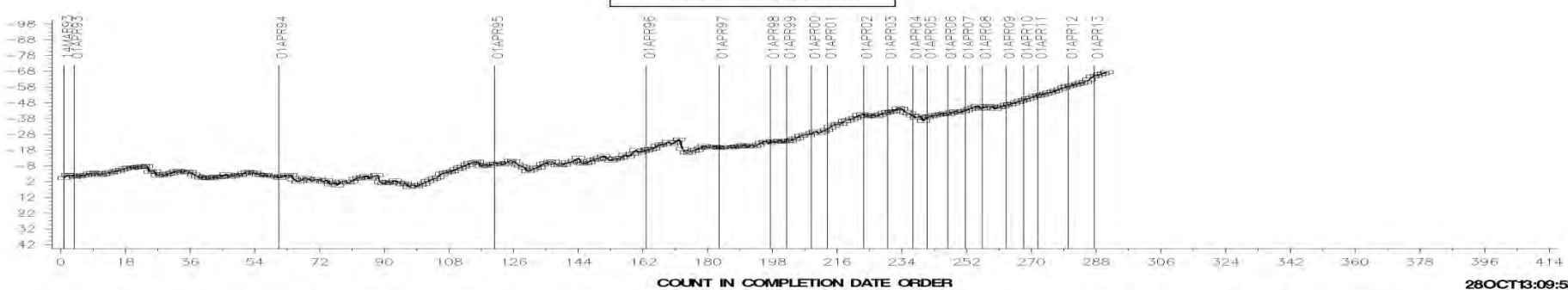
LTMS Severity Analysis



LTMS Precision Analysis



CUSUM Severity Analysis



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# Appendix 1.c

## 1 M-PC Control Charts

» Severity, Precision, and CuSum

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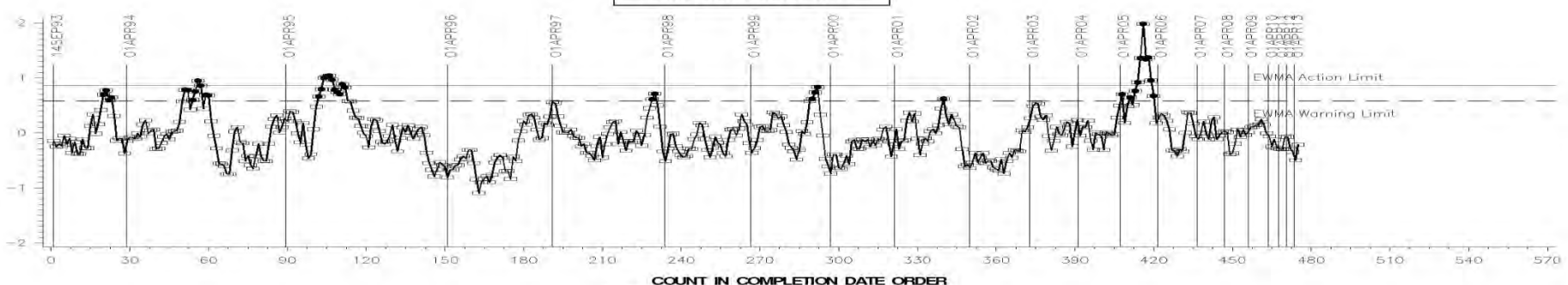


Weighted Total Demerits

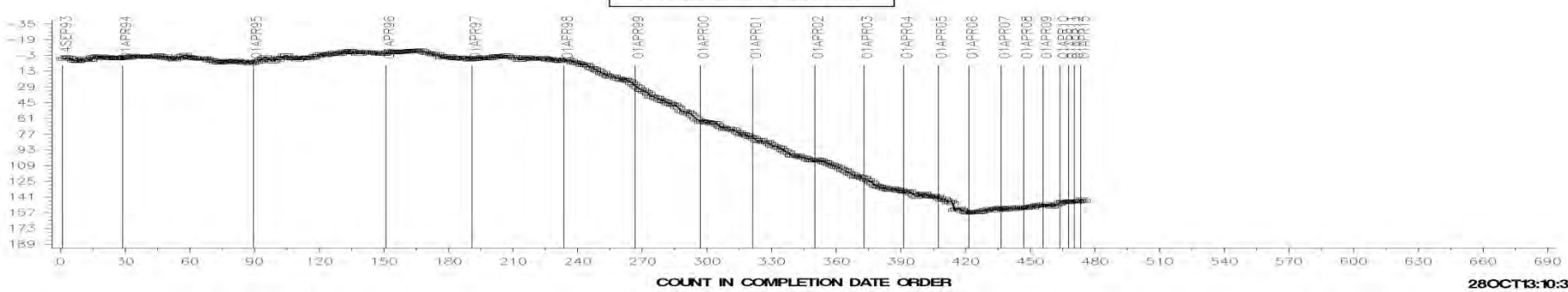
LTMS Severity Analysis



LTMS Precision Analysis



CUSUM Severity Analysis



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# Appendix 1.d

## 1 P Control Charts

» Severity, Precision, and CuSum

Test Monitoring Center

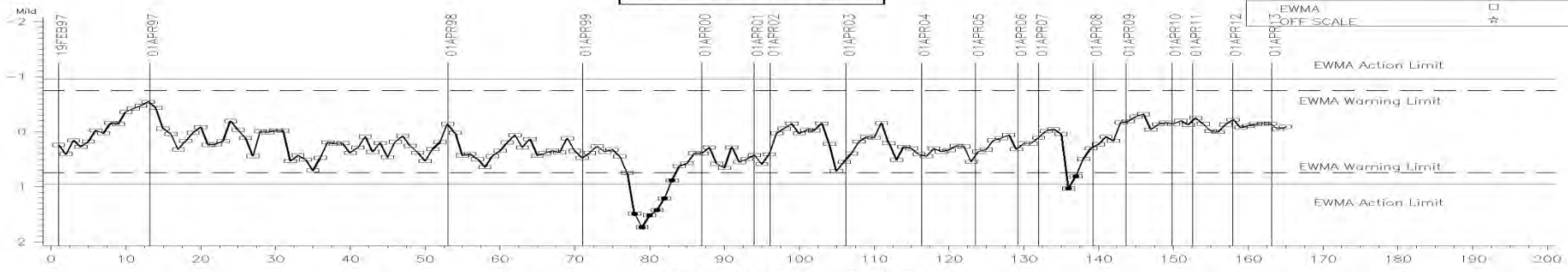
<http://astmtmc.cmu.edu>



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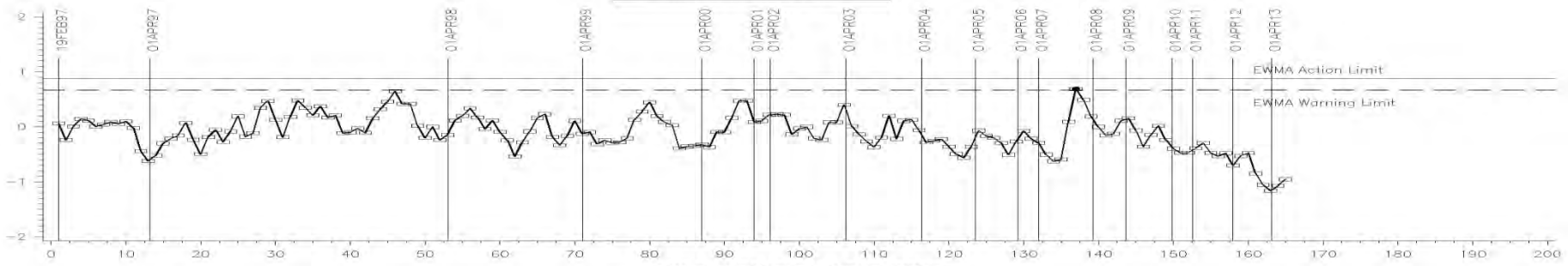
TOP GROOVE CARBON

LTMS Severity Analysis



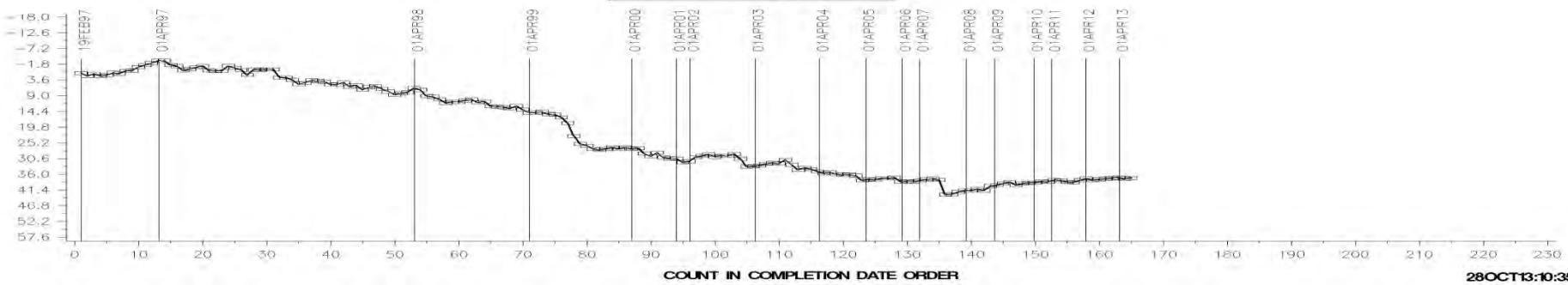
COUNT IN COMPLETION DATE ORDER

LTMS Precision Analysis



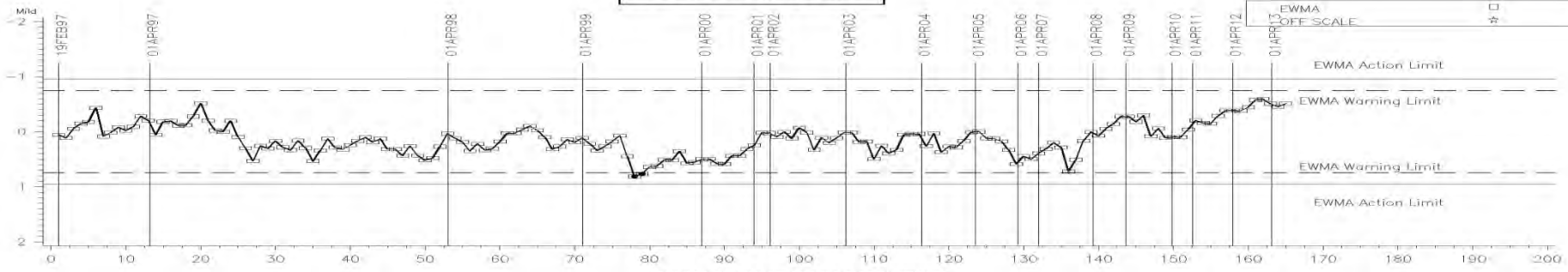
COUNT IN COMPLETION DATE ORDER

CUSUM Severity Analysis



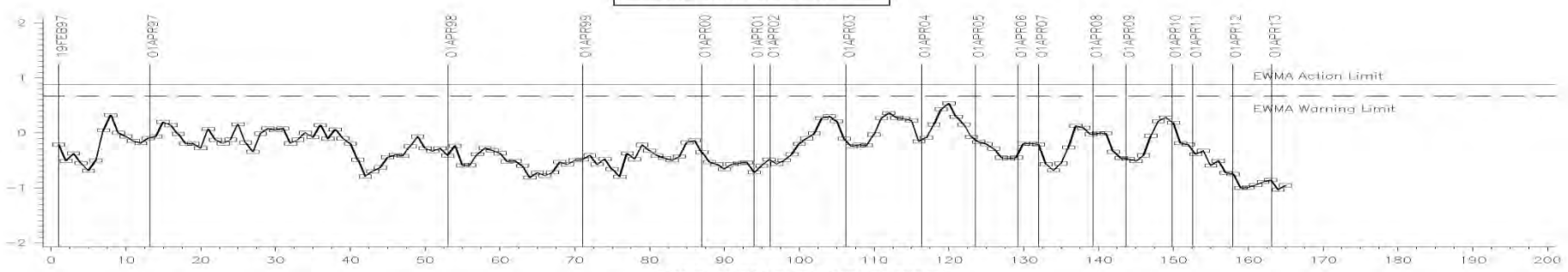
TOP LAND CARBON

LTMS Severity Analysis



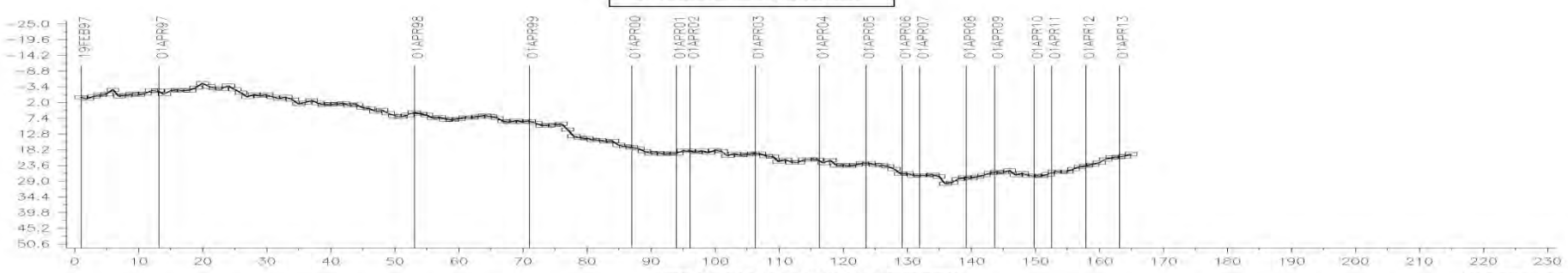
COUNT IN COMPLETION DATE ORDER

LTMS Precision Analysis



COUNT IN COMPLETION DATE ORDER

CUSUM Severity Analysis



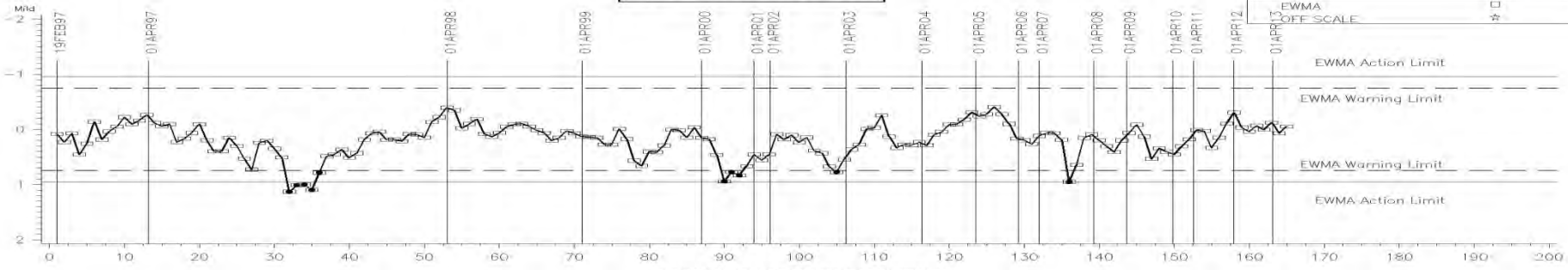
COUNT IN COMPLETION DATE ORDER

28OCT13:10:35



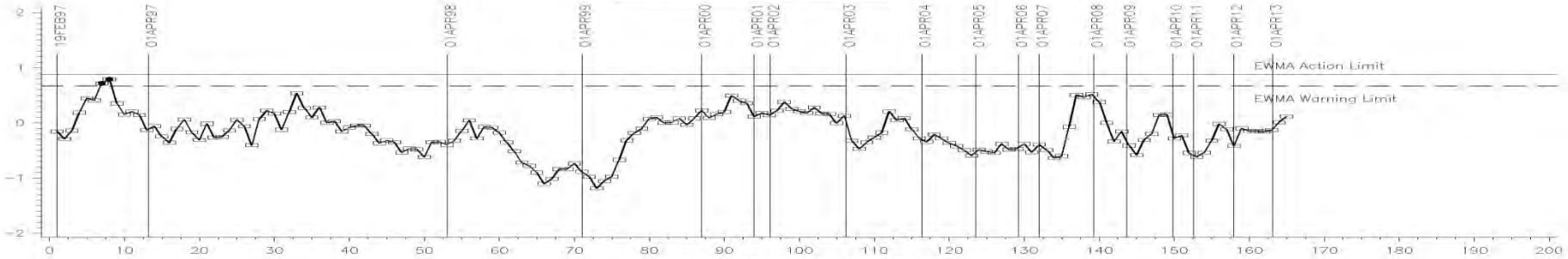
WEIGHTED TOTAL DEMERITS

LTMS Severity Analysis



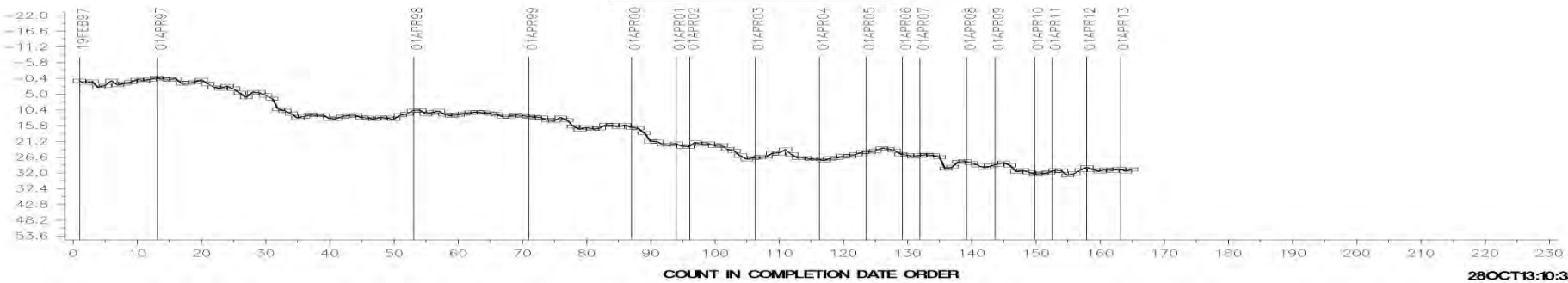
COUNT IN COMPLETION DATE ORDER

LTMS Precision Analysis



COUNT IN COMPLETION DATE ORDER

CUSUM Severity Analysis



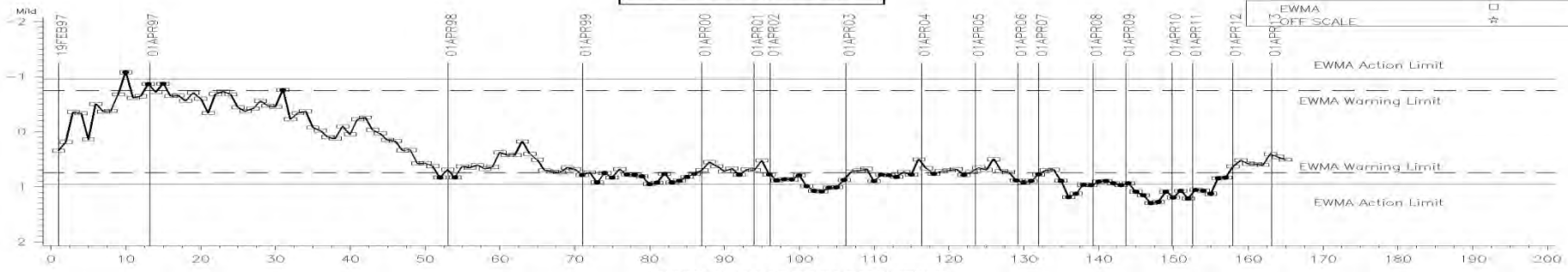
COUNT IN COMPLETION DATE ORDER

28OCT13:10:35



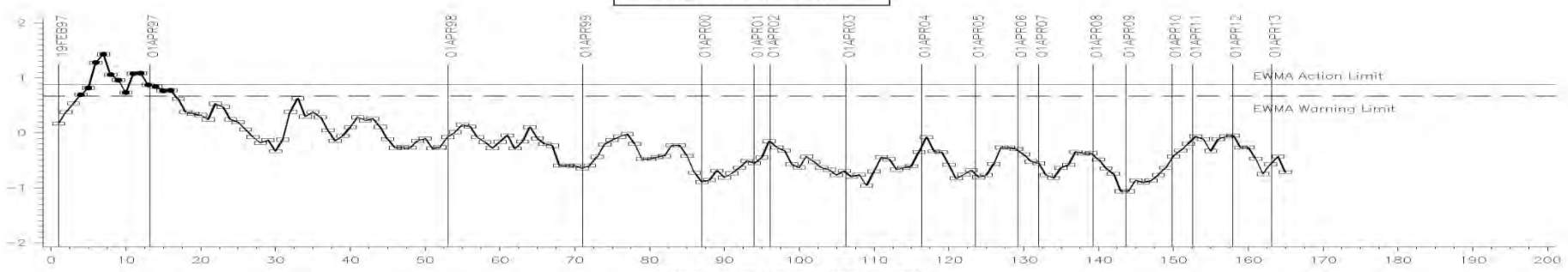
OIL CONSUMPTION

LTMS Severity Analysis



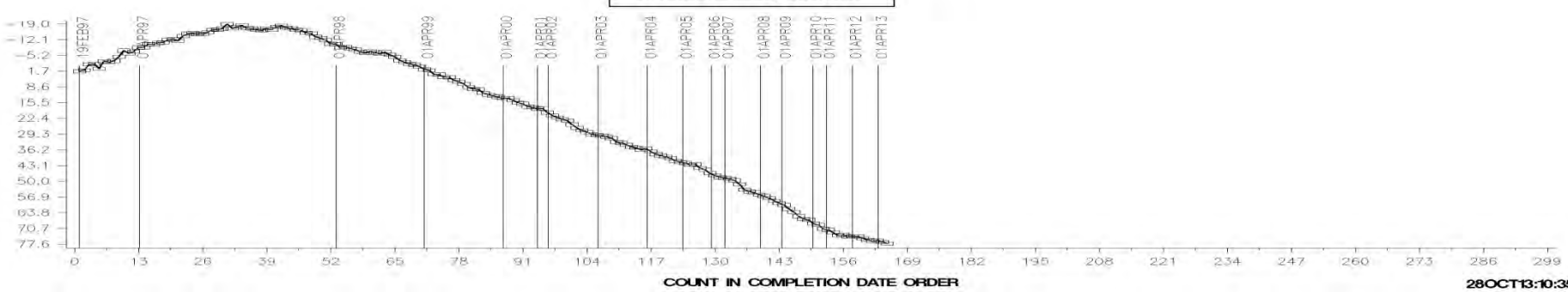
COUNT IN COMPLETION DATE ORDER

LTMS Precision Analysis



COUNT IN COMPLETION DATE ORDER

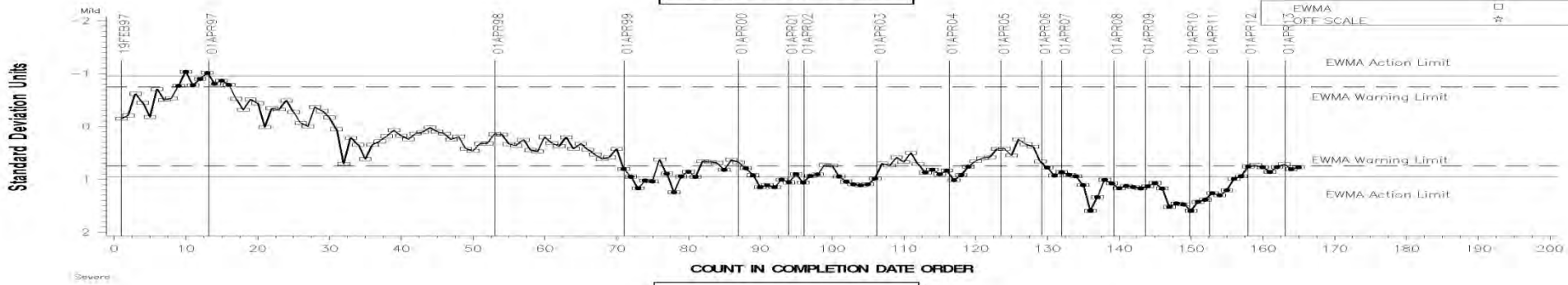
CUSUM Severity Analysis



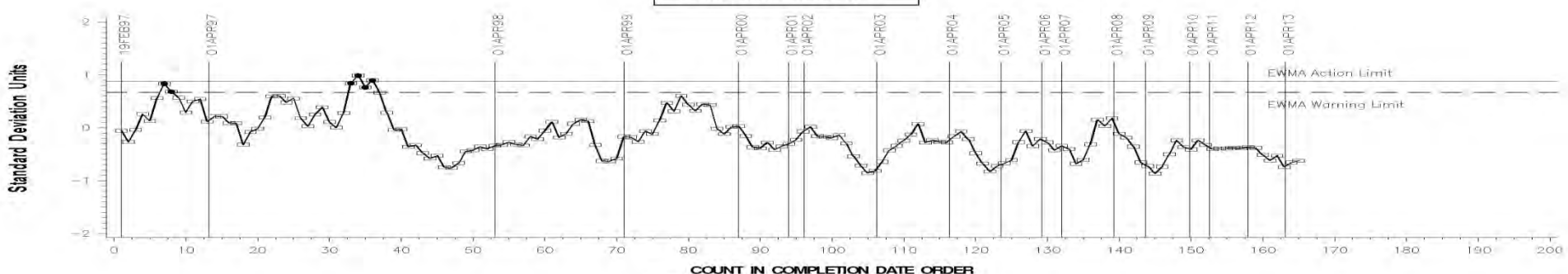
COUNT IN COMPLETION DATE ORDER

EOTOC

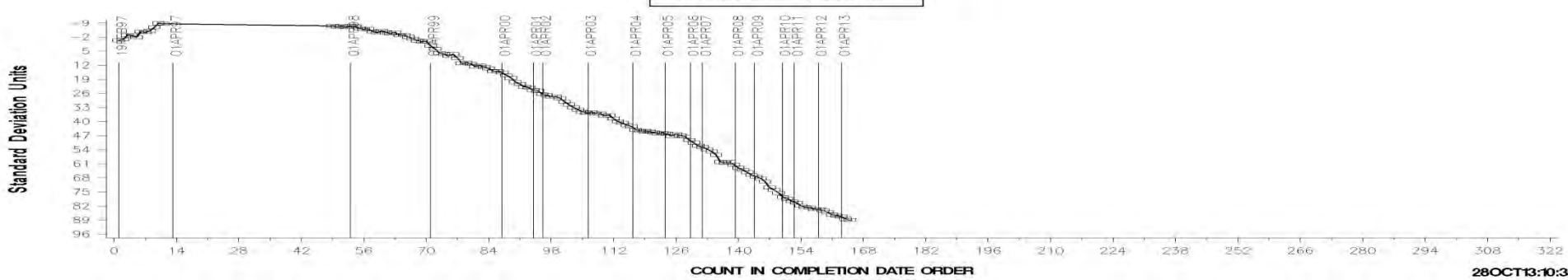
LTMS Severity Analysis



LTMS Precision Analysis



CUSUM Severity Analysis



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# Appendix 1.e

## 1 R Control Charts

» Severity, Precision, and CuSum

Test Monitoring Center

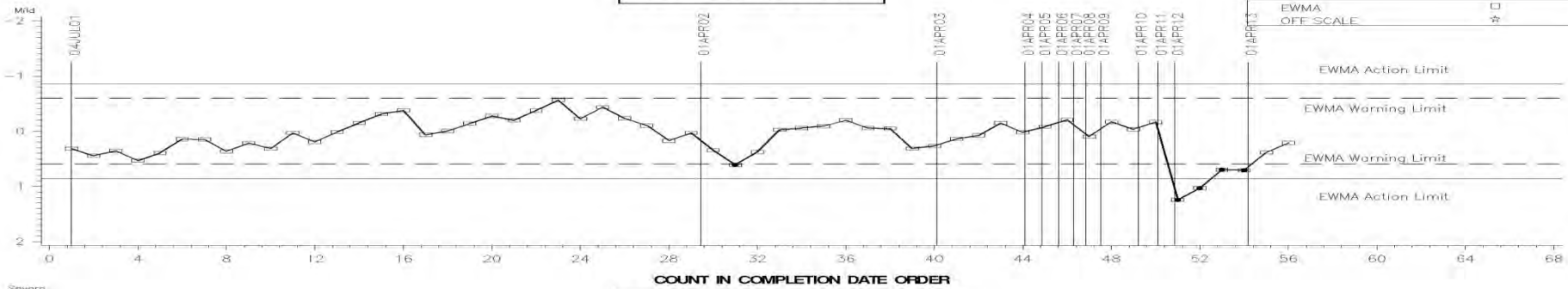
<http://astmtmc.cmu.edu>



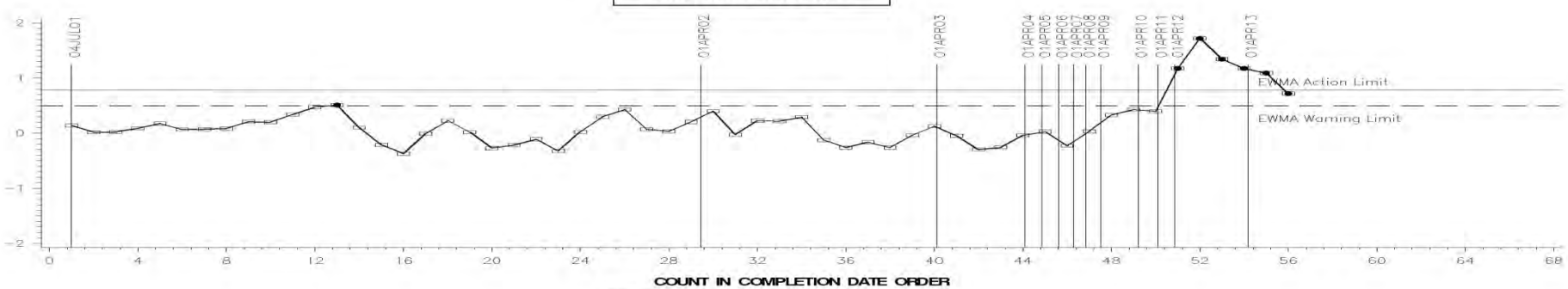
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FINAL WEIGHTED TOTAL DEMERITS (DEMERITS)

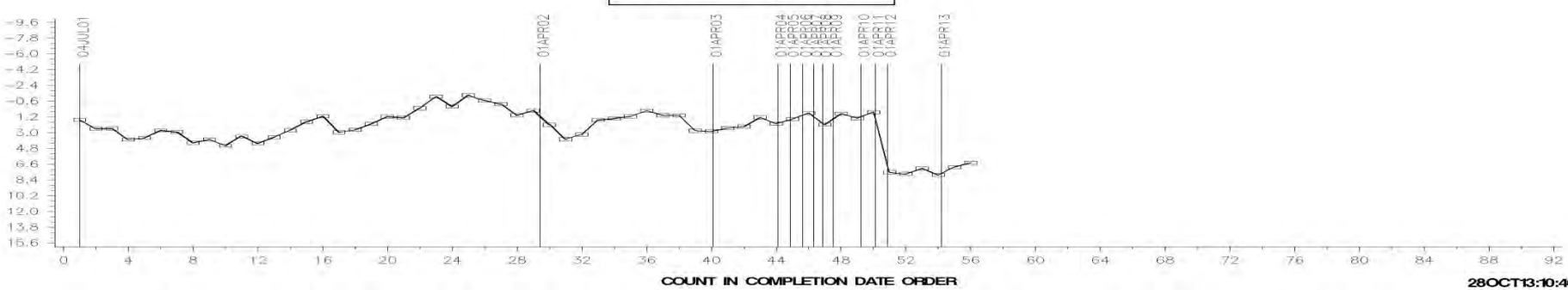
LTMS Severity Analysis



LTMS Precision Analysis



CUSUM Severity Analysis

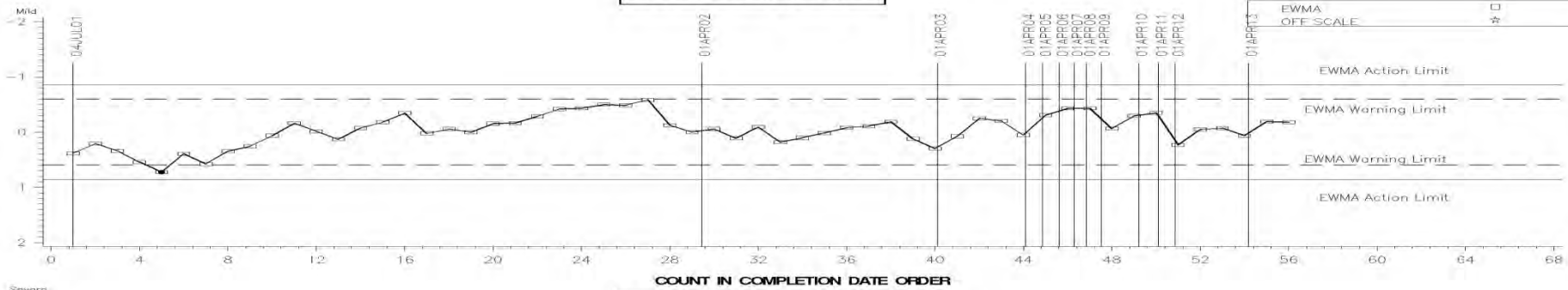


28OCT13:10:40

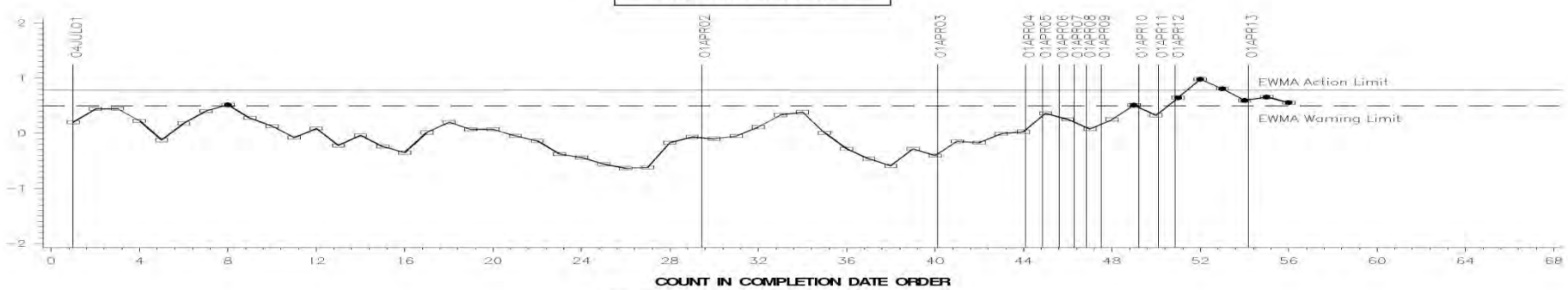


FINAL TOP GROOVE CARBON (DEMERITS)

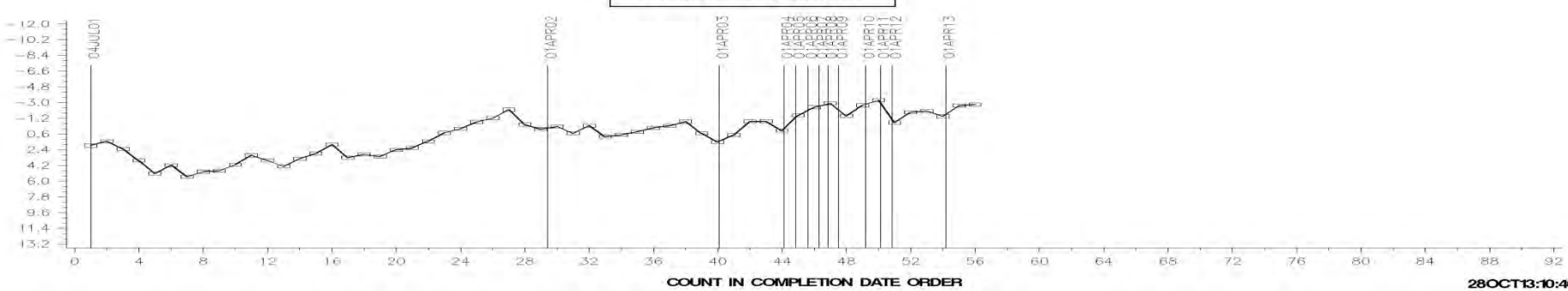
LTMS Severity Analysis



LTMS Precision Analysis



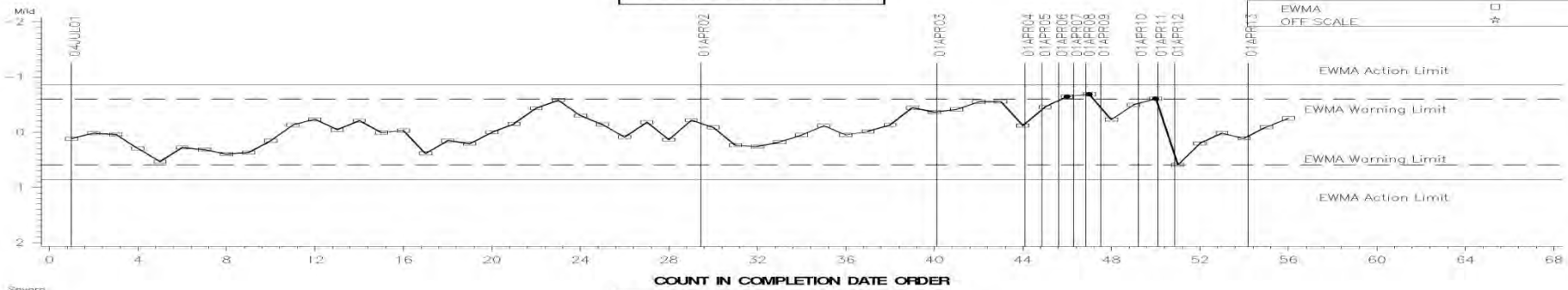
CUSUM Severity Analysis



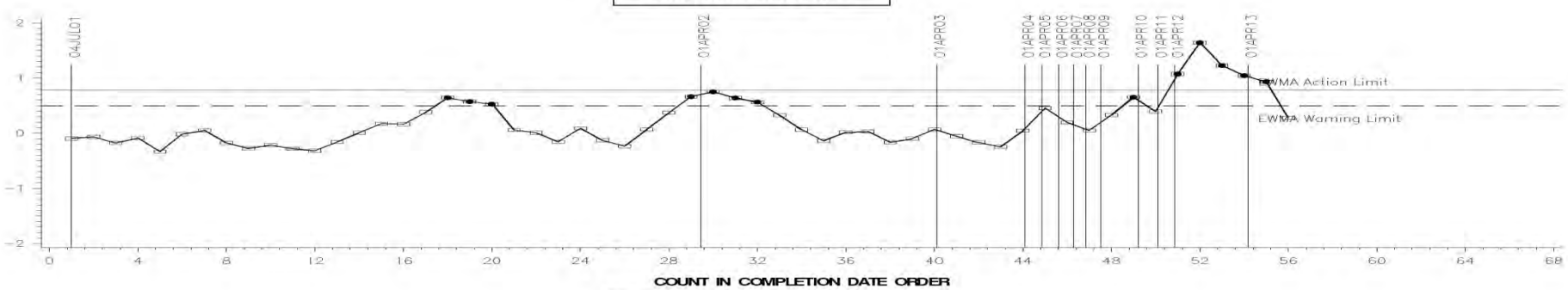
28OCT13:10:40

FINAL TOP LAND CARBON (DEMERITS)

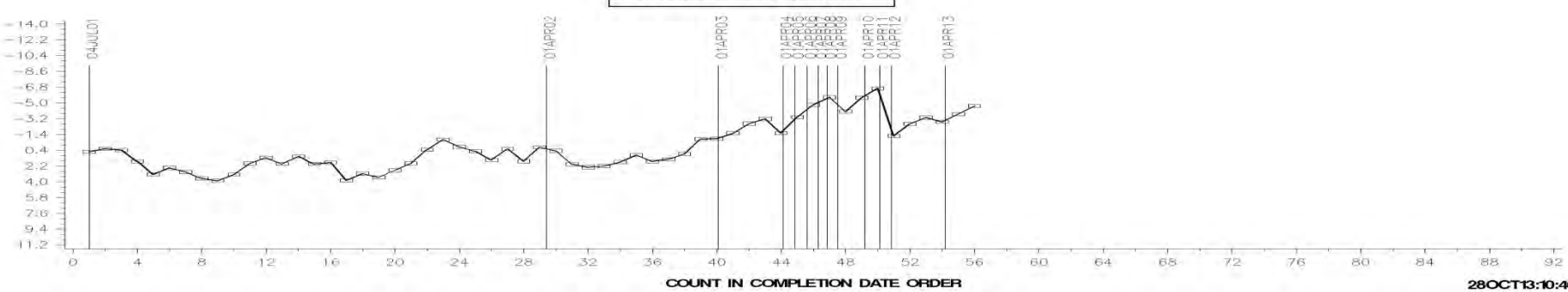
LTMS Severity Analysis



LTMS Precision Analysis



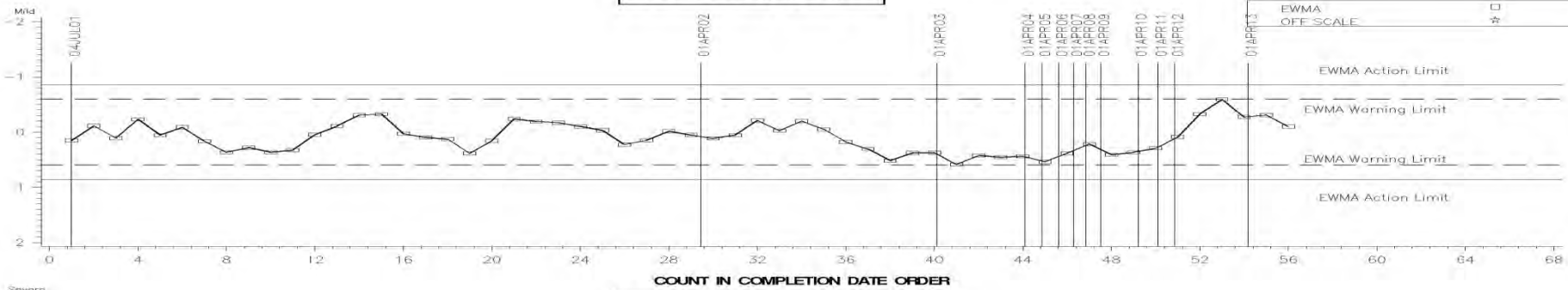
CUSUM Severity Analysis



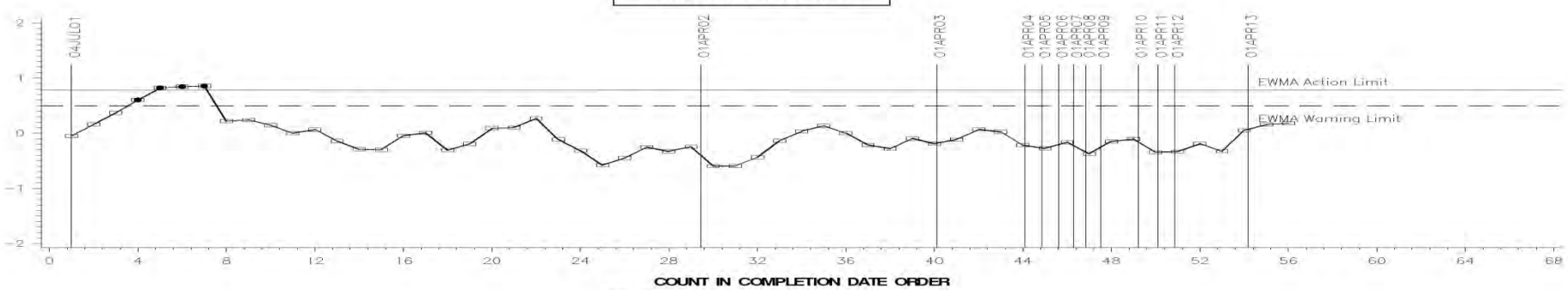
28OCT13:10:40

FINAL BOTO

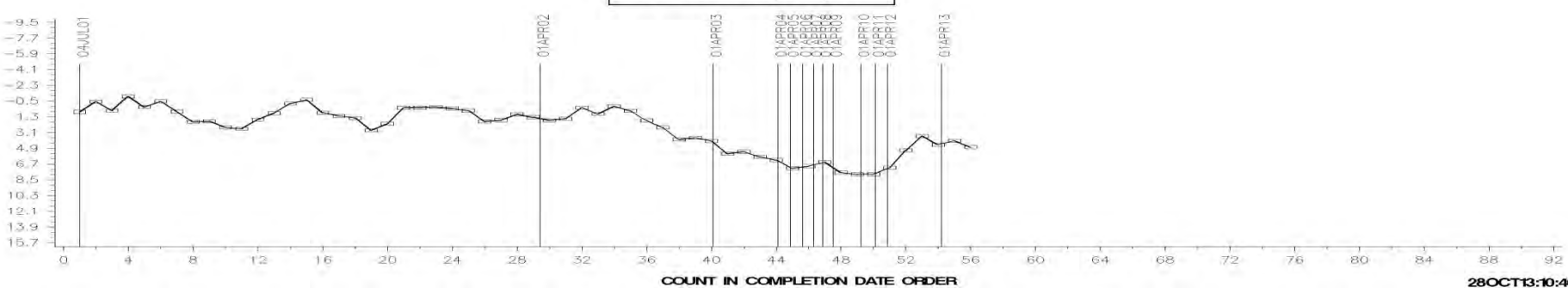
LTMS Severity Analysis



LTMS Precision Analysis



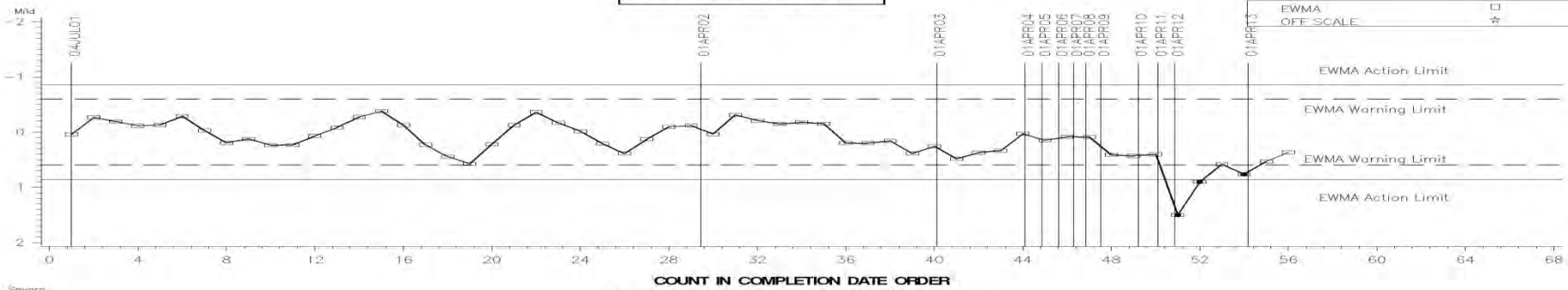
CUSUM Severity Analysis



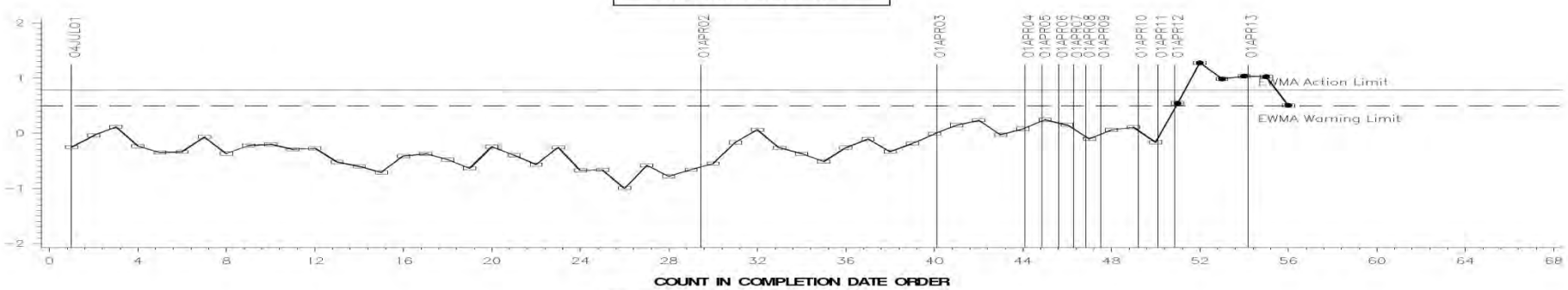
28OCT13:10:40

FINAL EOTOC (g/h)

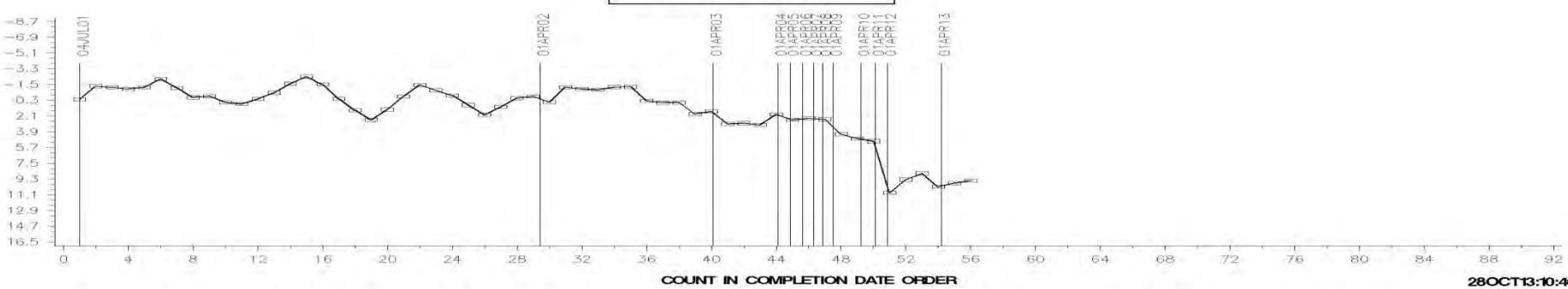
LTMS Severity Analysis



LTMS Precision Analysis



CUSUM Severity Analysis



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# Appendix 1.f

## C13 Control Charts

» Severity and CuSum

Test Monitoring Center

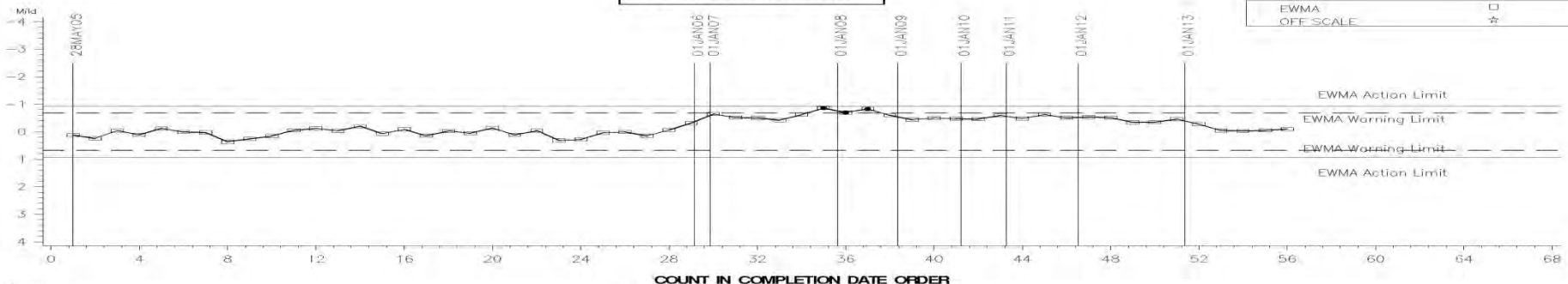
<http://astmtmc.cmu.edu>



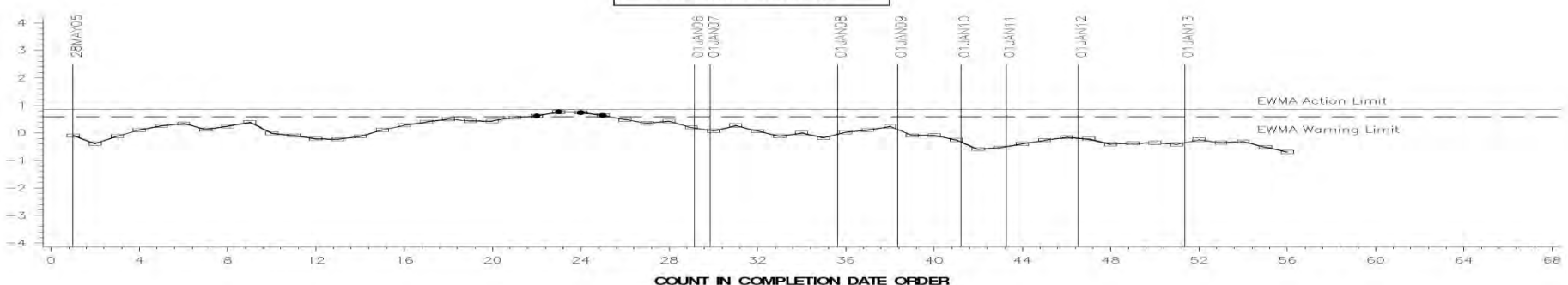
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TOP LAND CARBON AVG. — FINAL RESULT

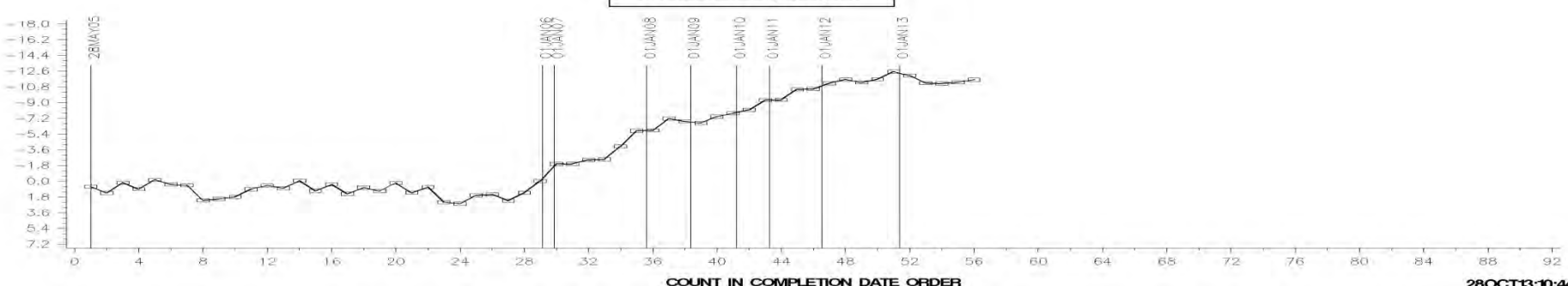
LTMS Severity Analysis



LTMS Precision Analysis



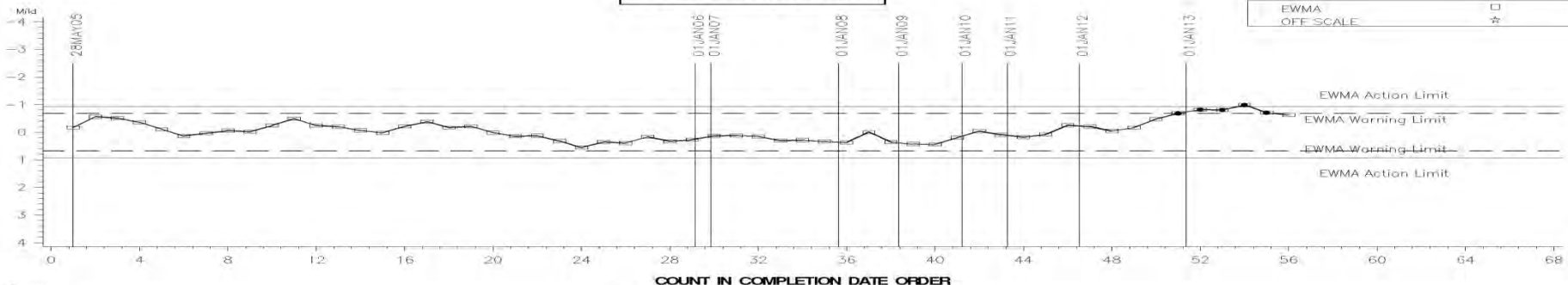
CUSUM Severity Analysis



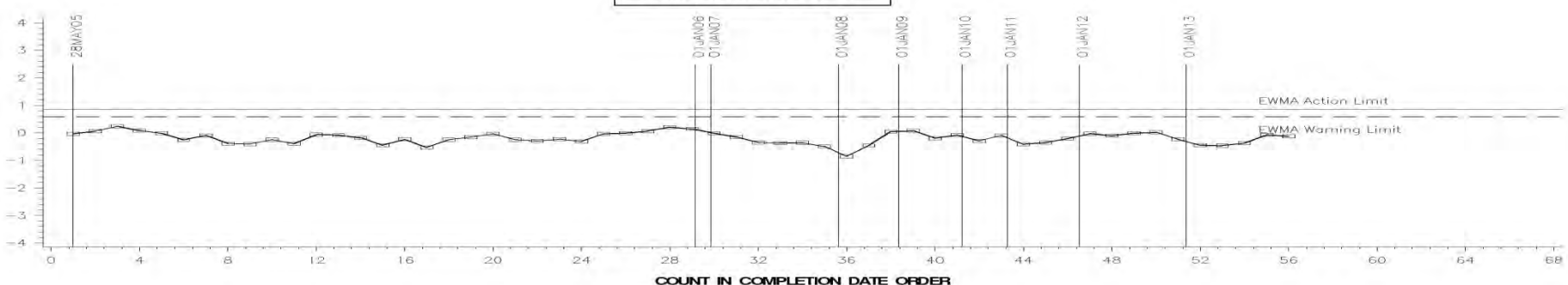
28OCT13:10:44

TOP GROOVE CARBON AVG — FINAL RESULT

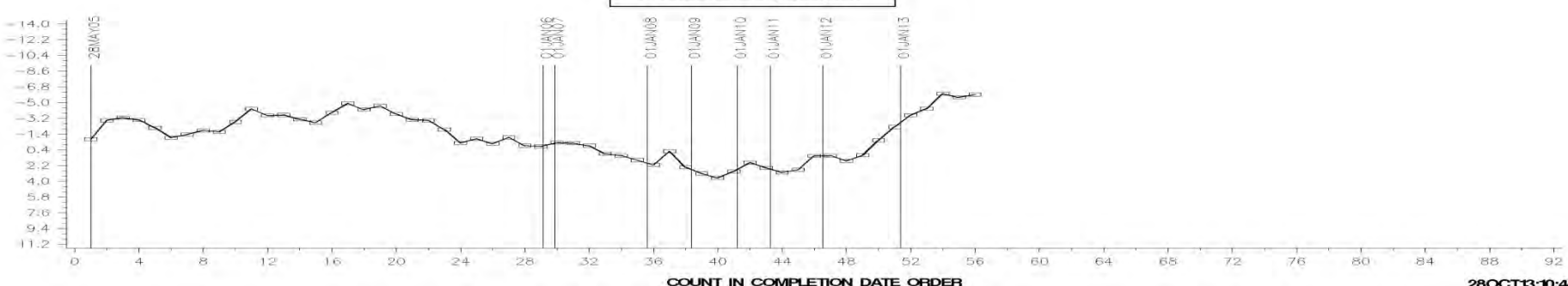
LTMS Severity Analysis



LTMS Precision Analysis



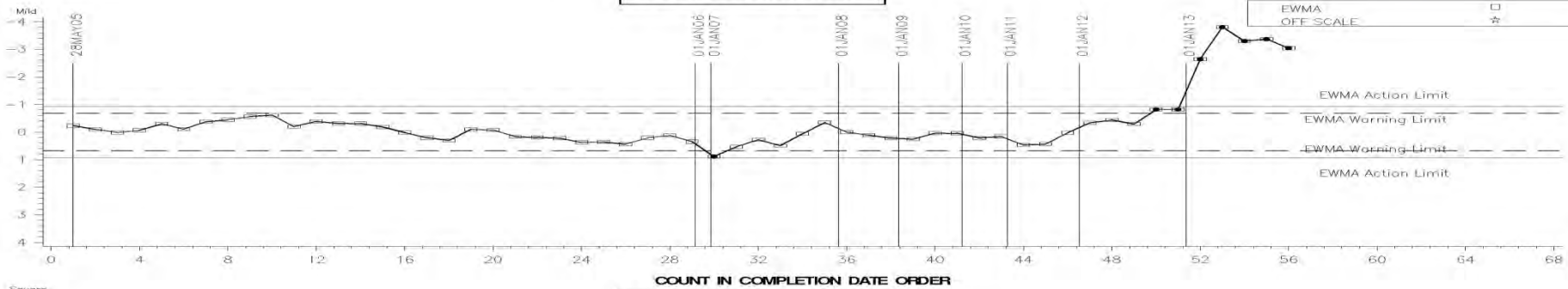
CUSUM Severity Analysis



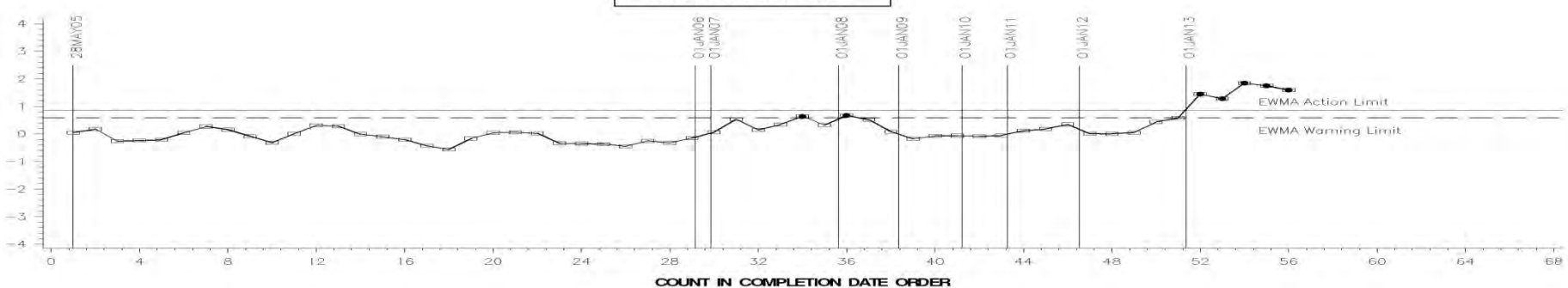
28OCT13:10:44

2ND RING TOP CARBON AVG. — FINAL RESULT

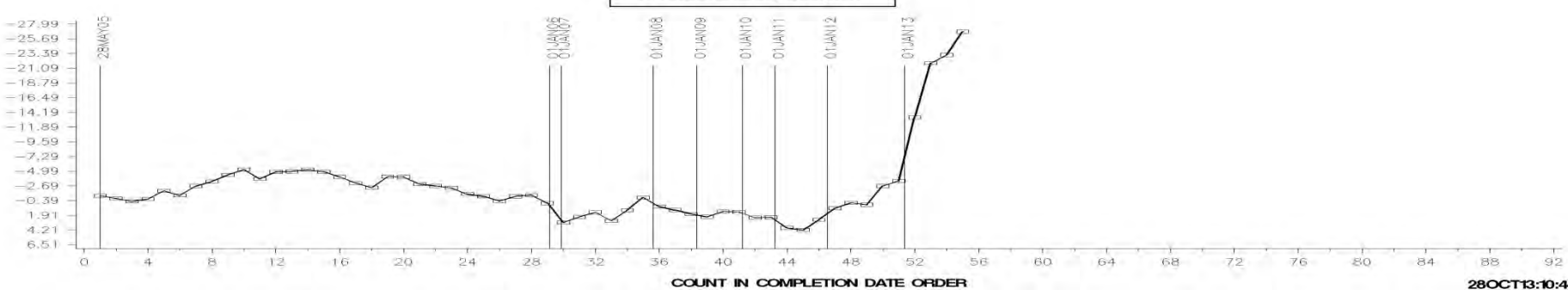
LTMS Severity Analysis



LTMS Precision Analysis



CUSUM Severity Analysis

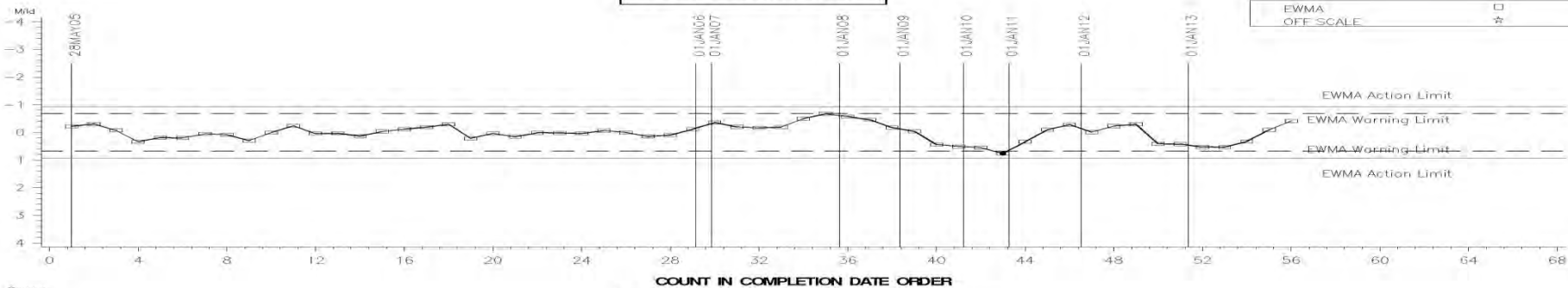


28OCT13:10:44

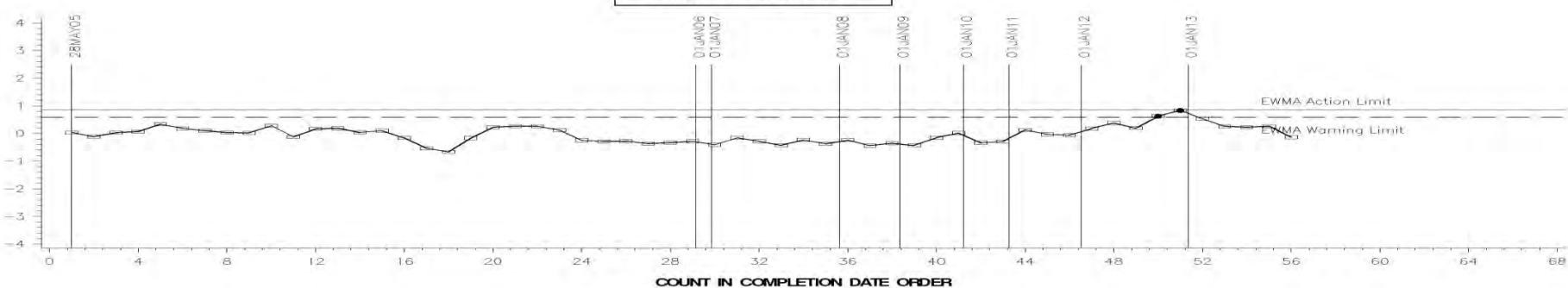


OIL CONS. DELTA - FINAL RESULT

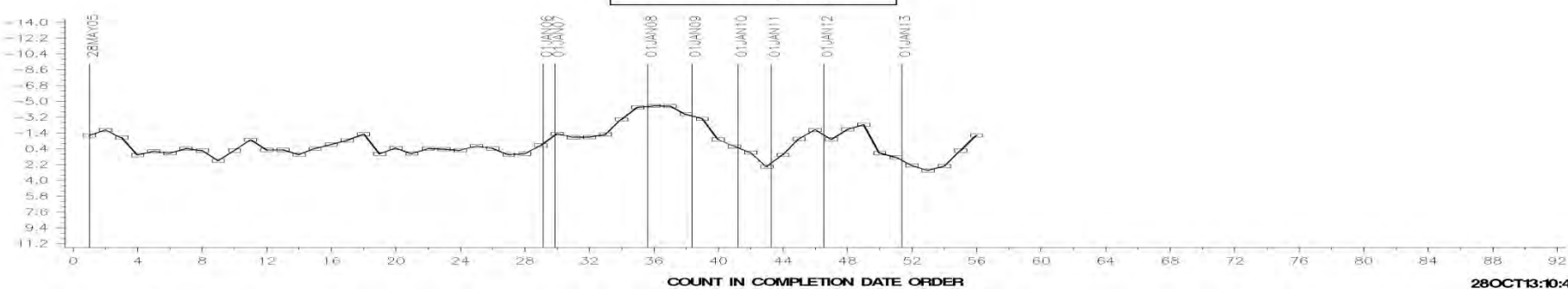
LTMS Severity Analysis



LTMS Precision Analysis



CUSUM Severity Analysis



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# Appendix 1.g

## ISB Control Charts

» Severity and CuSum

Test Monitoring Center

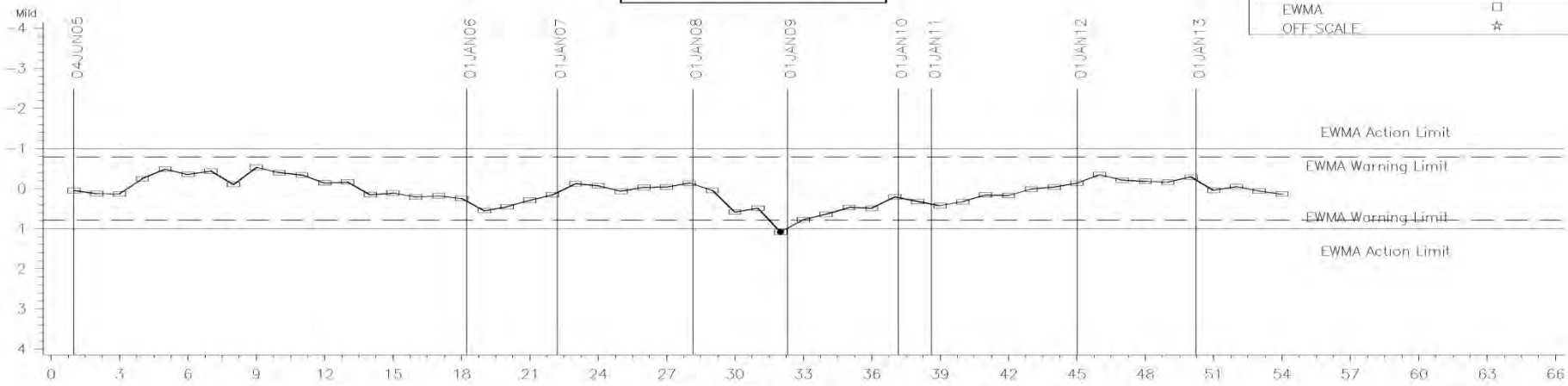
<http://astmtmc.cmu.edu>



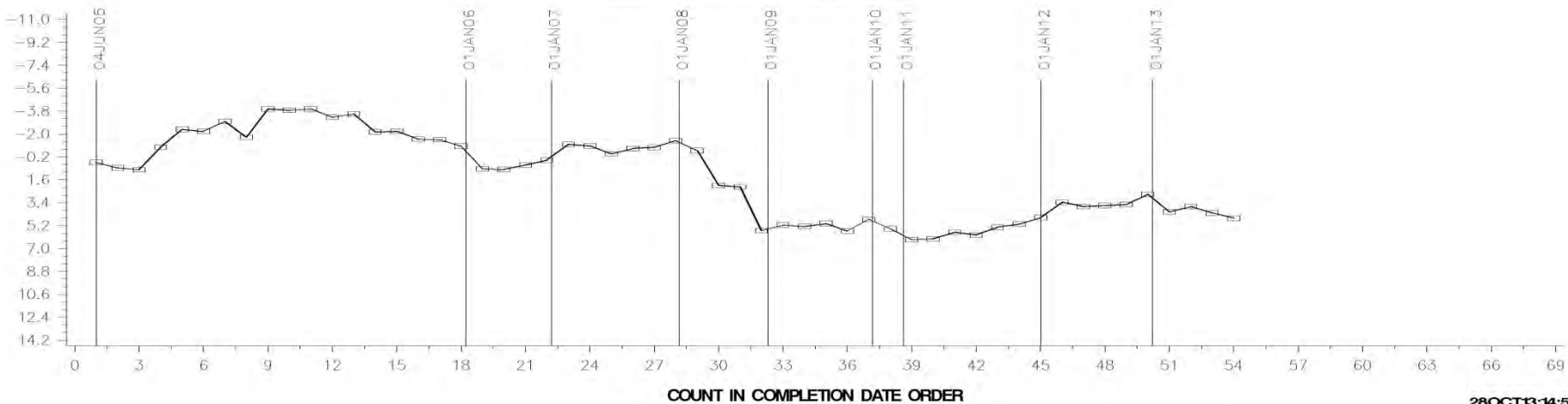
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AVERAGE CAMSHAFT WEAR

LTMS Severity Analysis



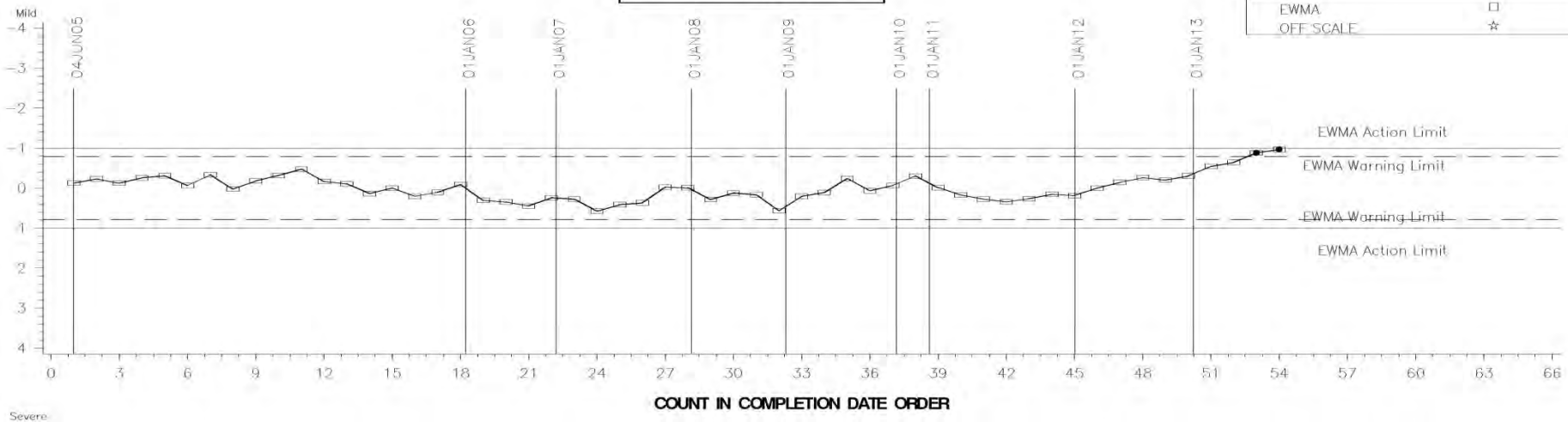
CUSUM Severity Analysis



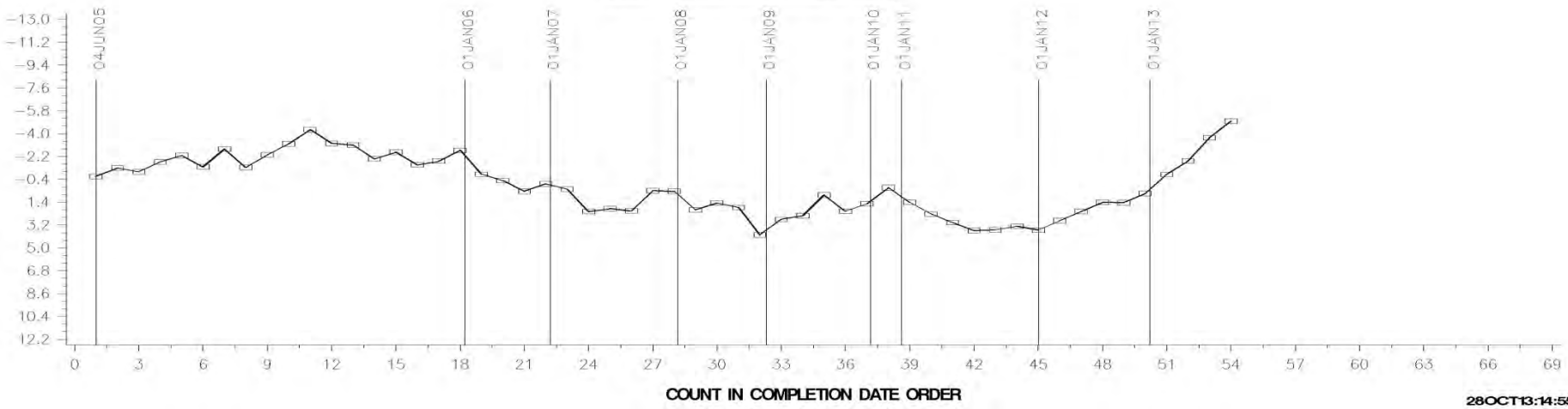
28OCT13:14:55

AVERAGE TAPPET WEIGHT LOSS

LTMS Severity Analysis



CUSUM Severity Analysis



28OCT13:14:55

[Return](#)



# Appendix 1.h

## ISM Control Charts

» Severity and CuSum

Test Monitoring Center

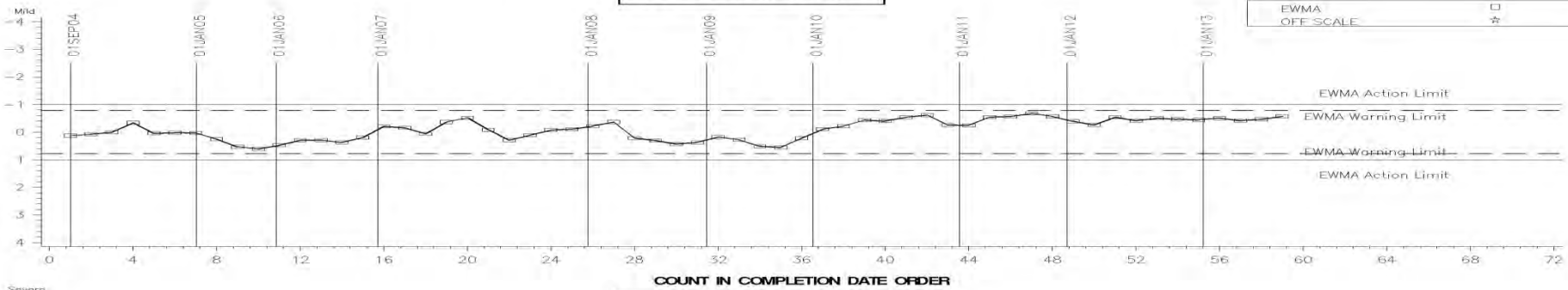
<http://astmtmc.cmu.edu>



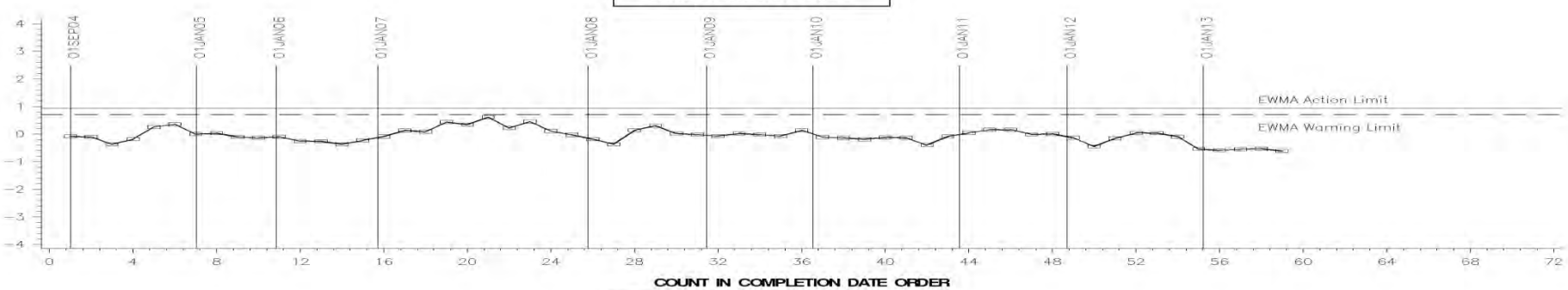
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CROSSHEAD WEIGHT LOSS ADJUSTED TO 3.9 % SOOT

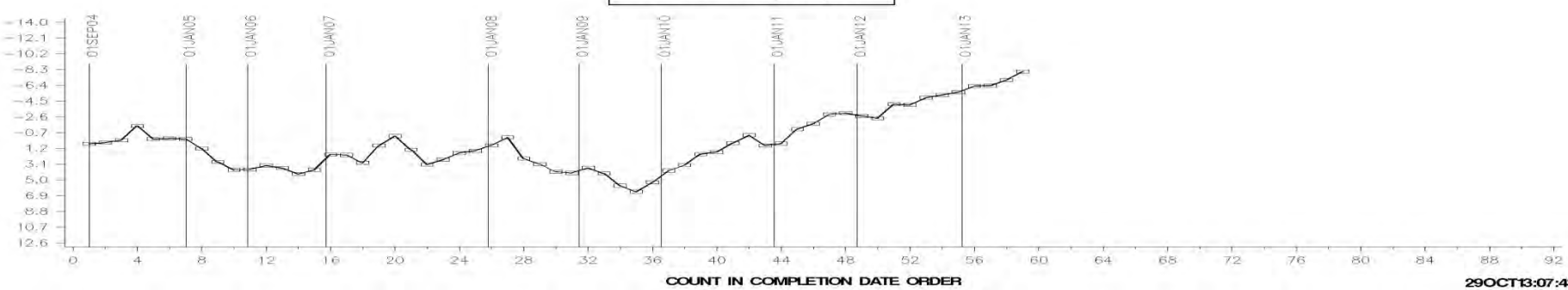
LTMS Severity Analysis



LTMS Precision Analysis



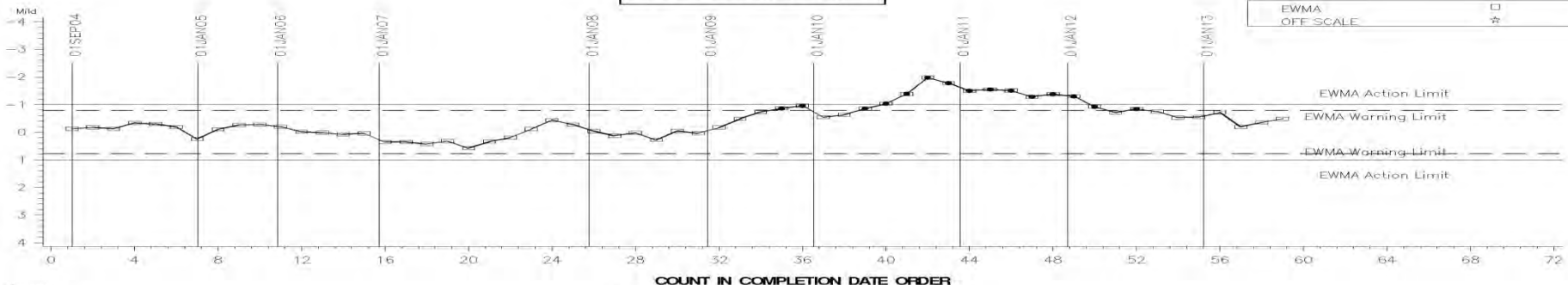
CUSUM Severity Analysis



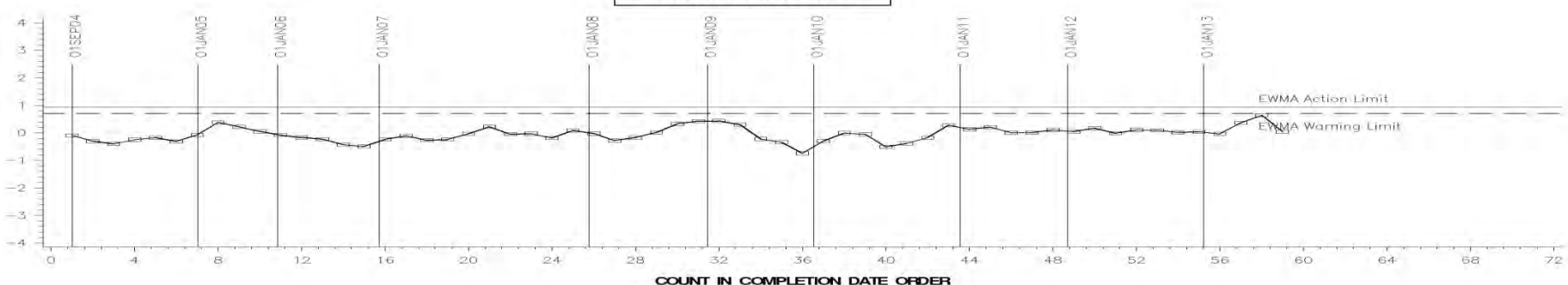
29OCT13:07:43

FILTER PLUGGING DELTA P

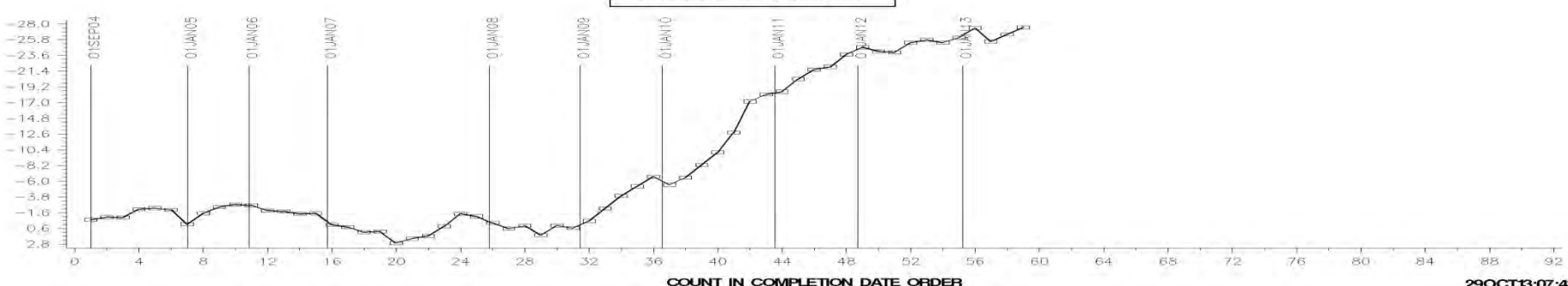
LTMS Severity Analysis



LTMS Precision Analysis



CUSUM Severity Analysis

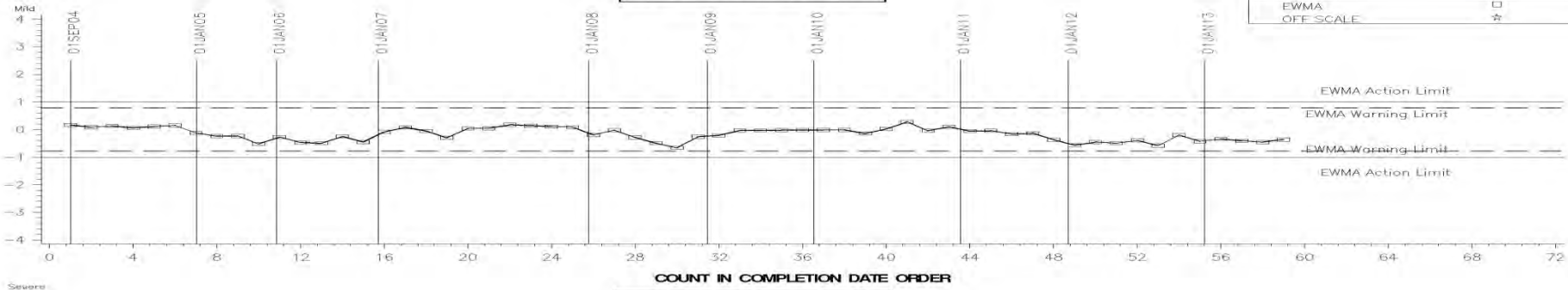


29OCT13:07:43

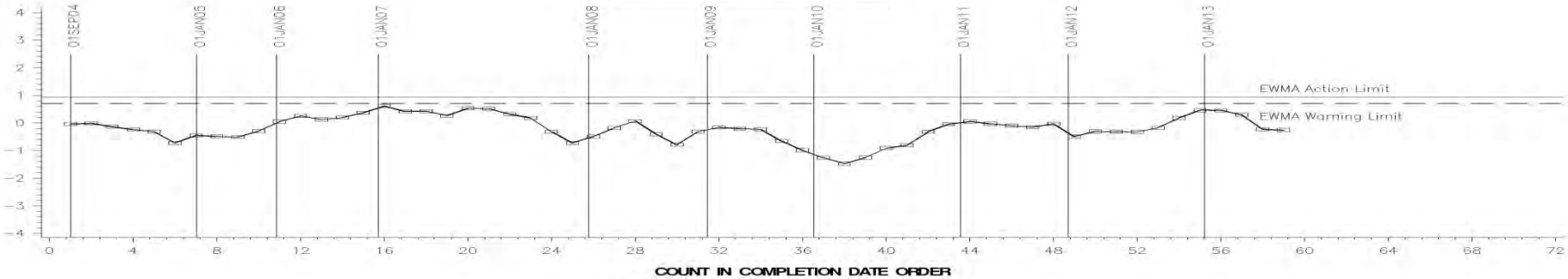
# ISM INDUSTRY OPERATIONAL VALID DATA

## AVERAGE SLUDGE RATING

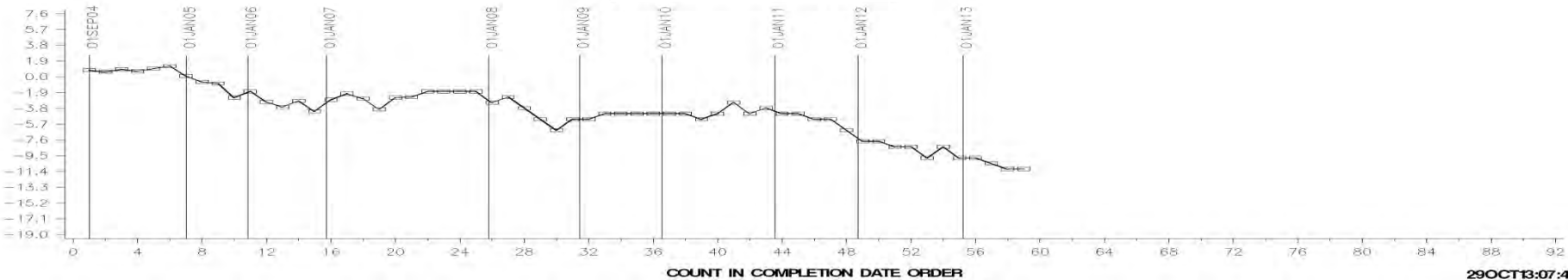
LTMS Severity Analysis



LTMS Precision Analysis



CUSUM Severity Analysis

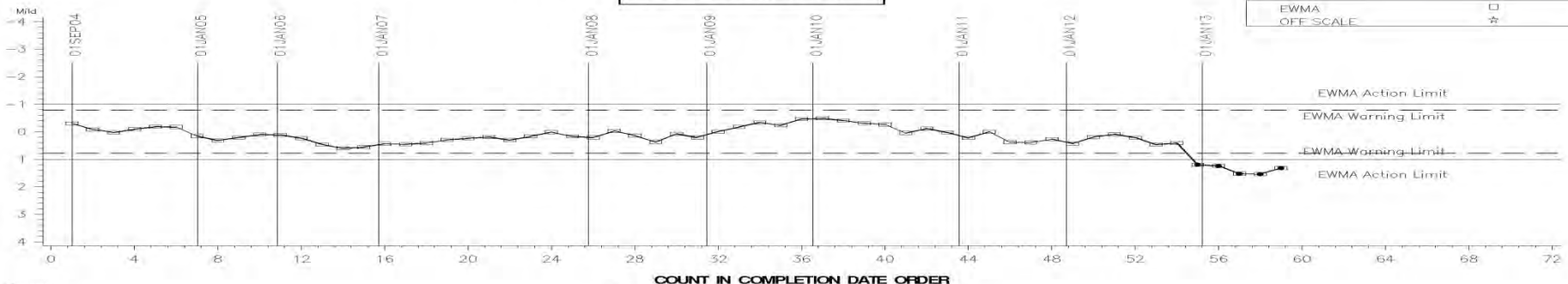


29OCT13:07:43

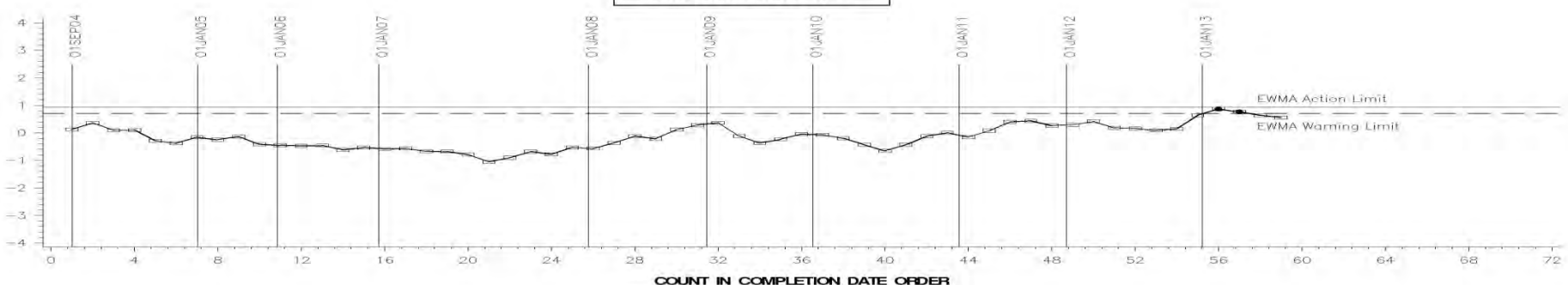


INJECTOR SCREW WEIGHT LOSS ADJUSTED TO 3.9% SOOT

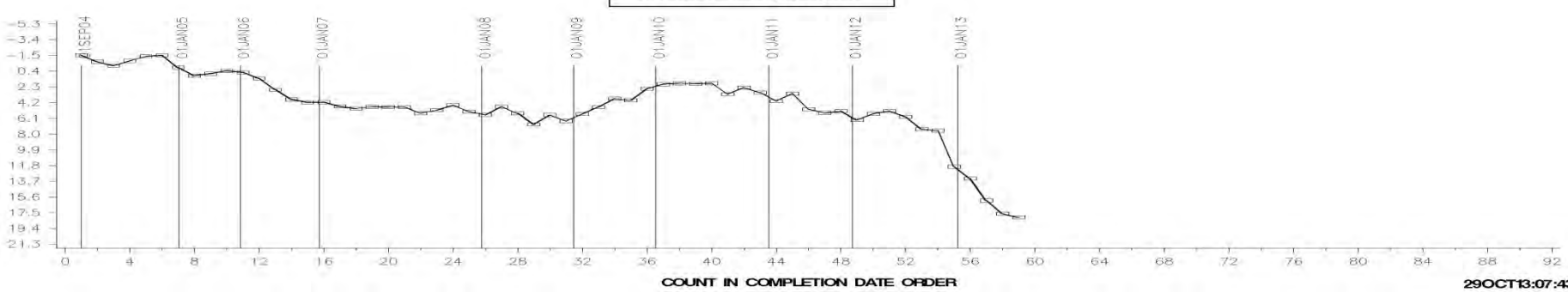
LTMS Severity Analysis



LTMS Precision Analysis



CUSUM Severity Analysis



29OCT13:07:43

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# Appendix 1.i

## EOAT Control Charts

» Severity, Precision, and CuSum

Test Monitoring Center

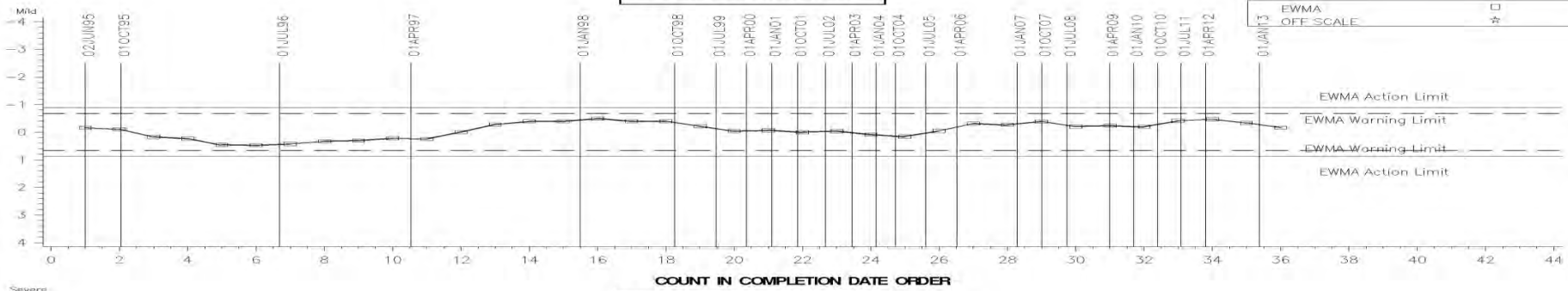
<http://astmtmc.cmu.edu>



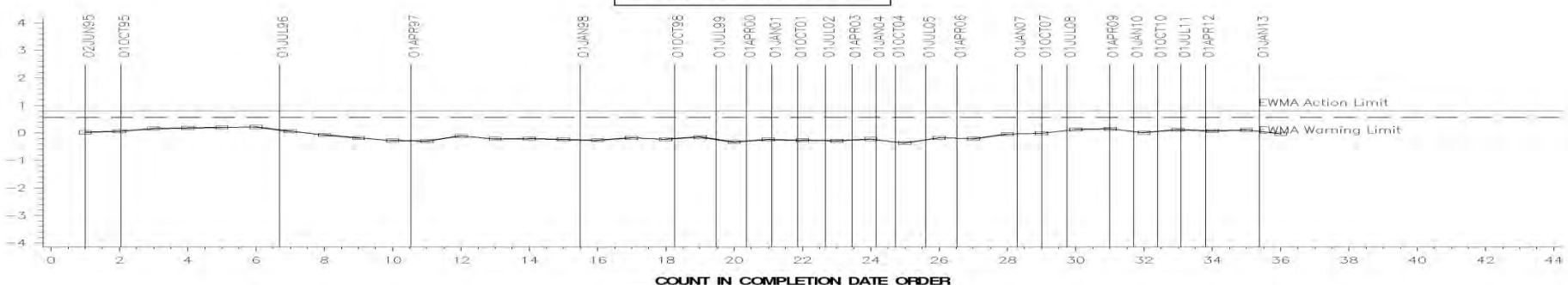
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## ENGINE OIL AERATION

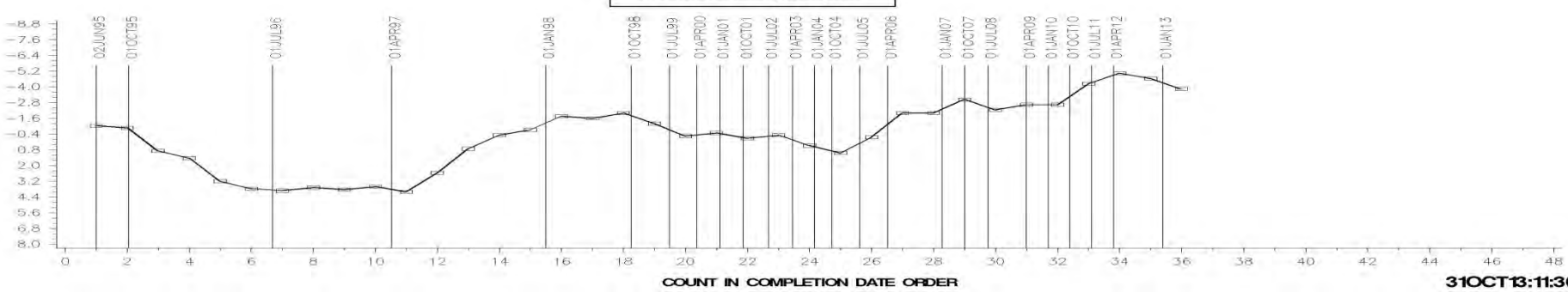
### LTMS Severity Analysis



### LTMS Precision Analysis



### CUSUM Severity Analysis



31OCT13:11:30

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# Appendix 1.j

## RFWT Control Charts

» Severity, Precision, and CuSum

Test Monitoring Center

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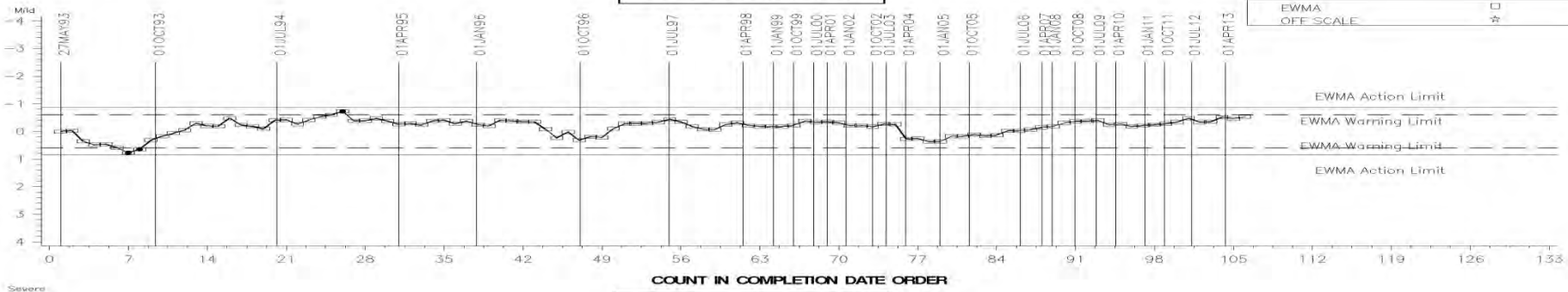


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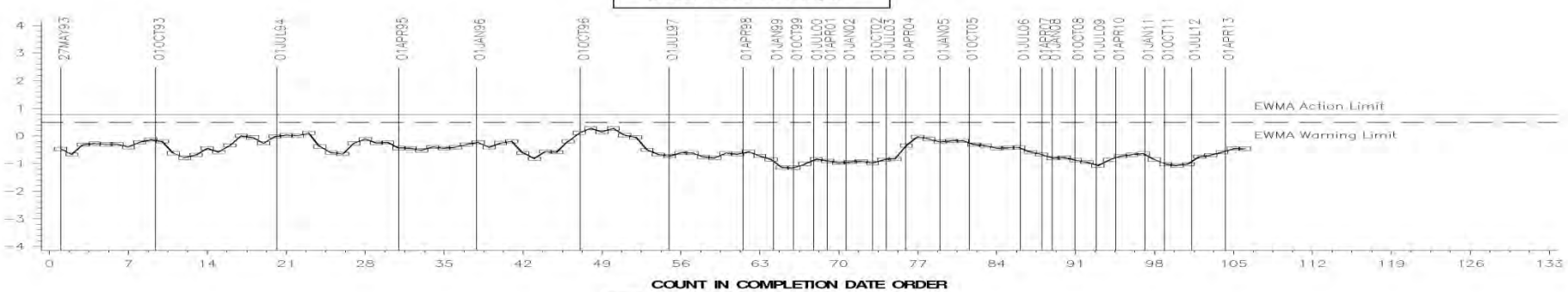


## Average Follower Wear

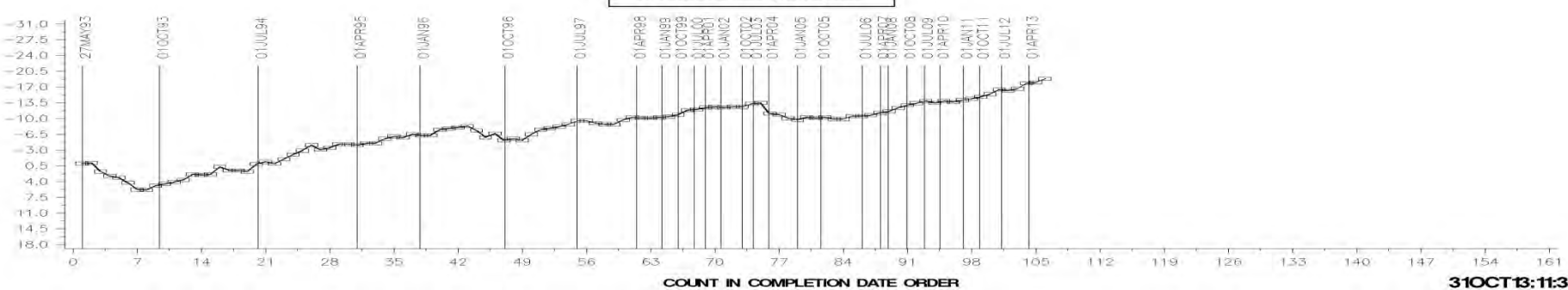
### LTMS Severity Analysis



### LTMS Precision Analysis



### CUSUM Severity Analysis



31OCT13:11:31

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# Appendix 1.k

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

» Severity, Precision, and CuSum

Test Monitoring Center

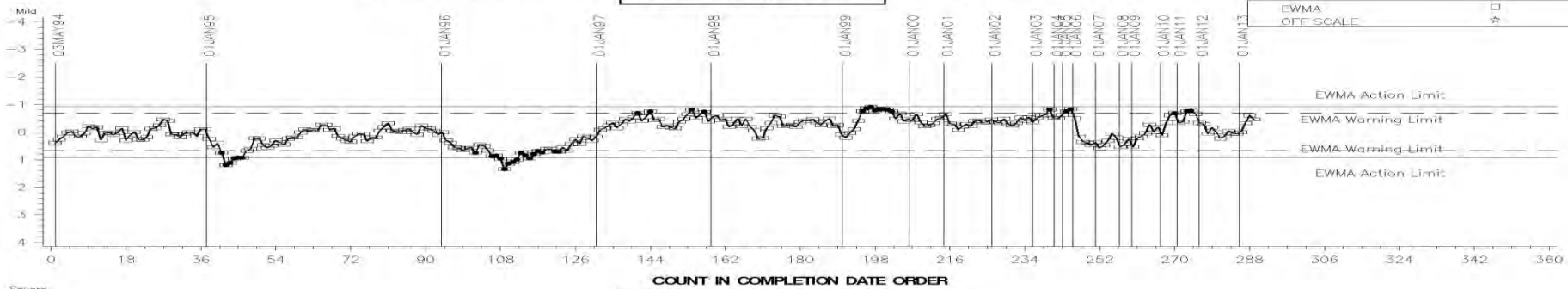
<http://astmtmc.cmu.edu>



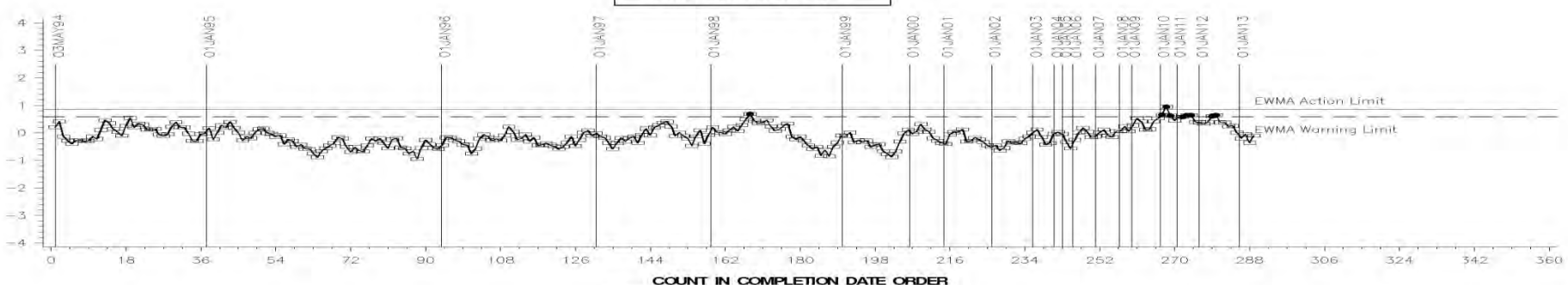
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## FINAL REFERENCE VISCOSITY AT 3.8% TGA SOOT LEVEL

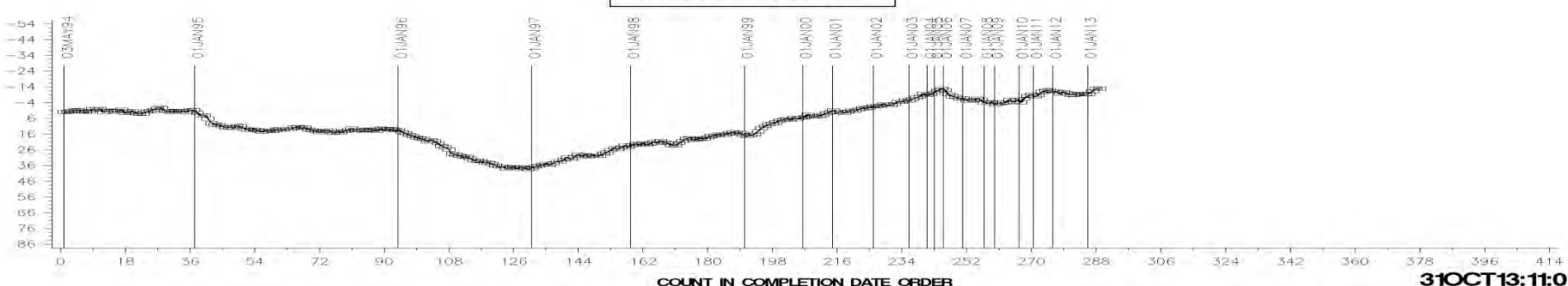
LTMS Severity Analysis



LTMS Precision Analysis



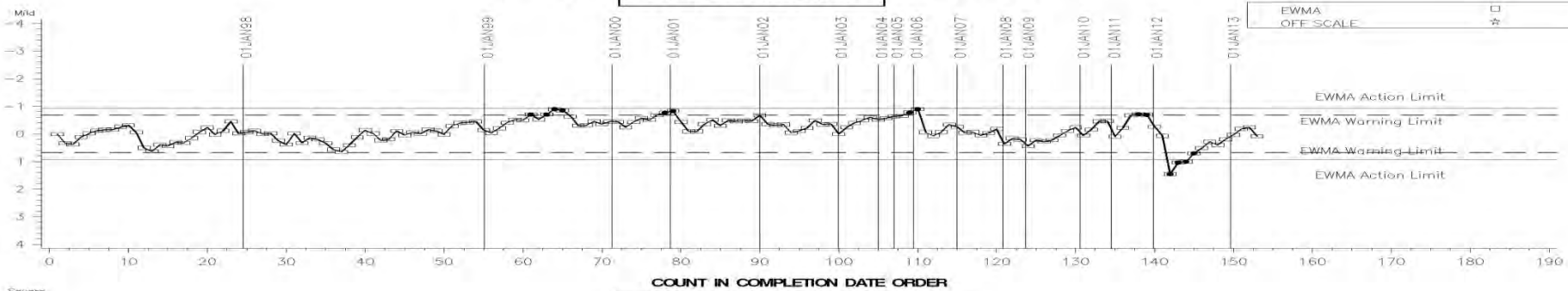
CUSUM Severity Analysis



31OCT13:11:01

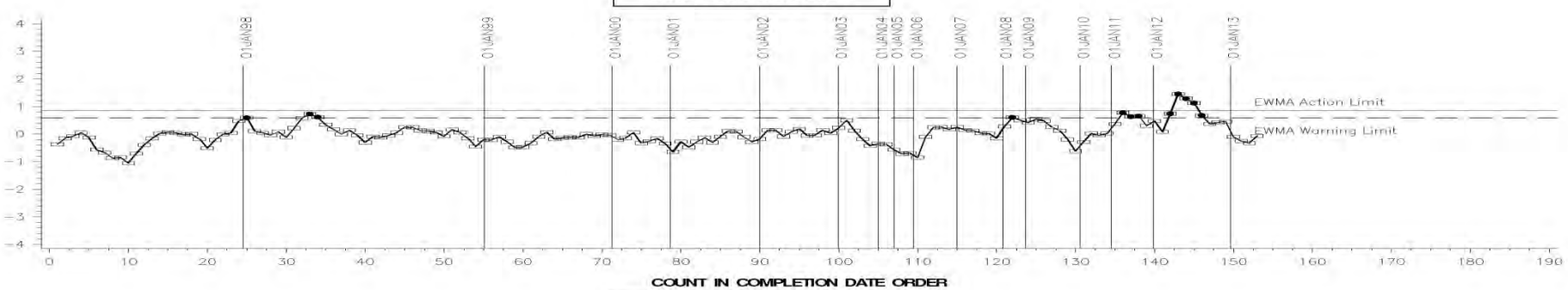
## FINAL RELATIVE VISCOSITY (50% LOSS)

LTMS Severity Analysis



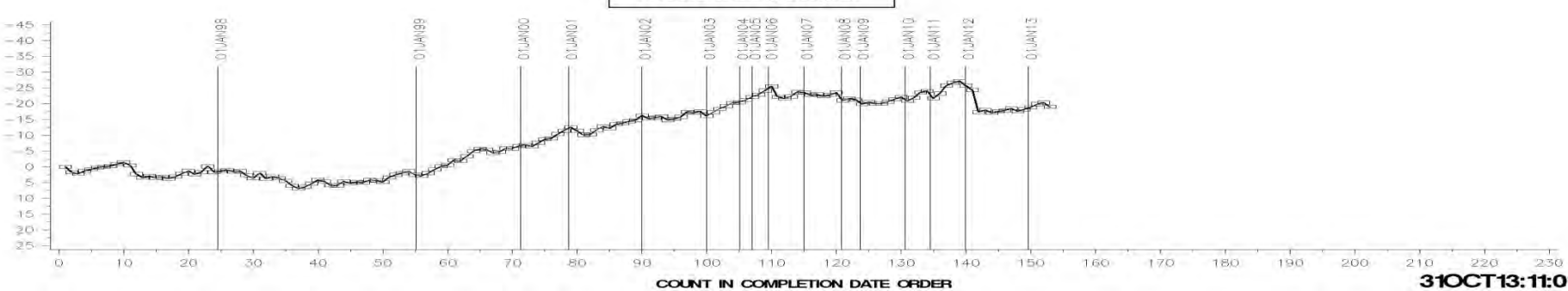
COUNT IN COMPLETION DATE ORDER

## LTMS Precision Analysis



COUNT IN COMPLETION DATE ORDER

## CUSUM Severity Analysis

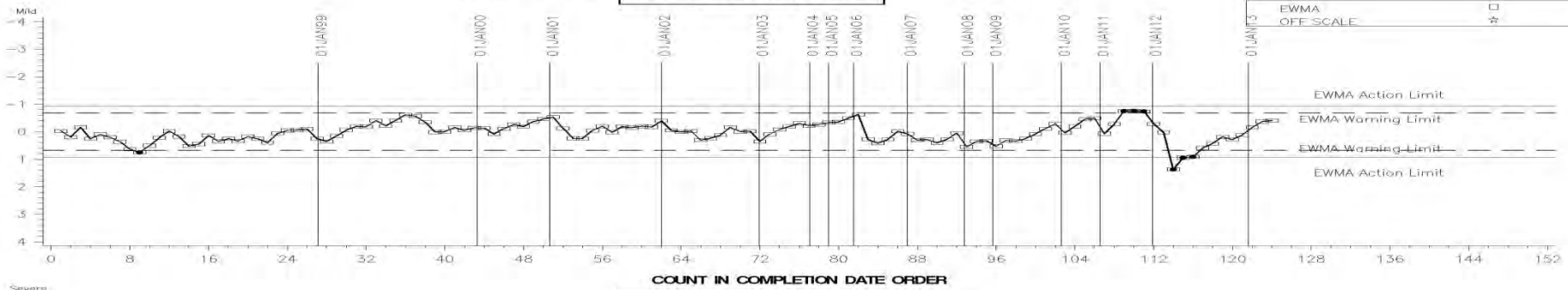


31OCT13:11:01

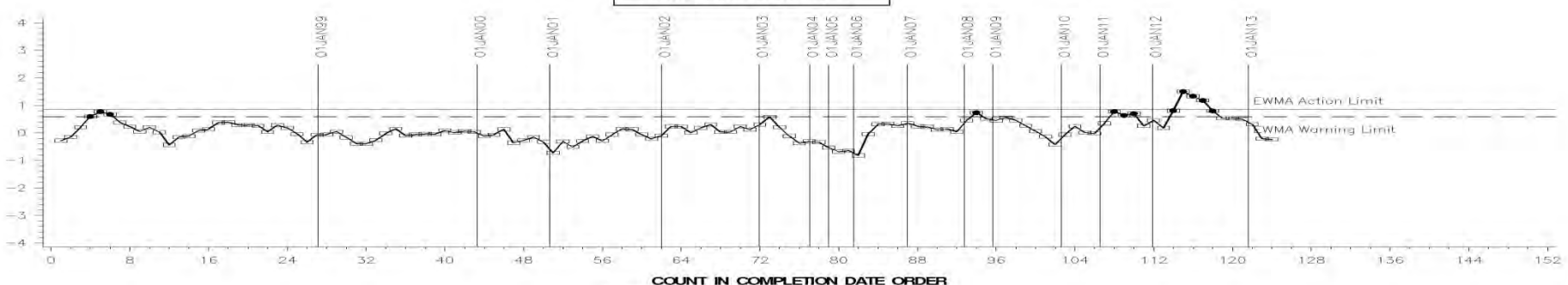


## FINAL RELATIVE VISCOSITY (100% LOSS)

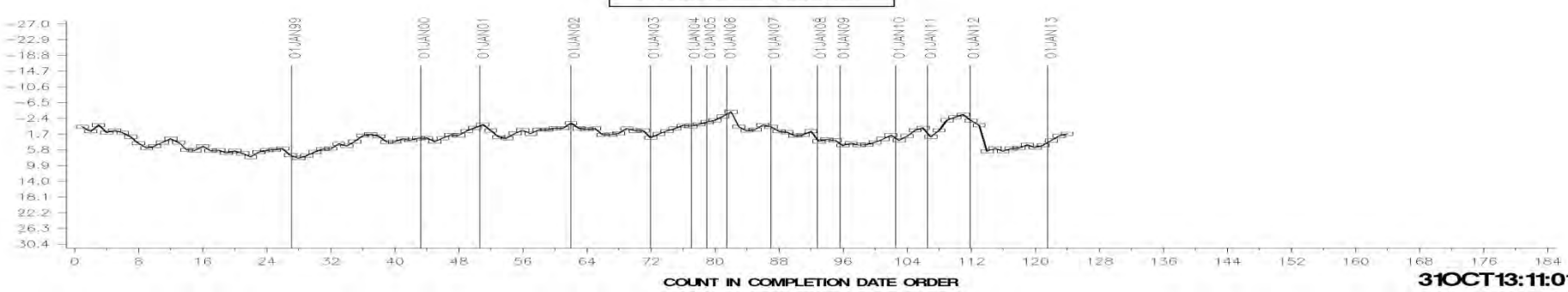
LTMS Severity Analysis



## LTMS Precision Analysis



## CUSUM Severity Analysis



31OCT13:11:01

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# Appendix 1.1

## T-10A Control Charts

» Severity, Precision, and CuSum

Test Monitoring Center

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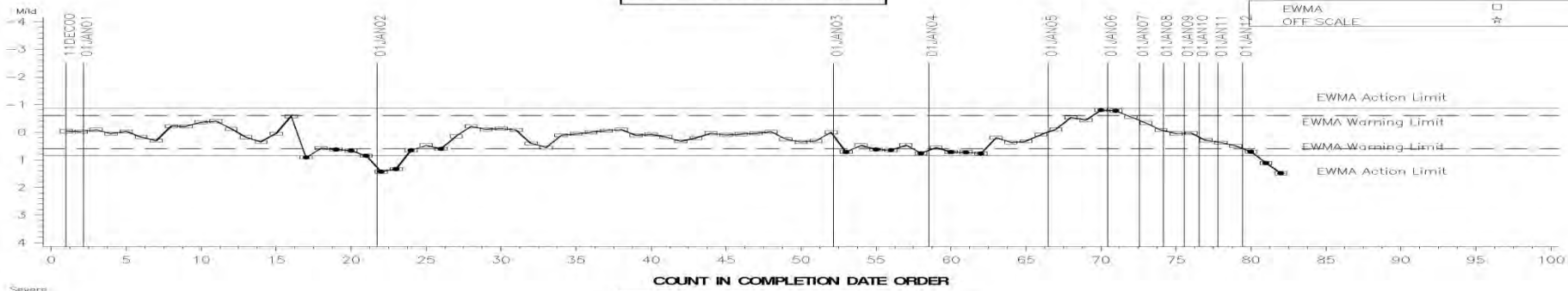
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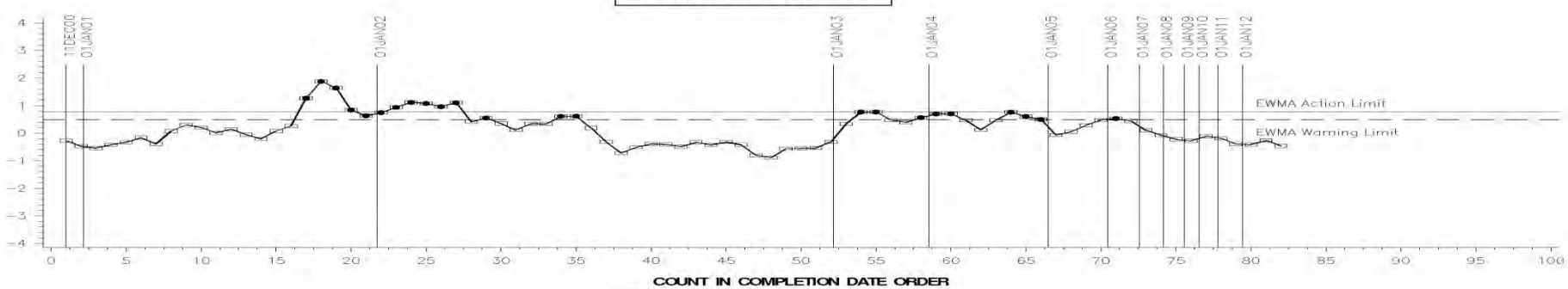
# T10A INDUSTRY OPERATIONALY VALID DATA

## MRV VISCOSITY @ 75H

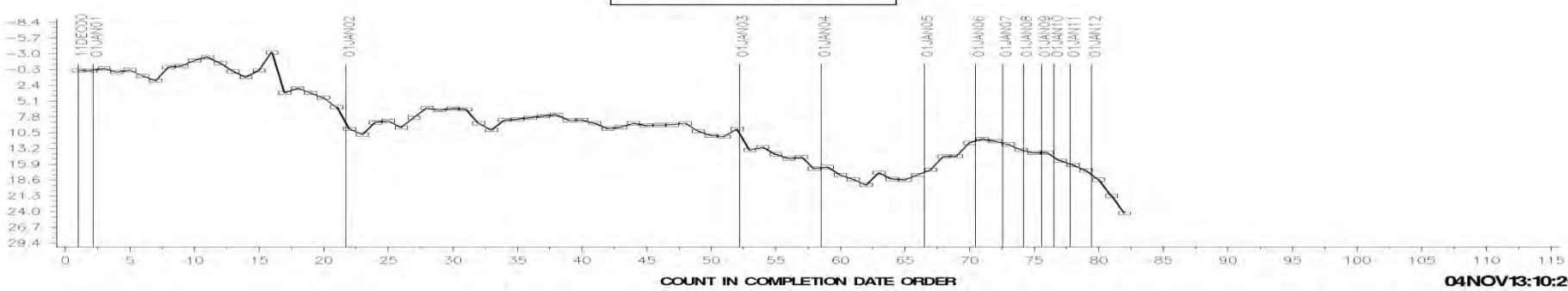
### LTMS Severity Analysis



### LTMS Precision Analysis



### CUSUM Severity Analysis



04NOV13:10:26

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# Appendix 1.m

## T-11 Control Charts

» Severity, Precision, and CuSum

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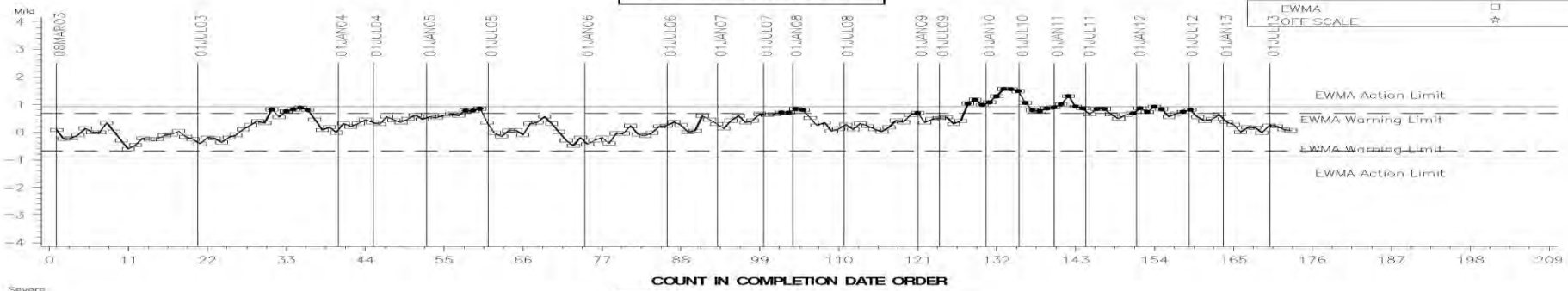
<http://astmtmc.cmu.edu>



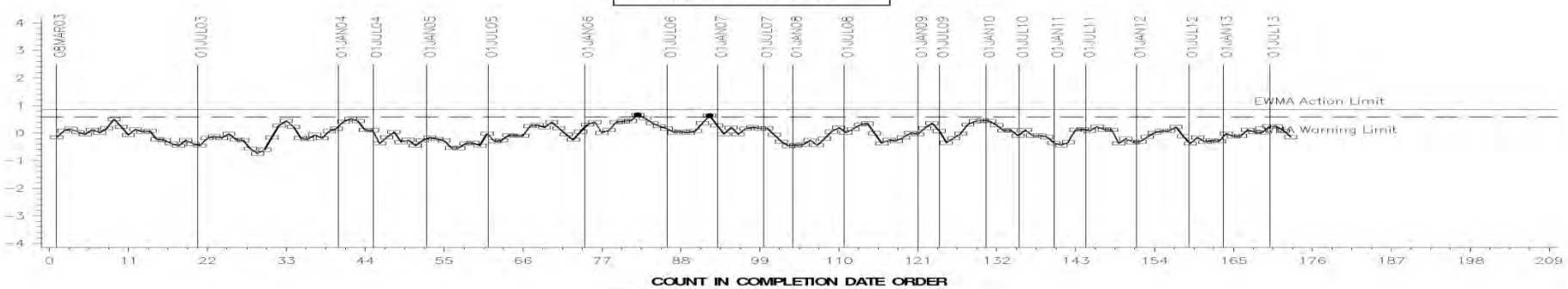
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# T-11 INDUSTRY OPERATIONALLY VALID DATA

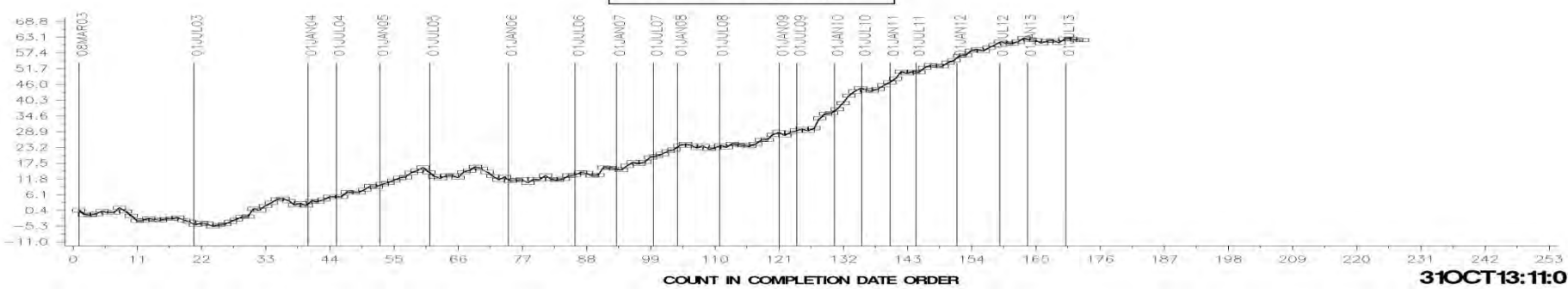
**SOOT AT 12 cSt**  
LTMS Severity Analysis



**LTMS Precision Analysis**



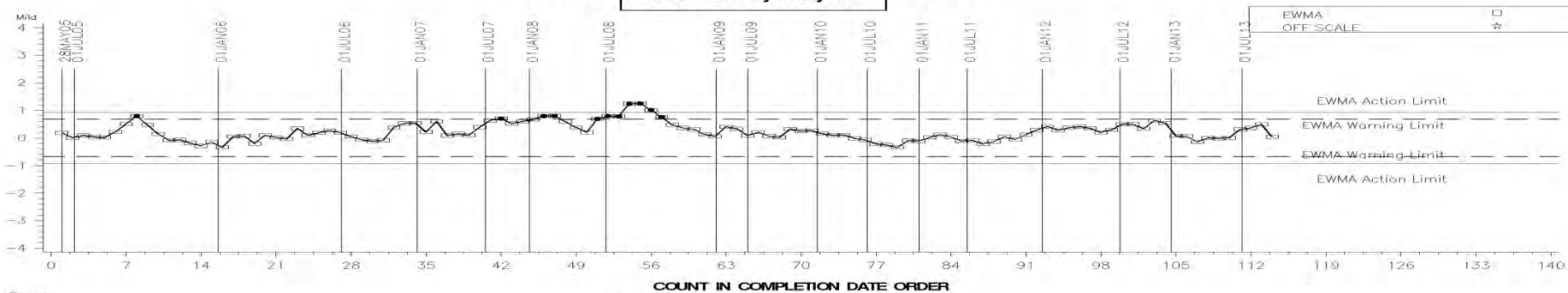
**CUSUM Severity Analysis**



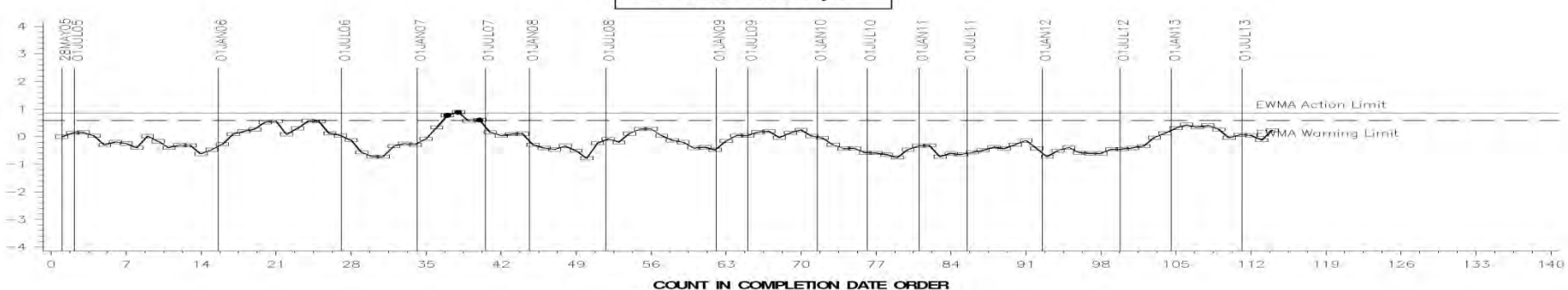
31OCT13:11:01

## SOOT @ 4 cSt — FINAL RESULT

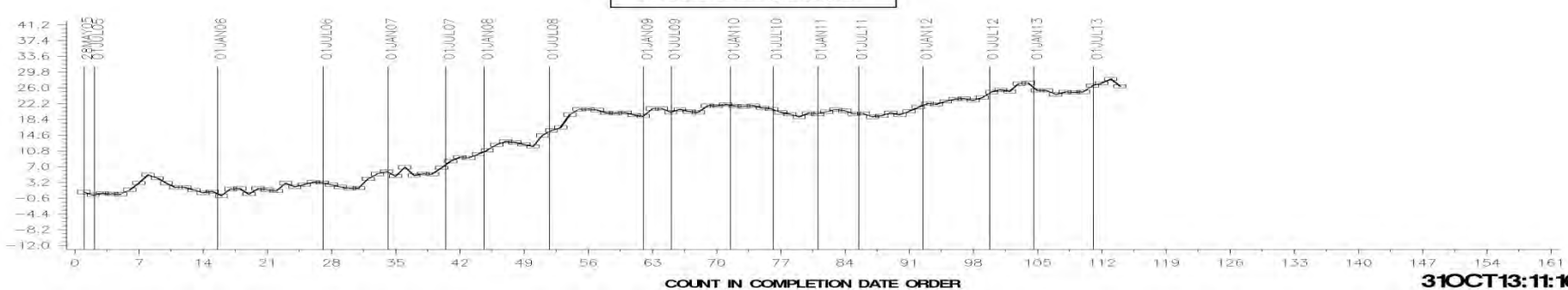
LTMS Severity Analysis



## LTMS Precision Analysis



## CUSUM Severity Analysis



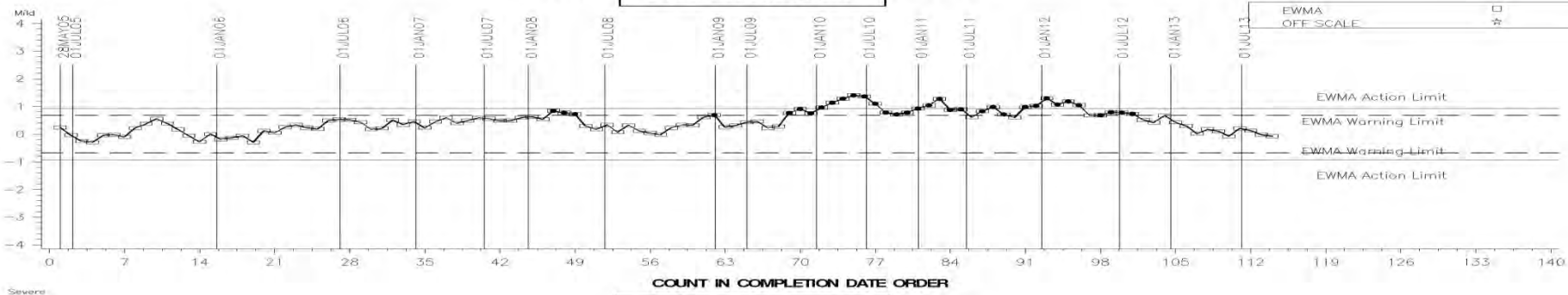
31OCT13:11:16



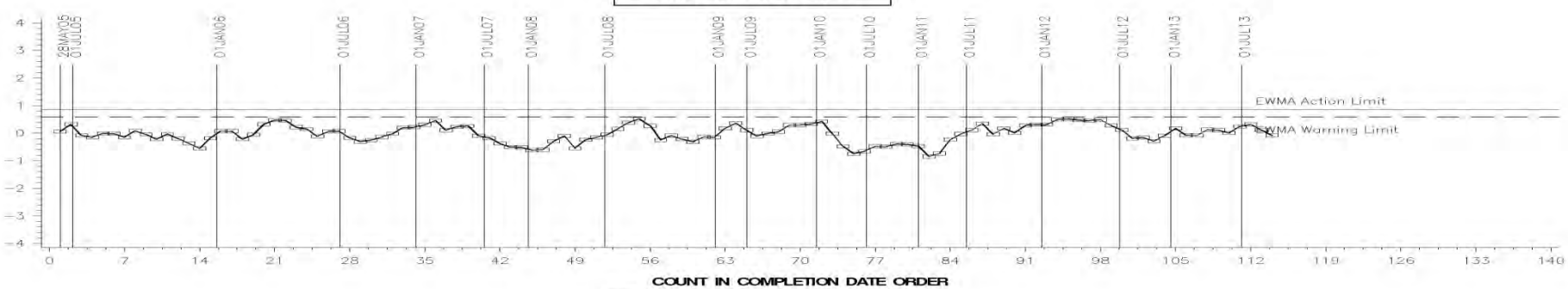
# T-11 INDUSTRY OPERATIONALLY VALID DATA

## SOOT @ 15 cSt — FINAL RESULT

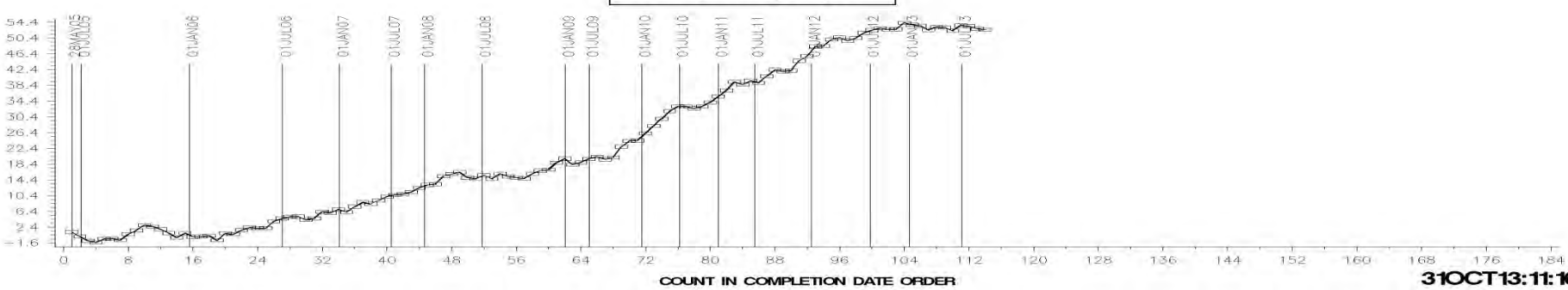
LTMS Severity Analysis



## LTMS Precision Analysis



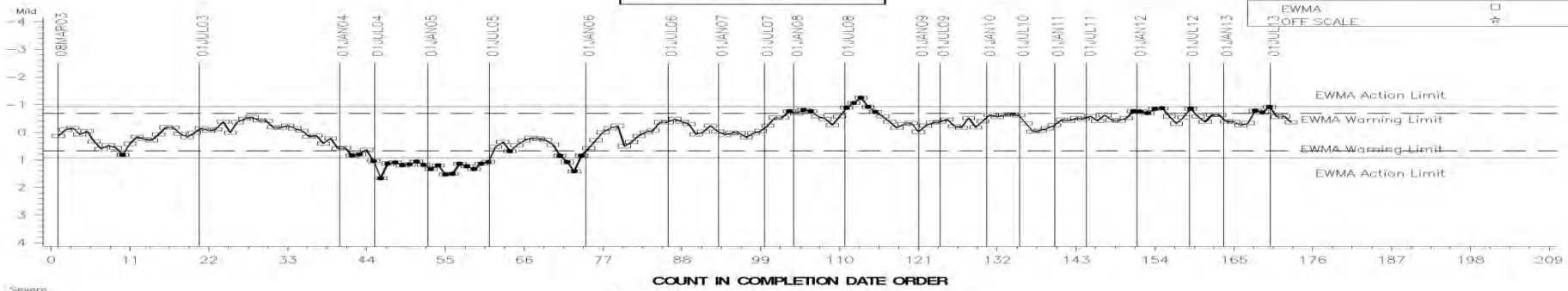
## CUSUM Severity Analysis



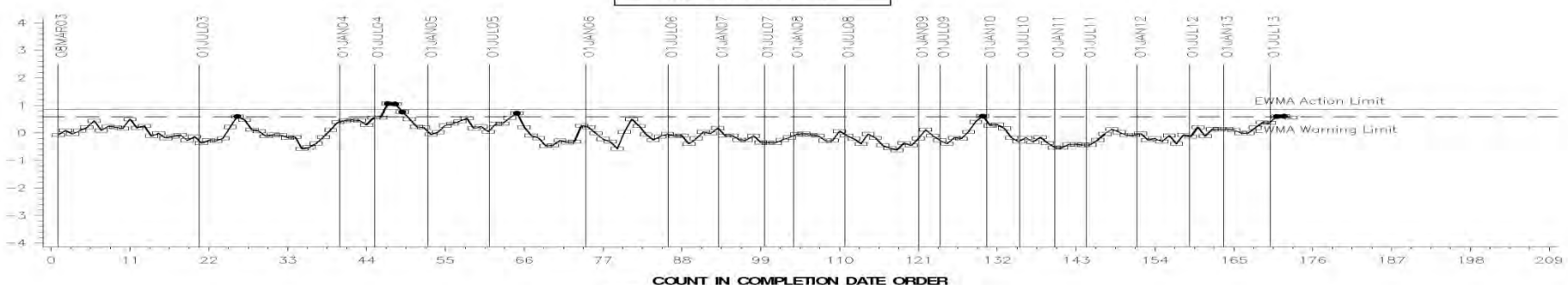
31OCT13:11:16

# T-11 INDUSTRY OPERATIONALLY VALID DATA

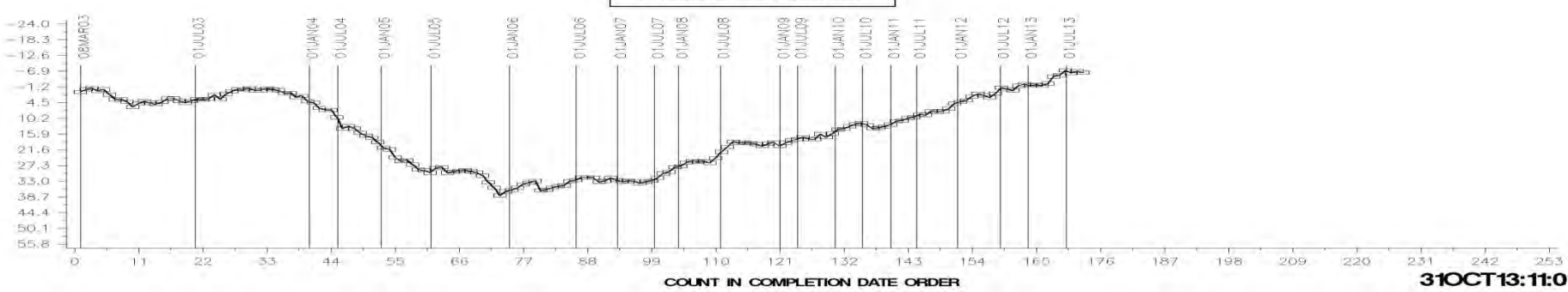
## MRV VISCOSITY LTMS Severity Analysis



## 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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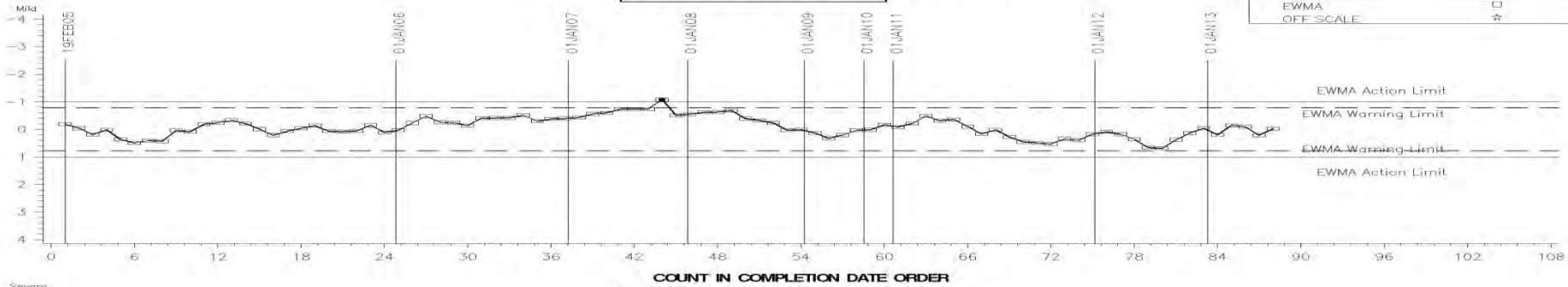
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# MACK T-12 INDUSTRY OPERATIONALLY VALID DATA



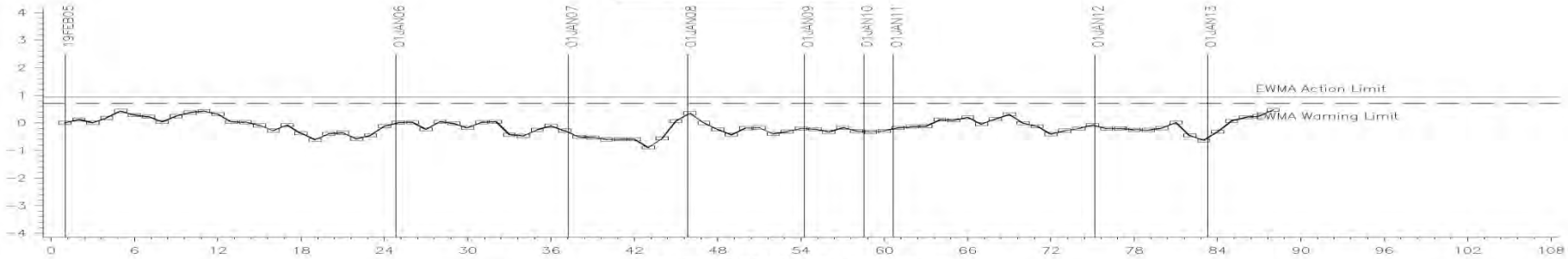
## FINAL TRANS. RES. DELTA PB @ EOT

LTMS Severity Analysis



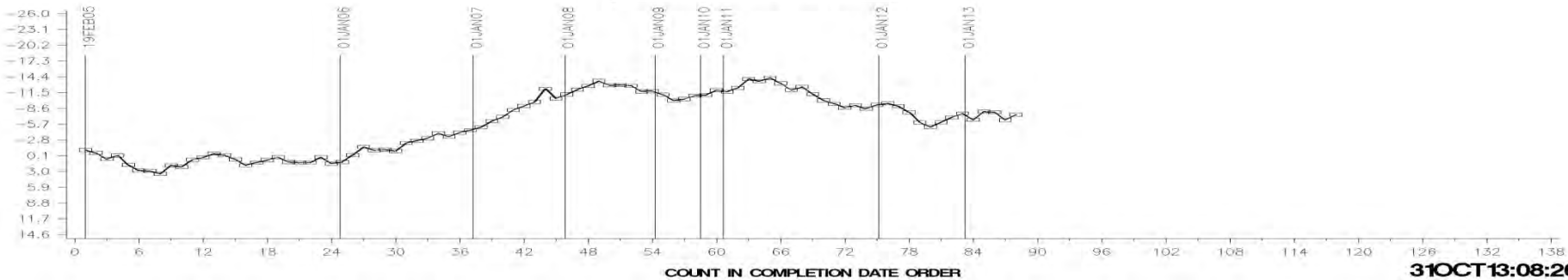
COUNT IN COMPLETION DATE ORDER

LTMS Precision Analysis



COUNT IN COMPLETION DATE ORDER

CUSUM Severity Analysis



COUNT IN COMPLETION DATE ORDER

31OCT13:08:20

Test Monitoring Center

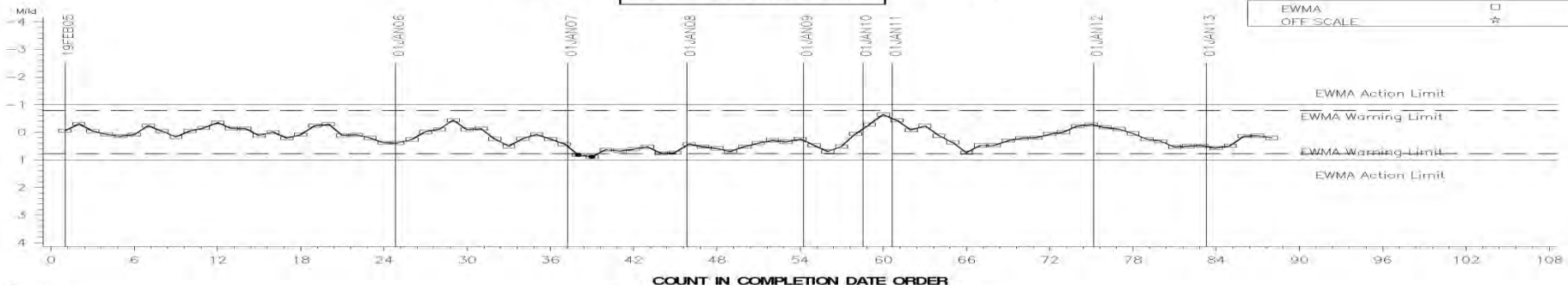
<http://astmtmc.cmu.edu>



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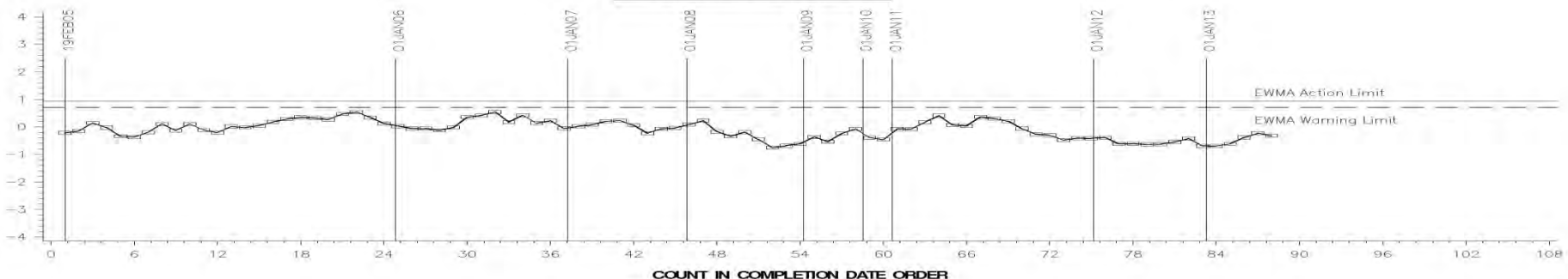
## AVG. CYLINDER LINER WEAR (CLW)

LTMS Severity Analysis



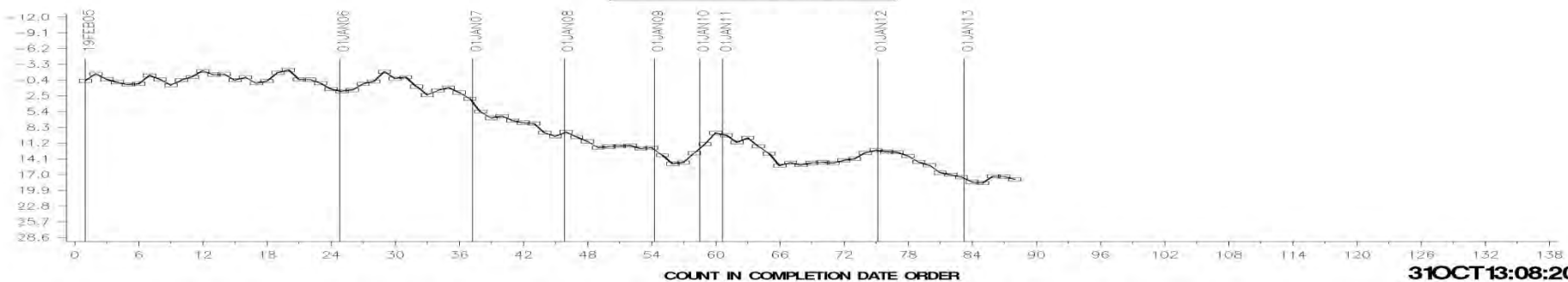
COUNT IN COMPLETION DATE ORDER

LTMS Precision Analysis



COUNT IN COMPLETION DATE ORDER

CUSUM Severity Analysis



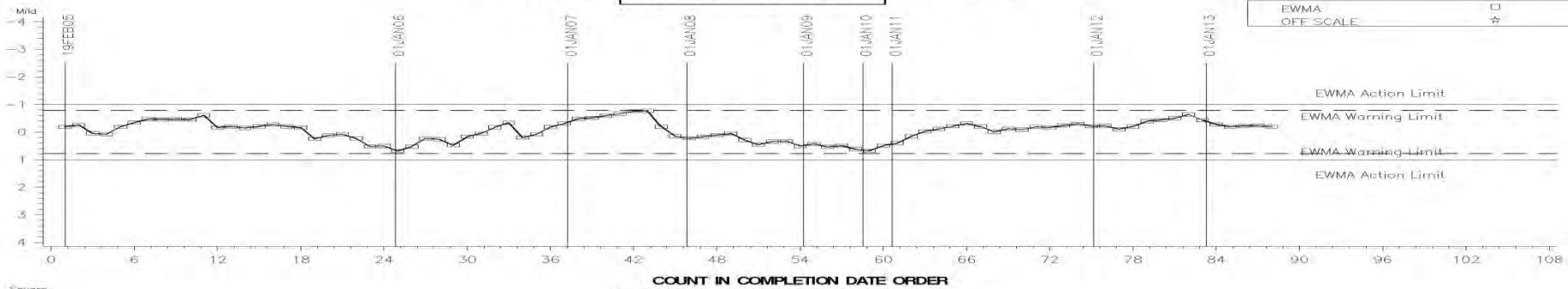
COUNT IN COMPLETION DATE ORDER

31OCT13:08:20

# MACK T-12 INDUSTRY OPERATIONALLY VALID DATA

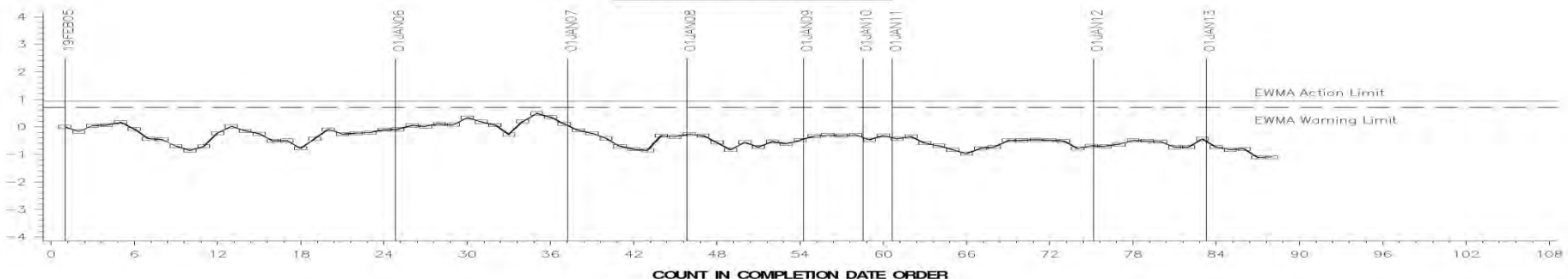
## AVG. TOP RING WEIGHT LOSS (TRWL)

LTMS Severity Analysis



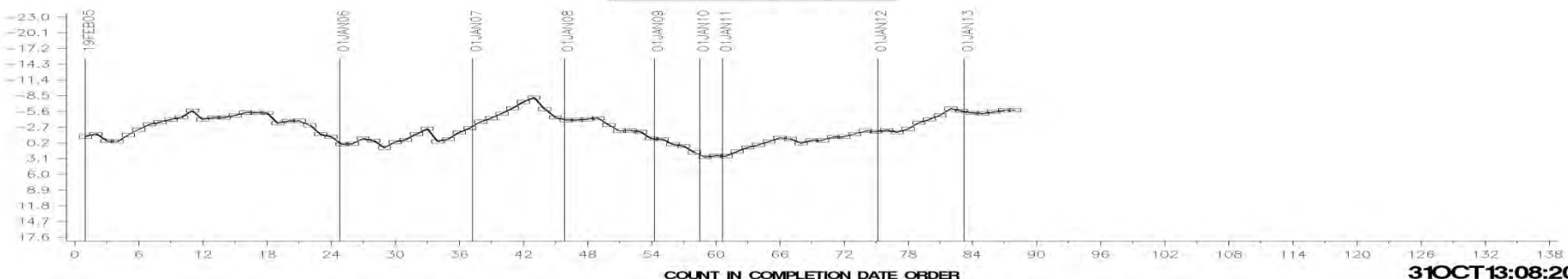
COUNT IN COMPLETION DATE ORDER

LTMS Precision Analysis



COUNT IN COMPLETION DATE ORDER

CUSUM Severity Analysis



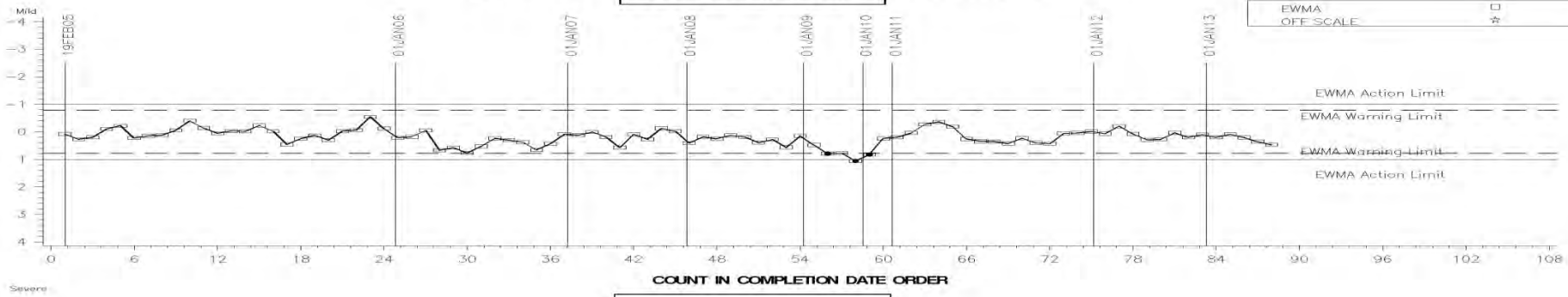
COUNT IN COMPLETION DATE ORDER

31OCT13:08:20



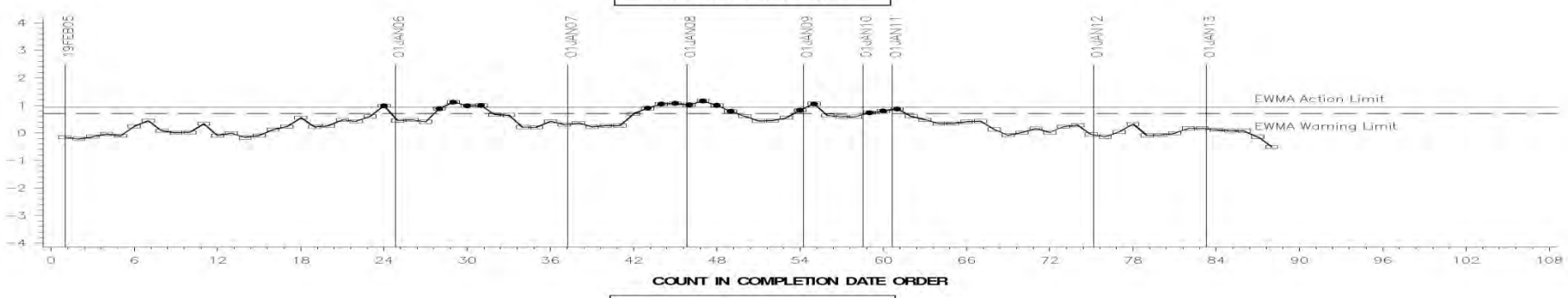
## FINAL TRANS. RES. OIL CONSUMPTION

LTMS Severity Analysis



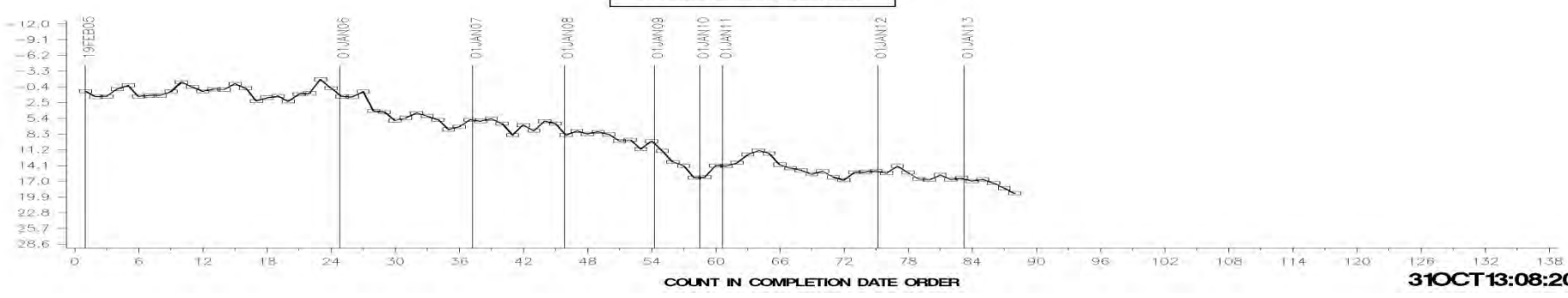
COUNT IN COMPLETION DATE ORDER

LTMS Precision Analysis



COUNT IN COMPLETION DATE ORDER

CUSUM Severity Analysis

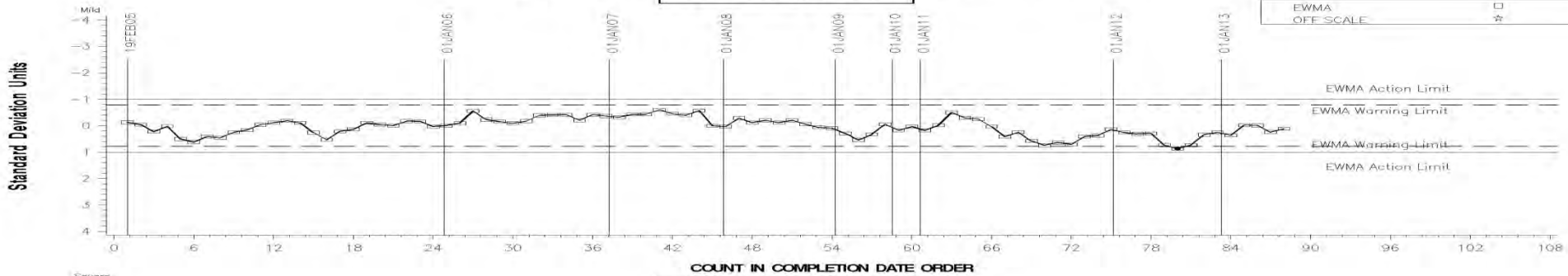


COUNT IN COMPLETION DATE ORDER

31OCT13:08:20

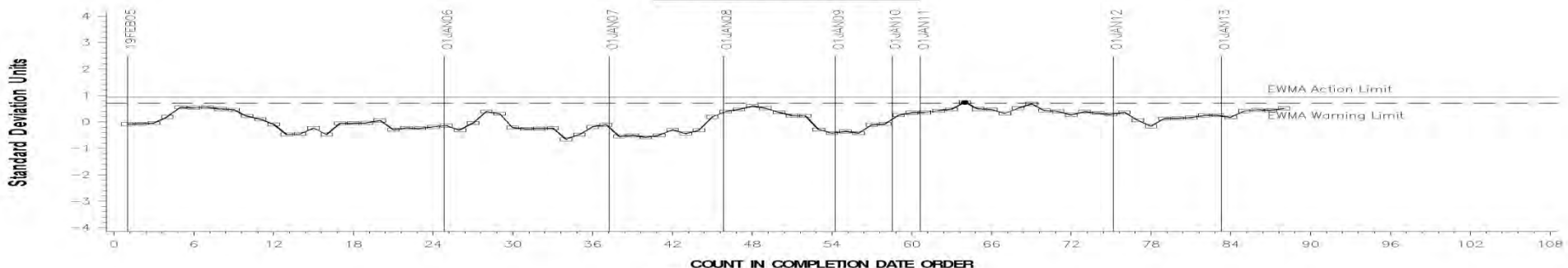
## FINAL TRANS. RES. DELTA PB 250-300H

LTMS Severity Analysis



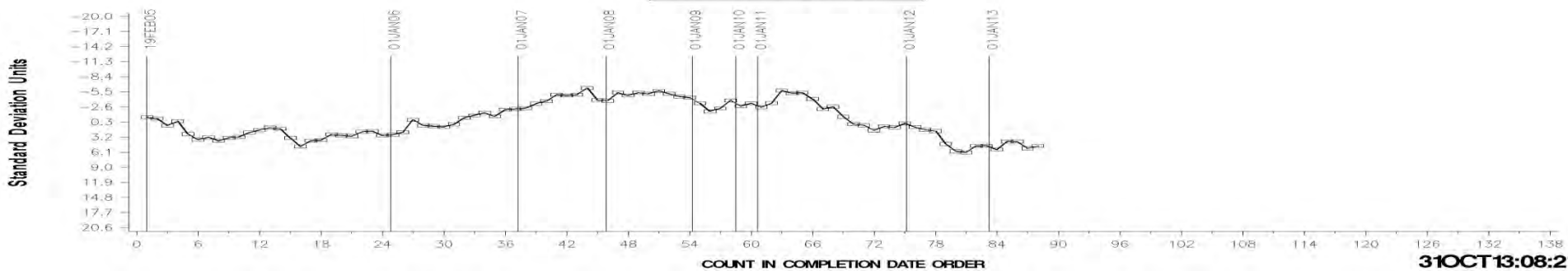
COUNT IN COMPLETION DATE ORDER

LTMS Precision Analysis



COUNT IN COMPLETION DATE ORDER

CUSUM Severity Analysis



COUNT IN COMPLETION DATE ORDER

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# Appendix 1.0

## T-12A Control Charts

» Severity, Precision, and CuSum

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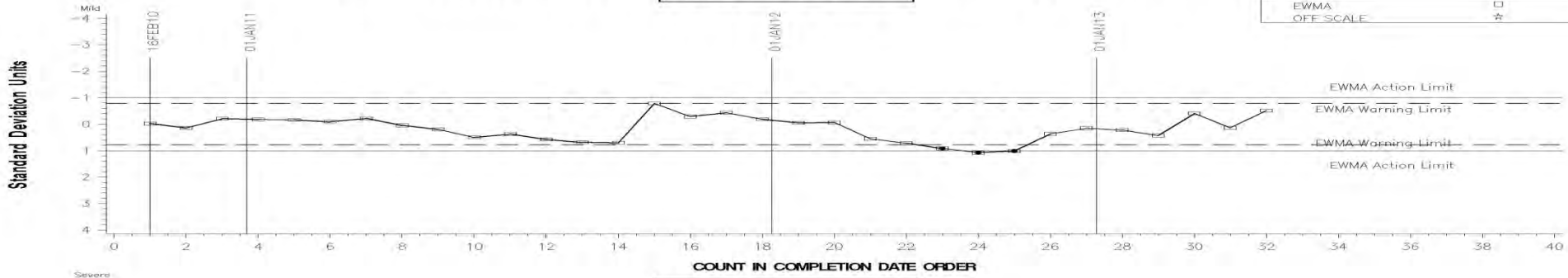


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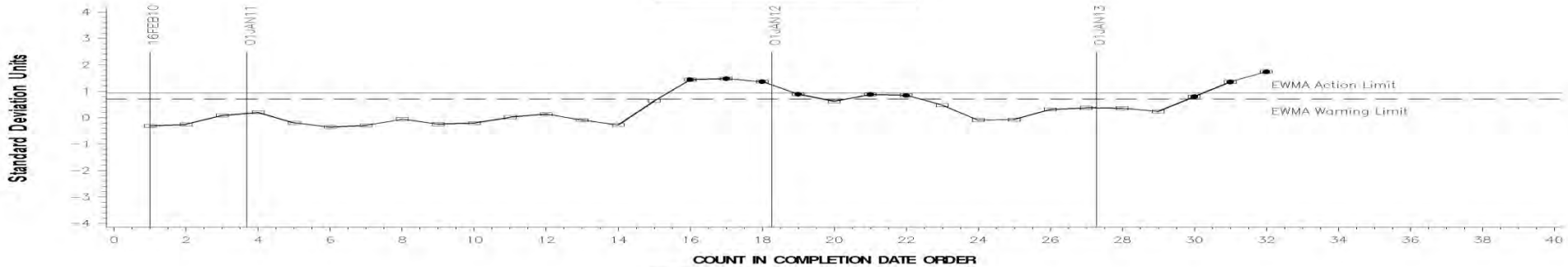
# MACK T-12A INDUSTRY OPERATIONALLY VALID DATA

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

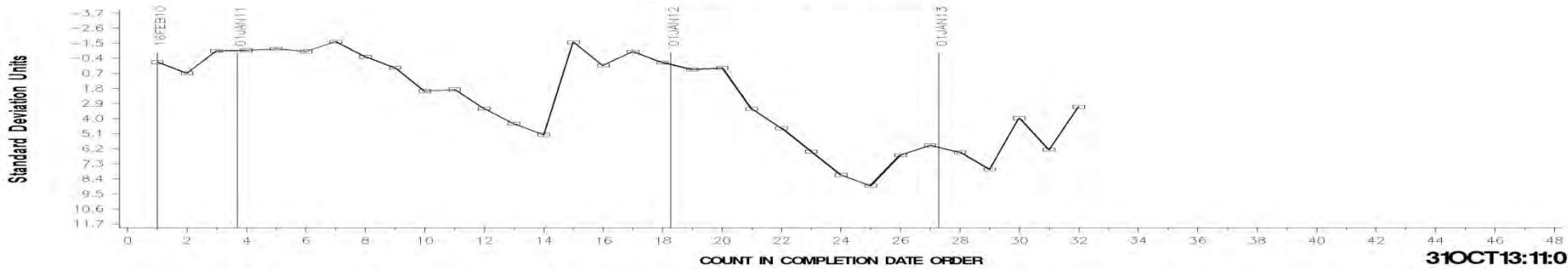
LTMS Severity Analysis



LTMS Precision Analysis



CUSUM Severity Analysis



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