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Committee D02 on PETROLEUM PRODUCTS AND LUBRICANTS

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Originally Issued: December 10, 2008

Reply to: Frank Farber
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Unapproved Minutes of the November 13, 2008 Sequence III Surveillance Panel Meeting held in Warren, MI

The meeting was called to order at 8:00 am by Chairman Dave Glaenzer. A membership list (Attachment 1) was circulated for members & guests to sign in.

<u>Agenda Review</u>
Bill Buscher is Action & Motion recorder.

The Agenda was accepted as shown on Attachment 2.

Sequence III Meeting Minutes
November 13, 2008
Warren, MI

Membership Changes

The chairman reviewed voting membership. The voting members are as follows:

Ed Altman	Afton
Dwight Bowden	OH Technologies
Jim Carter	Haltermann
Bruce Mathews	GM Powertrain
Greg Seman	Lubrizol
Pat Lang	Southwest Research Institute
Charlie Leverret	Intertek
Mark Mosher	ExxonMobil
Terry Kawlski	Toyota
Andy Ritchie	Infineium
Ron Romano	Ford
Mark Sutherland	Chevron
Tim Miranda	BP Castrol

Meeting Minute Status

The November 13, 2007 meeting minutes were approved by the surveillance panel.

Review of Action Items from Last Meeting

1. Action Item – OHT to investigate the use of the roll pin in the rocker cover bushing.
   Done. Determined pin is not necessary. A Tech memo to be issued.

2. Action Item – Update all test methods with the correct source for the rating aids and manuals.
   Done. To be discussed further today.

3. Motion – Recommend to Subcommittee B that the ASTM Test Monitoring Center be placed in charge of the control, maintenance, updating and distribution of the original CRC rating manuals.
   Dan Domonkos / Dwight Bowden / Passed Unanimously
   Done.

4. Action Item – Labs to consider purchasing SPO ancillary components now, rather than risking issues that could develop when these ancillary components transition to a third party supply.
   Done. Labs to decide.

5. Motion – Establish a task force to investigate AFR and NOx control and verification methods with Dan Domonkos as chair. Goal is to have investigation and recommendations completed by next surveillance panel meeting.
   Sid Clark / Ed Altman / Passed Unanimously
   Done. To be discussed further today.

6. Action Item – TMC will request the labs to update their phosphorus and calcium data from all reference oil tests conducted.

7. Motion – Table any further surveillance panel action on phosphorus retention until the surveillance panel has received ESCIT's letter of recommendation. A surveillance panel conference call will promptly be scheduled once ESCIT's letter has been received.
   Dan Domonkos / Charlie Leverett / Passed Unanimously
   Done.

8. Action Item – Surveillance panel members to solicit their companies for potential GF-5 calibration oils.
   Open. Post meeting one company has contacted the TMC about potentially supplying an oil.

9. Motion – Increase LTMS lambda for all parameters from 0.2 to 0.3.
   Trevor Miller / No Second / Motion Failed
   Done.

10. Motion – Remove "Most Recent Stand Reference Oil Test History" table from Form 4 of the Sequence III (all test types) test reports and associated data from the Sequence III data dictionaries. Note that this data is still available from other data sources.
    Dan Domonkos / Pat Lang / Passed Unanimously
    Done. Addressed in Report Packet Revision 20080516

11. Motion – Eliminate section 13.4 of the Sequence IIIG test procedure.
    Charlie Leverett / Pat Lang / Passed Unanimously
    Done. Addressed in IL-08-1

12. Motion – Revise section 12 of the Sequence IIIG test procedure to clarify oil level downtime.
    Charlie Leverett / Ed Altman / Passed with 1 Waive
    Done. Addressed in IL-08-1

13. Action Item – Chairman to plan and conduct a unified engine build prior to June 2009.

On hold until the availability of the honing machine dynamometer and the scheduling of calibrations at the labs can be done.

CPD Report

Jason Bowden presented Attachment 3 as the CPD report. Lab codes will be added to future rejected part lists to track rejection issues. CPD alerted labs to look for cracks when thrust plates are torqued. Three thrust plates have been replaced this report period

GM Motorsports Report

Scott Stap presented Attachment 4.

- **Sequence 3G Parts build out of GM sourced parts**
  - Based on 5000 total tests from industry survey
  - All parts have been received and are in long term storage
  - Blocks and heads are as received from GM Plant and will be finished machined as needed
  - **24502260B Heads**
    - Port leakage - Inspection of finished heads includes a pressure test. This test does not include pressure difference between ports. GM is open to researching port to port testing fixture at additional cost.
    - Stitch line - Stitch line appearance is normal due to casting procedures and does not necessarily indicate a problem
    - Porosity in intake gasket area - Intake surface is a “factory” finish and porosity is allowed up to two places and up to .060 long by .040 deep
    - GM will supply casting identification codes to labs so that existing inventories can be checked for casting defects in port area
  - **12593374 Connecting Rods**
    - Rust contamination – Has been addressed by inspection and repackaging.

The panel requested that GM present part supply counts on future reports.

IIIF/IIIG TMC Test Status

The complete TMC reports are posted to the TMC website.

Sequence IIIG			
Parameter	Δ/s	Average Δ, in Reported Units	Direction
PVIS	-0.014	-2.6 %	On Target
WPD	-0.533	-0.24 Merits	Severe
ALCW	*-0.462*	*-2.3 μm*	*Mild*

Sequence IIIF			
Parameter	Δ /s	Average Δ, in Reported Units	Direction
PVIS	*-0.873*	*-276 % VI*	*Severe*
APV	*0.819*	*0.28 Merits*	*Mild*
WPD	*-0.707*	*-0.26 Merits*	*Severe*
PV60	*0.647*	*44.3 % VI*	*Severe*

When Δ/s is in **RED Italic** the shift is significant!

The TMC presented a condensed update on Sequence IIIF & IIIG industry testing & trends (Attachment 5).

Candidate Activity Reports

Reports have been posted to the ACC Monitoring Agency website (https://acc-ma.org). No report review occurred at the meeting.

Fuel Supplier Report

Jim Carter presented the latest fuel batch analysis summaries (Attachment 6). The Detroit facility inventory of EEE fuel was not known at the meeting but Jim felt that the long term fuel supply for Sequence III testing was adequate. When a lab receives a report that a quarterly fuel sample is out of spec, they should provide an additional sample, if available, for repeat analysis. Labs are to obtain fuel samples from their tanks just prior to switching from an old shipment/batch to a new shipment/batch of EEE fuel. Samples are to be sent to Haltermann for analysis.

Old Business

AFR & NOx Control Task Force: Dan Domokos presented information from the Air/Fuel Ratio calibration task force visit to ECM. Attachment 7 shows O_2 sensor calibration information. Dan noted that calibration gases used in O2 sensor calibration introduce error because of the inaccuracy of the span gases. Differences in diffusion passage size also meant that the NTK UEGO sensor was less likely to plug. Dan requested that labs review the task forces calibration recommendations so that the panel could revisit at a later date.

New Business

TMC presented Attachment 8 discussing Sequence IIIG lab to lab variations regarding industry trends and ring batch differences.

Todd Dvorak from Afton presented Attachment 9 also discussing Sequence IIIG industry trends. After reviewing both presentations the panel opted to take no action regarding current industry trends.

After the two above presentations a lengthy discussion followed about possible causes for the current industry trends and specifically the current WPD severe trend. Concern was voiced regarding cylinder liner honing machine calibration, blow-by and fuel batch effects. Todd Dvorak agreed to analyze EEE fuel analysis results to see if there is a correlation with current trends. The chair was going to schedule honing dynamometer calibration with the labs as soon as possible. No formal panel was formed but labs were requested to review current fuel storage practices for impact on industry trends. Dan Worcester was to head up a LTMS task force to review lab to lab variations, industry oil mix and other potential causes for the current industry trends. At this point no action was taken on the current industry trends.

Oil Pan Gasket Issue:
OHT notified the panel that the current oil pan gasket material can not be manufactured anymore. Attachment 10 shows the current Sequence III pan gasket, current GM gasket and an aftermarket design. Jason Bowden of OHT motioned the panel to accept the aftermarket design. The motioned passed. Labs are to place a comment in the test report when the new gasket is introduced. The TMC is to capture the gasket introduction and enter the date when each lab starts to use the new gasket in the industry timeline.

Reference Oils:
The panel felt some input would be necessary from the ILSAC chair on selecting GF-5 reference oils. Also, it was felt that reference oil 438 could be dropped. However, no action was taken. The ROBO bench surveillance panel requested reference oil 435 from the TMC. The panel discussed this request and agreed to make 10 gallons of 435 along with a 55-gallon drum of 435-1 available to the ROBO group.

Perfect Seal #4 Supplier:
The Supplier for Perfect Seal #4 has changed. Post meeting the TMC issued IL08-03 updated the contact info for the new supplier.

Additional Torque Wrench:
The addition of the Snap-on torque wrench to the test method was missed from a previous meeting. Post meeting IL08-03 added the Snap-on wrench to the test method.

Sequence IIIGB:
Effective, November 13, 2008, a Sequence IIIGB report is to be submitted to the TMC when a Sequence IIIG reference test is conducted.

Freeze Plugs:
Afton noted some recent experience with leaking block freeze plugs. No other lab has seen this problem to date.

Reference Test Result Reporting:
All Sequence IIIF/G tests run to completion should report all data, no matter what the reported validity is. Descriptive comments to be included for all reported invalid tests. The TMC is to post the descriptive comments to the website ltms.csv file.

SCOPE & OBJECTIVES

SCOPE

The Sequence III Surveillance Panel is responsible for the surveillance and continual improvement of the Sequence IIIF and IIIFHD tests documented in ASTM Standard D6984-05 as update by the Information Letter System. The Sequence III Surveillance Panel is also responsible for the surveillance and continual improvement of the Sequence IIIG, IIIGA and IIIGB tests documented in ASTM Standard D7320 as updated by the Information Letter System. Data on test precision will be solicited and evaluated at least every six (6) months for Sequence III test procedures. The Surveillance Panel is to provide continual improvement of rating techniques, test operation, test monitoring and test validation through communication with the Test Sponsor, ASTM Test Monitoring Center, the Central Parts Distributor, Fuel Supplier, ASTM B0.01 Passenger Car Engine Oil Classification Panel, ASTM Committee B0.01, ACC Monitoring Agency and ASTM Deposit/Distress Workshop. Actions to improve the process will be recommended when appropriate based on input to the Surveillance Panel from one or more of the previously stated groups. This process will provide the best possible Sequence III Type Test Procedure for evaluating engine oil performance with respect to its ability to prevent oil thickening, varnish formation, oil consumption and engine wear.

OBJECTIVES	**TARGET DATE**
Solicit reference oils for GF-5 testing	**June 2009**
Plan and conduct unified engine build	**June 2009**
Initiate updated control and verification of AFR	**June 2009**

David L. Glaenzer, Chairman
Sequence III Surveillance Panel

Updated 11/13/2008
Detroit, MI USA

The meeting was adjourned at 1:07 pm.

Motions and Action Items

As Recorded at the Meeting by Bill Buscher

1. Action Item – Will look for some assistance from ILSAC chair to acquire additional reference oils meeting the Surveillance Panel's objectives (GF-5 capable oil).

2. Action Item – Labs to be sure to report all rejected parts back to OHT and GM Raceshop. Pay close attention to the camshaft thrust plate.

3. Action Item – Labs to inspect cylinder heads for a casting flaw that results in port-to-port leakage. GM to supply casting identification information to the labs for the cylinder head casting batch in question. Any rejected parts should be returned to GM Raceshop.

4. Action Item – GM to report to the Surveillance Panel on a semi-annual basis the remaining quantities of the GM Raceshop build-out parts.

5. Motion – When a lab receives a report that a quarterly fuel sample is out of spec, they should provide an additional sample, if available, for repeat analysis.

   Charlie Leverett / Pat Lang / Passed Unanimously

6. Action Item – Labs to evaluate the AFR task force's proposed AFR calibration process over the next six months, or sooner, for a follow-up Surveillance Panel discussion.

7. Action Item – Chairman to summarize concerns of the Sequence III Surveillance Panel for LTMS task force to consider.

8. Action Item – Surveillance Panel and LTMS task force to review Sequence III LTMS lab to lab differences at the January 2009 LTMS task force meeting.

9. Action Item – Charlie Leverett and Sid Clark will locate the Sunnen honing machine dynamometer and coordinate another honing machine load calibration round robin.

10. Action Item – Chairman will evaluate a honing machine load calibration procedure for inclusion into the Sequence III test procedures.

11. Action Item – Chairman to schedule a firm date and location for the unified engine build and report by December 1, 2008.

12. Action Item – Todd Dvorak to analyze available EEE fuel data, from Haltermann and the labs, to see if trends can be identified and determine if further action/investigation is possible.

13. Action Item – Labs to obtain fuel samples from their tanks just prior to switching from an old shipment/batch to a new shipment/batch of EEE fuel. Samples to be sent to Haltermann for analysis.

14. Action Item – Findings and conclusions from the above action items will be reported to the test fuel task force for review.

15. Action Item – Effective, November 13, 2008, a Sequence IIIGB report is to be submitted to the TMC when a Sequence IIIG reference test is conducted.

16. Action Item – Labs to closely inspect cylinder block freeze plugs for leaks.

17. Motion – Accept the use of the aftermarket oil pan gasket, OHT p/n OHT3G-093-2, as a replacement gasket.

    Jason Bowden / Larry Hamilton / Passed Unanimously

18. Motion – All Sequence IIIF/G tests run to completion should report all data, no matter what the reported validity is. Descriptive comments to be included for all reported invalid tests.

    Pat Lang / Rich Grundza / Passed Unanimously

19. Motion – Issue an information letter to include the approved Snap-on replacement torque wrench in the Sequence III test procedures.

Charlie Leverett / Rich Grundza / Passed Unanimously

Attachment 1

Sequence III — November 13, 2008

Name	Company	Email
Richard Grundza	ASTM TMC	reg@astmtmc.cmu.edu
David L. Glaenzer	Afton Chemical	dave.glaenzer@aftonchemical.com
Gordon Farnsworth	Consultant	Gordon.Farnsworth@Infineum.com
Andrew Ritchie	Infineum	Andrew.Ritchie@Infineum.com
Robert Stockwell	ConocoPhillips	Robert.T.Stockwell@conocophillips.com
Doyle Boese	Infineum	Doyle.Boese@Infineum.com
Jason Bowden	OHT	jhbowden@ohtech.com
Dwight Bowden	OHT	DHBOWDEN@OHTECH.COM
Adam Bowden	OHT	ADBOWDEN@OHTECH.COM
Frank Farber	TMC	FMF@ASTMTMC.CMU.EDU
Ron Romano	Ford	rromano@ford.com
Jim Carter	Haltermann	JECARTER@JHALTERMANN.com
Bill Buscher	SwRI	wbuscher@swri.edu
Pat Lang	SwRI	plang@swri.edu
Bruce Matthews	GM	bruce.matthews@GM.com
Chris May	Imperial	chris.j.may@esso.ca
Kristen Lyon	ExxonMobil	Kristen.A.Lyon@exxonmobil.c
Mark Mosher	"	mark.r.mosher@exxonmobil.com
Bob Olree	Consultant	—
Sid Clark	SwRI	Sidney.L.Clark@SBCGlobal.NET
Jim Linden	GM	JAMES.L.LINDEN@GM.com
Tim Caudill	Valvoline	TLCAUDILL@Ashland.Com
Brad Cosgrove	Chrysler	BGC4@Chrysler.com
Scott Stap	GM Racing	Scott.Stap@tgidirect.com
Jeff Kettman	GM Racing	jeff.kettman@gm.com
Matthew J. Snider	GMPT	matthew.j.snider@gm.com
Chris Castanien	LZ	Chris.Castanien@Lubrizol.com

Attachment 1 (continued)

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Todd Dvorak	Afton	todd.dvorak@aftonchemical.com
Charlie Leverett	Intertek	charlie.leverett@intertek.com

Attachment 2

AGENDA
SEQUENCE III SURVEILLANCE PANEL MEETING

GM Research, Warren, Michigan
November 13, 2008
8:00 AM to Noon

1. **APPOINTMENT OF RECORDER OF ACTIONS/MOTIONS**
2. **AGENDA REVIEW**
3. **MEMBERSHIP CHANGES – GM Representative**
4. **APPROVAL OF THE MINUTES FROM THE MAY 2008 MEETING**
5. **REVIEW OF ACTION ITEMS FROM THE LAST MEETING**

6. **SEQUENCE III TEST HARDWARE REPORTS**
   CPD, OH TECHNOLOGIES
   GM MOTORSPORTS

7. **ASTM-TMC REPORTS**
   D 6984 - SEQUENCE IIIF
   D 7320 - SEQUENCE IIIG/IIIGA

8. CANDIDATE ACTIVITY REPORTS
   ACC-MA REPORT-D 6984 - SEQUENCE IIIF
   ACC-MA REPORT-D 7320 - SEQUENCE IIIG/IIIGA

9. **SEQUENCE III FUEL SUPPLIER REPORT**

10. **OLD BUSINESS**
    AFR & NOx Control Task Force

11. **NEW BUSINESS**
    TMC Review of IIIG Severity and Precision
    Evaluation of Reference oil mix for GF-5
    Afton presentation on IIIG Severity & Precision – Todd Dvorak
    Implementation of used oil analysis as required for IIIGB
    Observation on cylinder block freeze plugs
    Perfect Seal #4 sealer
    Oil pan gasket options – OHT

12. **REVIEW OF SCOPE & OBJECTIVES**

13. ADJOURNMENT

CENTRAL PARTS DISTRIBUTOR REPORT

OH Technologies, Inc.

Sequence III Surveillance Panel Meeting
GM Research, Warren, MI
November 13, 2008

OH Technologies, Inc.

Attachment 3 (continued)

REJECTION REPORT

Reporting period: 5/06/08 to 11/10/08

ITEM	DESCRIPTION	REASON REJECTED	QTY	REPLACED	DATE REPLACED
OHT3F-008-6	CAMSHAFT, SPECIAL TEST, IIIF	RUST	1	YES	11/7/2008
OHT3F-008-8	CAMSHAFT, SPECIAL TEST, IIIG	RUST VETO BUILDUP / STAINS	3	YES	5/27/2008
OHT3F-008-8	CAMSHAFT, SPECIAL TEST, IIIG	RUST	3	YES	6/19/2008
OHT3F-008-8	CAMSHAFT, SPECIAL TEST, IIIG	THREAD DAMAGE	1	YES	7/22/2008
OHT3F-008-8	CAMSHAFT, SPECIAL TEST, IIIG	RUST VETO BUILDUP / STAINS	4	YES	10/3/2008
OHT3F-011-2	THRUST PLATE	CRACKED	2	YES	6/4/2008
OHT3F-011-2	THRUST PLATE	CRACKED	3	YES	10/3/2008
OHT3F-011-2	THRUST PLATE	CRACKED	4	YES	11/7/2008
3F028-09	BUSHING, CAM, POSITIONS 1 & 4	SHIPPING DAMAGE	2	YES	10/3/2008
3F028-10	BUSHING, CAM, POSITIONS 2 & 3	SHIPPING DAMAGE	2	YES	10/3/2008
OH101 ASSY	BEARING, MAIN (SET)	DAMAGE DUE TO LOOSE PACKAGING	3	YES	10/3/2008
OH106 ASSY	BEARING, CONNECTING ROD (SET)	DAMAGE DUE TO LOOSE PACKAGING	1	YES	10/3/2008
OHT3F-053-1	PISTON, GRADE 12	CASTING FLAW	1	YES	5/8/2008
OHT3F-055-1	PISTON, GRADE 56	CASTING FLAW	1	YES	10/7/2008
OHT3F-055-1	PISTON, GRADE 56	SKIRT DIAMETER (HANDLING DAMAGE)	1	YES	9/29/2008

OH Technologies, Inc.

Technical Memos Issued

6/12/08

- **Seq. III CPD Technical Memo 13**
- OHT3F-053/054/055-1, BATCH CODE 21, TEST PISTONS- INCORRECT ETCHING

6/23/08

- **Seq. III CPD Technical Memo 14**
- OHT3G052-RN5-1, RINGS PISTON (5TH BLOCK RUN) incorrect 2nd rings in one each engine set

OH Technologies, Inc.

Batch Code Changes

Reporting period: 5/06/08 to 11/10/08

IIIF	Batch Code	Date Introduced
Wrist Pin	BC 7	10/2/2008
Oil Filter	BC 5	8/8/2008
IIIF Run 1 Rings	BC 10	9/16/2008
IIIF Run 2 Rings	BC 10	8/4/2008
IIIF Run 3 Rings	BC 10	8/8/2008
Piston Grade 56	BC 22	10/17/2008
Oil Cooler Plating	080619	6/19/2008
	080708	7/8/2008
	080820	8/22/2008

IIIG	Batch Code	Date Introduced
Wrist Pin	BC 7	9/16/2008
Oil Filter	BC 5	8/8/2008
Piston Grade 56	BC 22	10/15/2008
Oil Cooler Plating	080619	12/12/2007
	080708	1/30/2008
	080820	4/2/2008

OH Technologies, Inc.

Attachment 4

Oil Test 3G Hard Parts

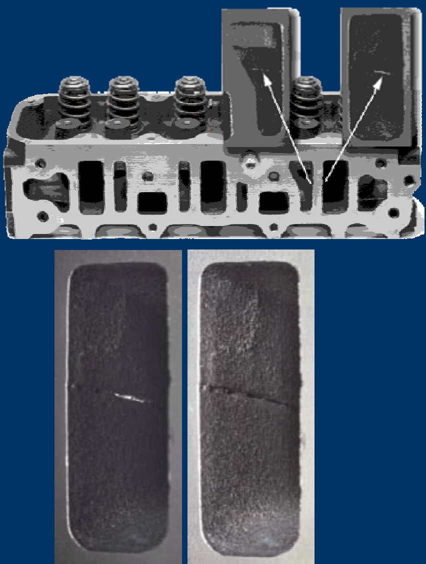
GM Racing Warehouse

- **Sequence 3G Parts build out of GM sourced parts**
  - Based on 5000 total tests from industry survey
  - All parts have been received and are in long term storage
  - Blocks and heads are as received from GM Plant and will be finished machined as needed.

GM Racing 3G parts discrepancies

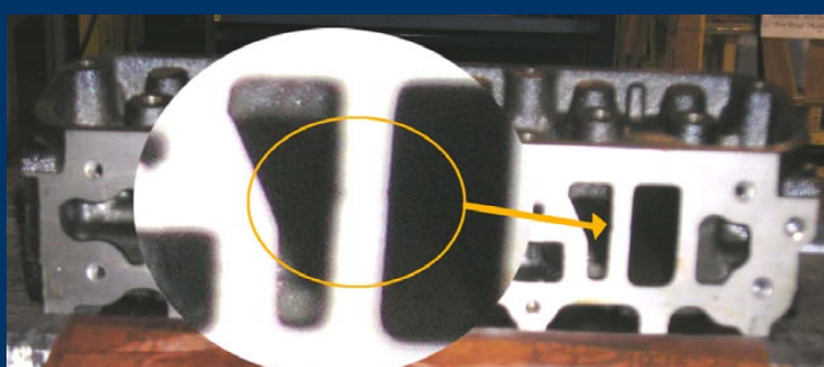
- **24502260B Heads**
  - Port leakage
  - Stitch line
  - Porosity in intake gasket area
- **12593374 Connecting Rods**
  - Rust contamination

Cylinder Head – Port Leakage



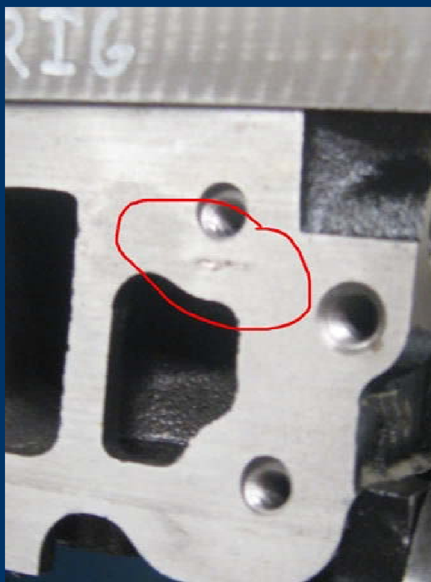
- Inspection of finished heads includes a pressure test
- Test does not include pressure difference between ports
- Open to researching port to port testing fixture at additional cost

Cylinder Head – Stitch line



- Stitch line appearance is normal due to casting procedures and does not necessarily indicate a problem

Cylinder Head – Porosity in gasket area



- Intake surface is a “factory” finish and porosity is allowed up to two places and up to .060 long by .040 deep

Connecting Rod

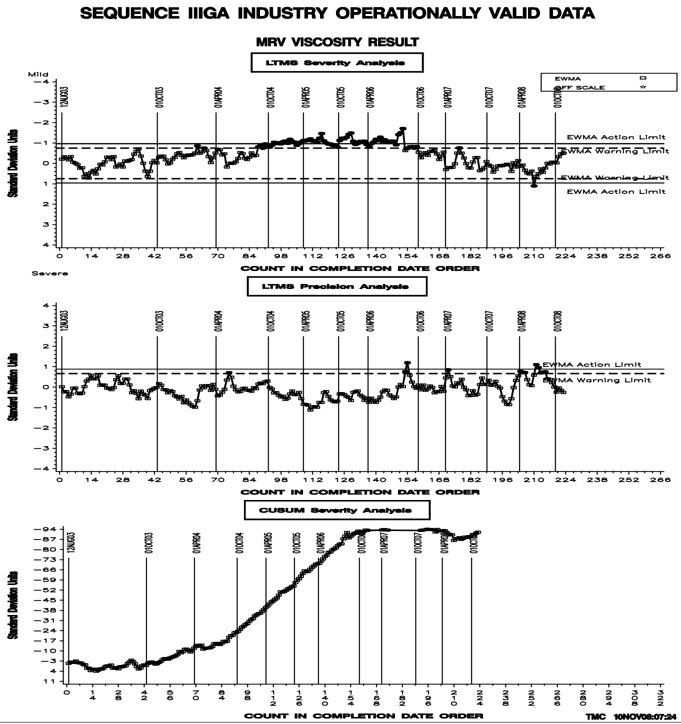
- Inspected incoming stock of new connecting rods (old stock has been depleted)
- Separated descrepant pieces
- All rods that met quality standards were preserved and packaged for long term storage
- New boxes are marked for better batch identification by individual received skid

Sequence IIIG Update

November 13, 2008

IIIG/A

- Severity and precision in control.
- Cusum chart shows test on or near target to slightly mild.

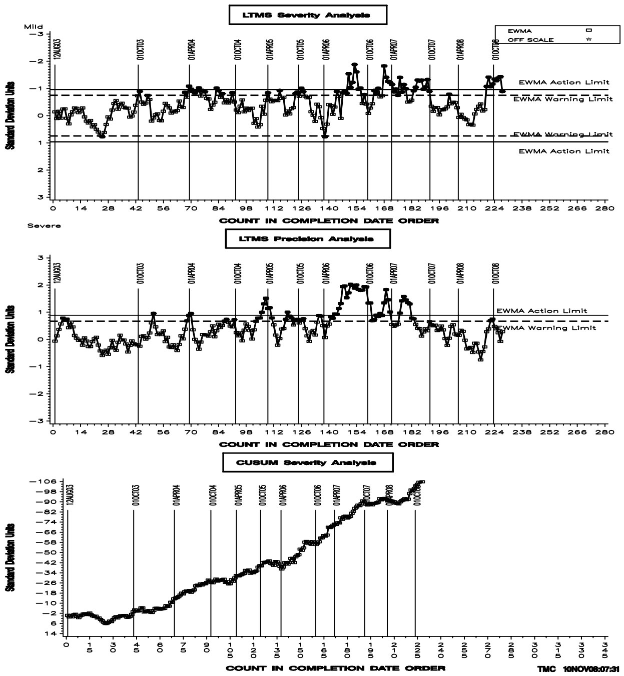


IIIG

- Calibration per start rate has increased slightly.
- Lost test rate has decreased.
- Rejected test rate increased.
- ACLW in mild warning alarm, WPD severe warning alarm
- PVIS on or near target.
- Pooled precision estimates for all parameters compare well with historic estimates

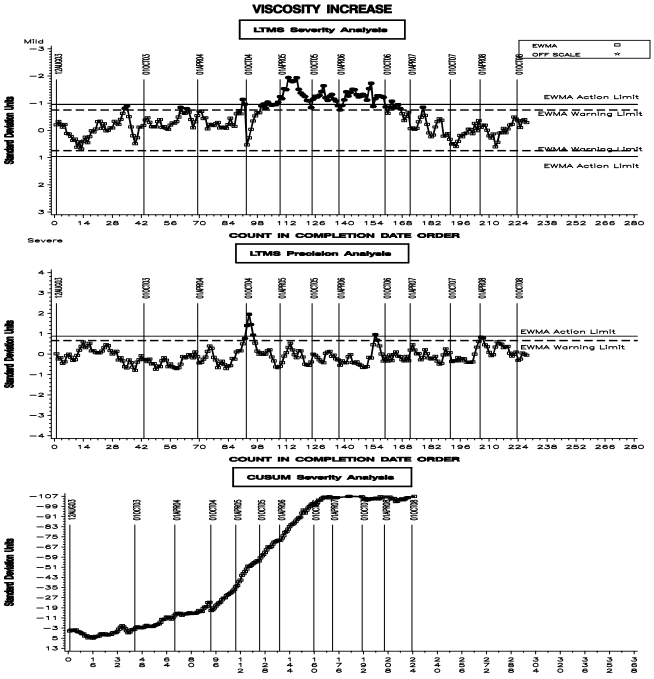
SEQUENCE IIIG INDUSTRY OPERATIONALLY VALID DATA

AVERAGE CAM + LIFTER WEAR

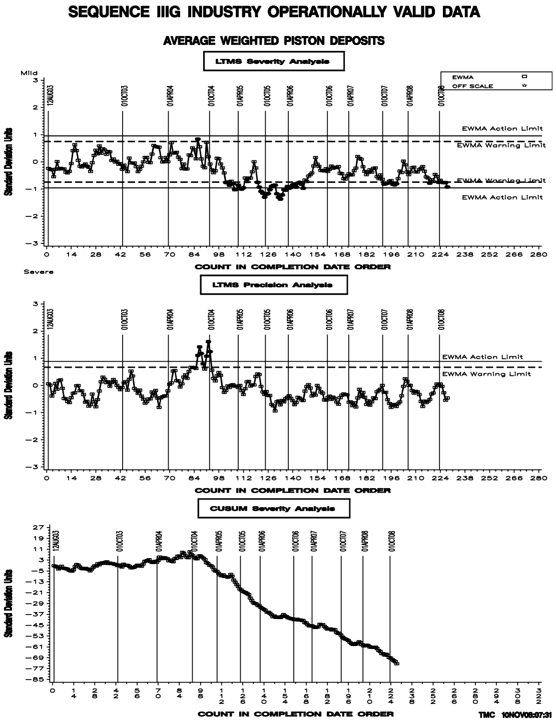


SEQUENCE IIIG INDUSTRY OPERATIONALLY VALID DATA

VISCOSITY INCREASE



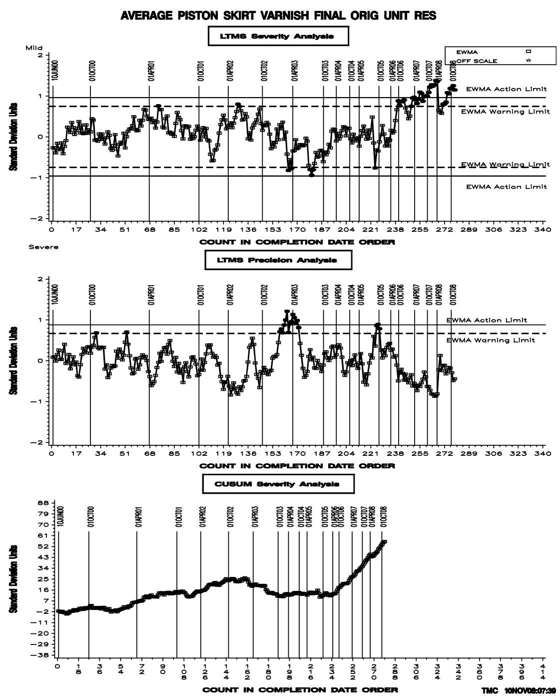
Attachment 5 (continued)



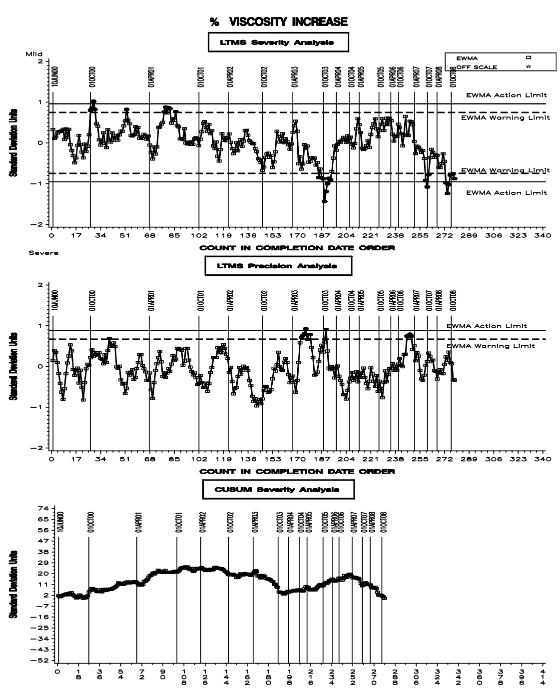
IIIF

- Calibration per start rate slightly less than last period.
- No rejected tests.
- Lost test rate higher than last period.
- Vis increase and WPD in severe warning alarm.
- APV in mild alarm
- Pvis@60 h in severe alarm

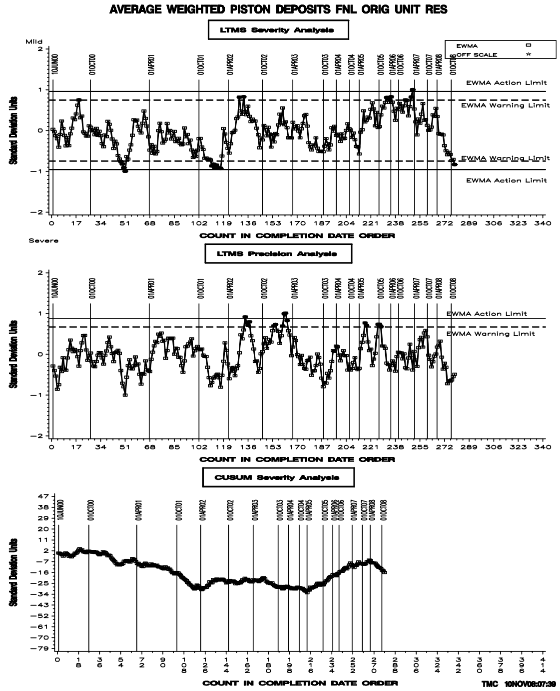
SEQUENCE IIIF INDUSTRY OPERATIONALLY VALID DATA



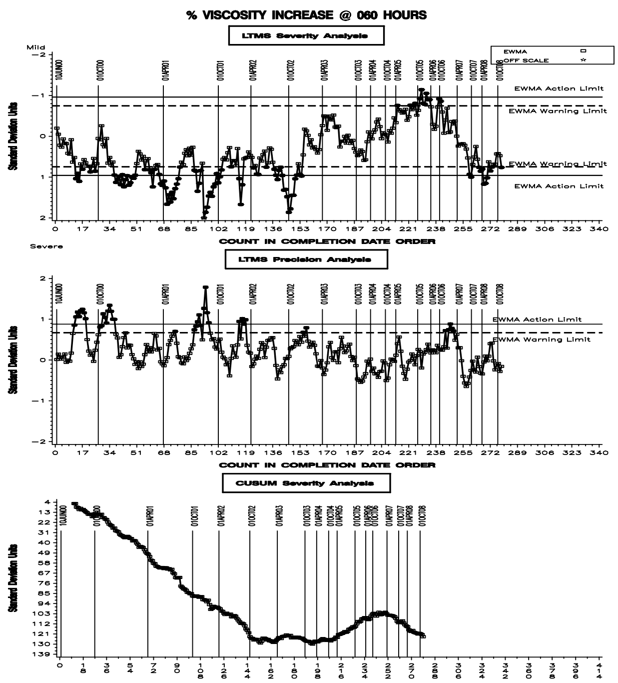
SEQUENCE IIIF INDUSTRY OPERATIONALLY VALID DATA



SEQUENCE IIIF INDUSTRY OPERATIONALLY VALID DATA



SEQUENCE IIIF INDUSTRY OPERATIONALLY VALID DATA



Other Items

- Quarterly fuel analysis reported from 3 of 6 labs for 3rd qtr of 08.
- One lab slightly low RVP, High 90%
- No other anomolies noted.

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HALTERMANN

PRODUCT CODE: HF003

PRODUCT: EEE Unleaded Gasoline

Seq. III & VI

Attachment 6

						Batch No.: WI0921LT10	Batch No.: WE1921LT10	Batch No.: WE1921LT10	Batch No.: WC3121LT10
						TMO No.: MTS	TMO No.:	TMO No.: MTS	TMO No.: MTS
						Tank No.: 110	Tank No.: 110	Tank No.: 110	Tank No.: 110
						10/1/2008	6/27/2008	5/29/2008	4/16/2008
TEST	**METHOD**	**UNITS**	**HALTERMANN Specs**			**RESULTS**	**RESULTS**	**RESULTS**	**RESULTS**
			MIN	**TARGET**	**MAX**				
Distillation - IBP	ASTM D86	°C	23.9		35.0	28.8	29.6	30.3	30.8
5%		°C				41.1	42.6	44.7	41.7
10%		°C	48.9		57.2	49.1	51.4	52.6	49.9
20%		°C				61.6	65.0	65.0	61.8
30%		°C				75.2	79.3	78.8	74.4
40%		°C				91.9	95.1	94.5	90.1
50%		°C	93.3		110.0	104.3	105.2	105.0	103.5
60%		°C				111.4	111.1	110.9	110.6
70%		°C				117.7	116.8	116.8	117.4
80%		°C				130.3	128.2	128.3	129.3
90%		°C	151.7		162.8	159.0	159.5	158.7	159.2
95%		°C				168.1	168.7	168.3	166.9
Distillation - EP		°C			212.8	198.4	199.0	196.8	195.2
Recovery		vol %		Report		97.0	97.0	97.6	97.4
Residue		vol %		Report		1.1	1.1	1.1	0.8
Loss		vol %		Report		1.9	1.9	1.3	1.8
Gravity @ 60°F/60°F	ASTM D4052	°API	58.7		61.2	59.08	59.0	59.0	59.1
Density @ 15° C	ASTM D4052	kg/l	0.734		0.744	0.742	0.742	0.742	0.742
Reid Vapor Pressure	ASTM D5191	kPa	60.6		63.4	63.0	63.4	63.3	62.9
Carbon	ASTM D3343	wt fraction		Report		0.8649	0.8649	0.8649	0.8650
Carbon	ASTM E191	wt fraction		Report		0.8626	0.8604	0.8604	0.8655
Hydrogen	ASTM E191	wt fraction		Report		0.1322	0.1353	0.1353	0.1328
Hydrogen/Carbon ratio	ASTM E191	mole/mole		Report		1.826	1.873	1.873	1.828
Oxygen	ASTM D4815	wt %			0.05	<0.01	<0.05	<0.05	<0.05
Sulfur	ASTM D5453	mg/kg	3		15	6	8	4	5
Lead	ASTM D3237	mg/l			2.6	<2.6	<2.6	<2.6	<2.6
Phosphorous	ASTM D3231	mg/l			1.3	<0.02	<0.2	<0.2	<0.2
Composition, aromatics	ASTM D1319	vol %	26.0		32.5	27.8	27.6	28.0	28.2
Composition, olefins	ASTM D1319	vol %			10.0	0.7	0.6	0.5	0.4
Composition, saturates	ASTM D1319	vol %		Report		71.5	71.8	71.4	71.5
Particulate matter	ASTM D5452	mg/l			1	0.6	0.5	0.5	0.3
Oxidation Stability	ASTM D525	minutes	1000			>1000	>1000	>1000	>1000
Copper Corrosion	ASTM D130				1	1a	1a	1	1
Gum content, washed	ASTM D381	mg/100mls			5.0	<0.5	<0.5	<0.5	<0.5
Fuel Economy Numerator/C Density	ASTM E191		2401		2441	2432	2422	2425	2432
C Factor	ASTM E191			Report		1.0016	1.0002	1.0002	1.0051
Research Octane Number	ASTM D2699		96.0			96.9	97.7	97.7	97.0
Motor Octane Number	ASTM D2700			Report		88.4	89.0	89.0	88.7
Sensitivity			7.5			8.5	8.7	8.7	8.3
Net Heating Value, btu/lb	ASTM D3338	btu/lb		Report		18484	18491	18486	18465
Net Heating Value, btu/lb	ASTM D240	btu/lb		Report		18395	18364	18364	18389
Color	VISUAL	1.75 ptb		Red		Red	Red	Red	RED

Normal Test Stand configuration

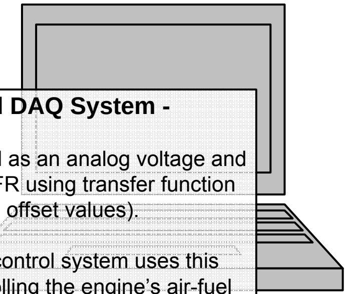
mA/%oxygen →

UEGO controller -

Converts sensor current (mA) to AFR using built-in electronics. Output voltage is linearized for AFR.

Controller contains programmable memory that allows calibration of sensor according to percentage of dry oxygen in free-air.

→ Volts/AFR →



Test Stand DAQ System -

Receives AFR signal as an analog voltage and converts back to AFR using transfer function (gain and offset values).

The Seq III AFR control system uses this feedback for controlling the engine's air-fuel ratio.

STEP 1: Sensor Calibration

See Page 2 for description of calibration of older NTK "blue box" controllers

mA/%oxygen →

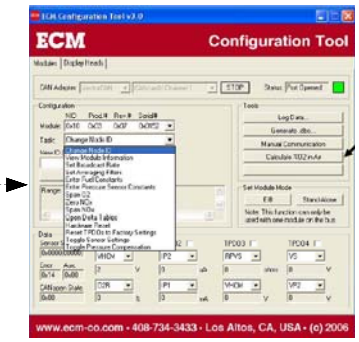
UEGO controller -

Sensor is exposed to open, quiescent air for a period of 1 hour.

Using an interface between the controller and a PC, the value for oxygen percentage is programmed into the controller.

Some controllers allow direct entry using a keypad and do not require a PC interface.

← CAN →



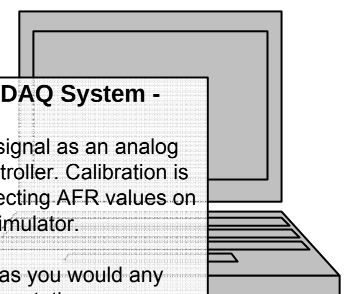
STEP 2: DAQ system (output signal) calibration

mA/%O2 →

UEGO controller

Converts mA (oxygen) to volts (AFR) using built-in curve "tweeks" and previously set sensor calibration factors.

→ Volts/AFR →



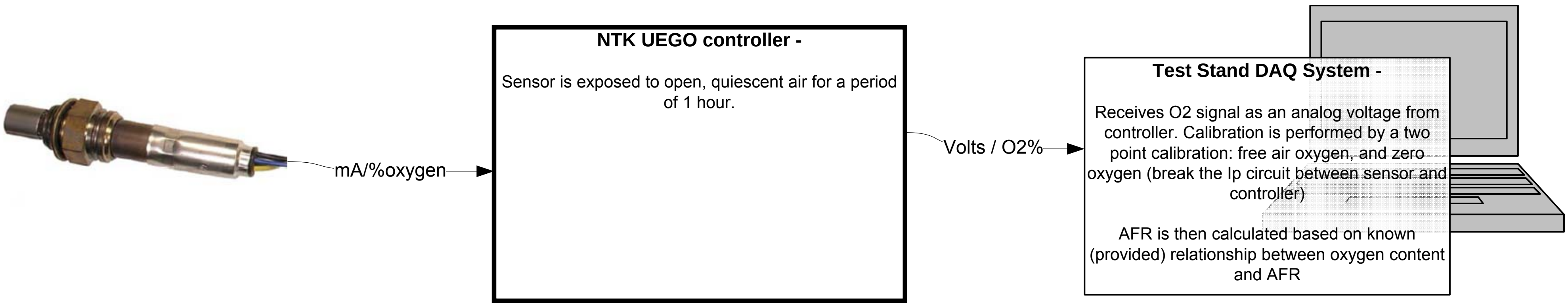
Test Stand DAQ System -

Receives AFR signal as an analog voltage from controller. Calibration is performed by selecting AFR values on the simulator.

Calibrate just as you would any instrumentation.

Calibration of older NTK "blue box" controllers and Controllers that can output Oxygen Percentage (vs AFR)

Complete System Calibration



Combustion Equilibrium:

$$C_1H_m + \lambda(1 + m/4)(O_2 + 3.773N_2) \rightarrow CO_2 + aO_2 + bH_2O + cN_2$$

Conservation of O2: λ (1 + m/4) = 1 + a + b/2
Conservation of H: m = 2b
Conservation of N2: λ (1 + m/4) 3.773 = c

Xo2 = %O2/100 = a / (1 + a + b + c), Note: "Wet" %O2 (water "b" in denominator).

After some math: **λ = (z + Xo2 (m/4)) / (z (1 – 4.773 Xo2))** , where z = 1 + (m/4), Xo2 = %O2/100

Then, to convert Lambda to AFR, stoichiometry must be calculated for fuel with a H/C ratio of 1.86.
From Heywood, Stoich = 34.56 x (4 + H/C) / (12.011 + 1.008 x H/C)
Stoich = 14.585
Therefore AFR = λ * 14.585
Substitution and simplification provides the expression for AFR = f(oxygen%) ...

$$AFR = \frac{14.58 + 0.00317 * O2\%}{1 - 0.04773 * O2\%}$$

O2% is in percentage (not decimal)

% Oxygen Calibration

The analog input from the O2 controller to the DAQ system must be calibrated as follows. This procedure results in a relationship between controller output voltage and measured O2 percentage (O2% = voltage * slope + offset).

1. remove sensor from exhaust, reconnect to controller harness, turn on controller, and allow sensor to warmup for a period of at least 1 hour

2. determine the ambient dry oxygen level by determining the water vapor pressure (Psw), barometric pressure (Pbar), and relative humidity (Rh), then use the formula below to calculate the corrected dry oxygen percentage:
   %O2dry = 20.95 x (Pbar – Pws x Rh/100) / Pbar
   Formulas for determining Pws and Rh are shown below.

3. Use the value calculated above for %O2dry as the first point of calibration while exposing the sensor to quiescent air (do not wave sensor in air).

4. The second calibration point is 0% oxygen and is simulated by disconnecting the sensor's output current circuit (Ip). To facilitate the process it is recommended that a switch be installed in the circuit that allows the circuit to be opened temporarily.

5. The above two points are then used to calculate slope and offset values.

6. Reinstall sensor in exhaust and verify that the sensor current circuit switch is in the normal position.

Water saturation vapor pressure (kPa)

Pws = $Ax^3 + Bx^2 + Cx + D$
where x is ambient temperature in ºC (in the range of 10 to 40º), and the constants are as follows:

A = 6.9602E-05
B = -2.0236E-04
C = 6.8762E-02
D = 0.4866

Relative Humidity (%)

Rh = ep / es x 100
where Td is dewpoint temperature in ºC (in the range of 10 to 40º), and T is the ambient temperature

ep = e^((17.269 x Td)/(273 + Td))
es = e^((17.269 x T)/(273 + T))

Sequence IIIG Severity

November 13, 2008

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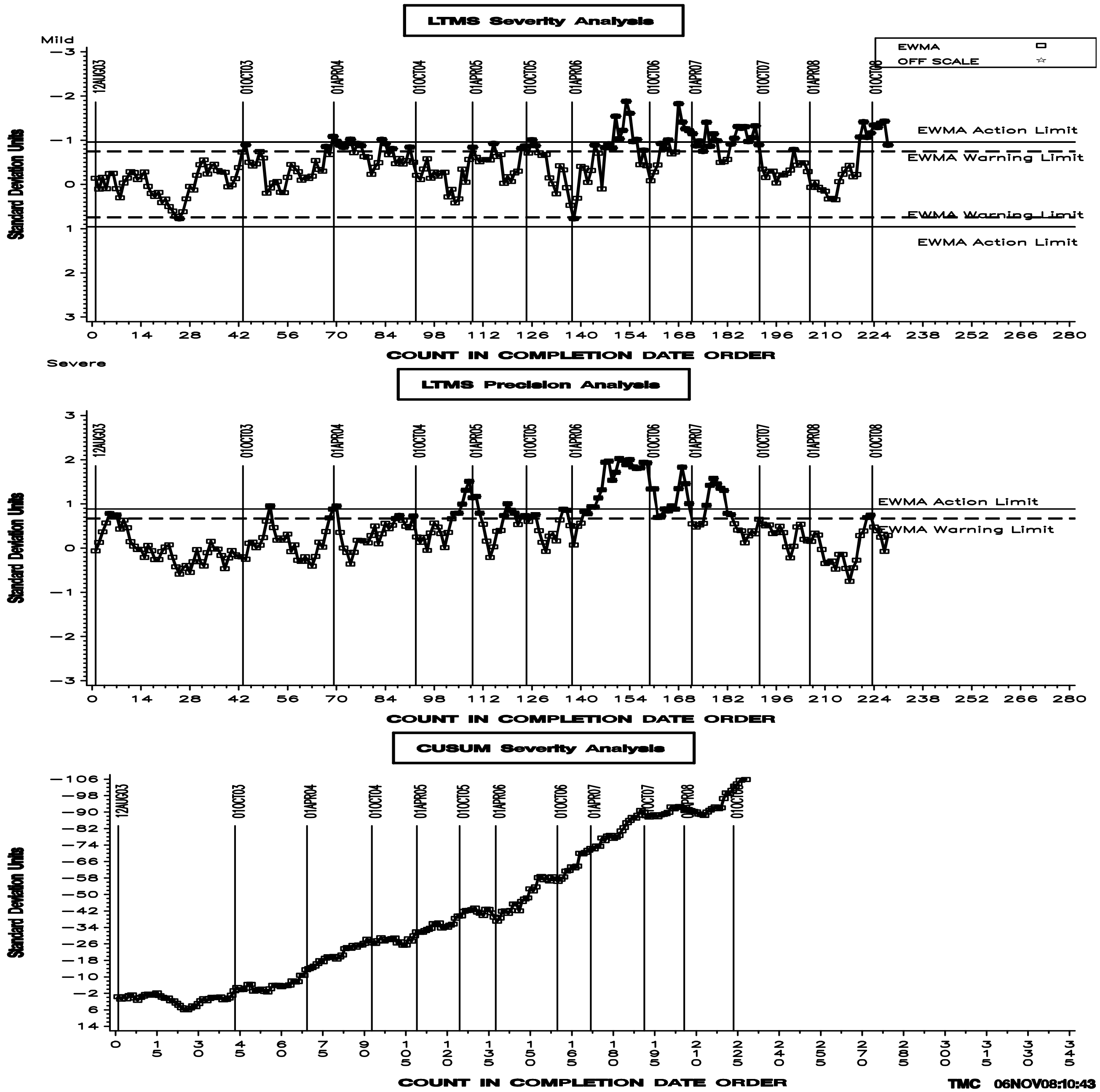
Average Cam & Lifter Wear Severity

- Industry is Currently in Action Alarm
- Severity Issues appear to be lab related
- Three of six labs have been mild
- Two in SA

SEQUENCE IIIG INDUSTRY OPERATIONALLY VALID DATA

AVERAGE CAM + LIFTER WEAR



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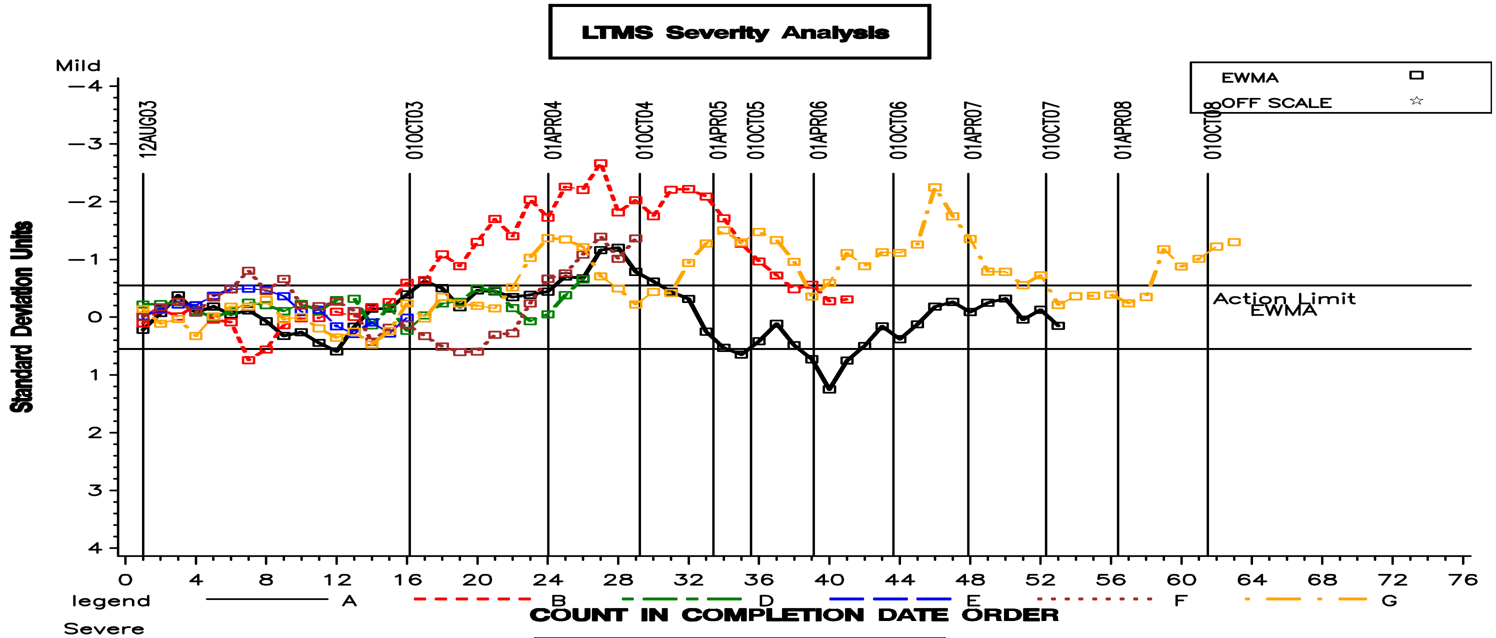
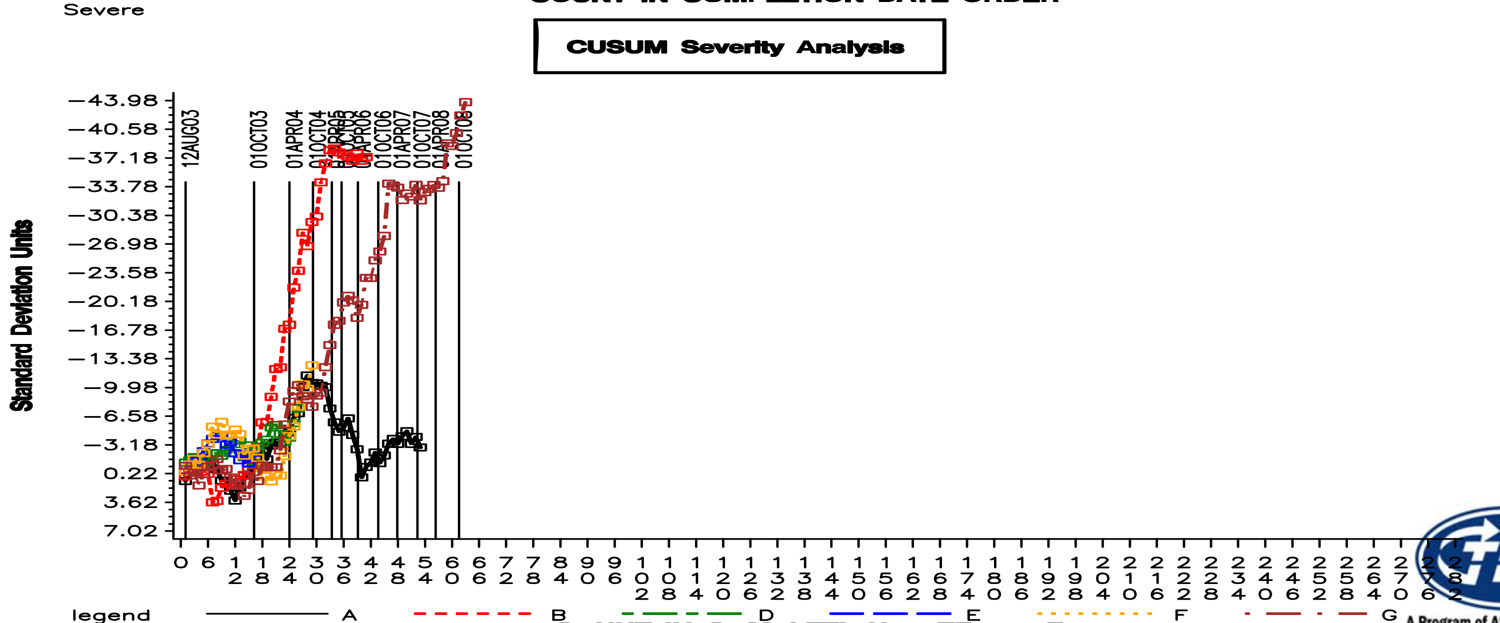
SEQUENCE IIIG LABORATORY OPERATIONALLY VALID DATA

AVERAGE CAM + LIFTER WEAR





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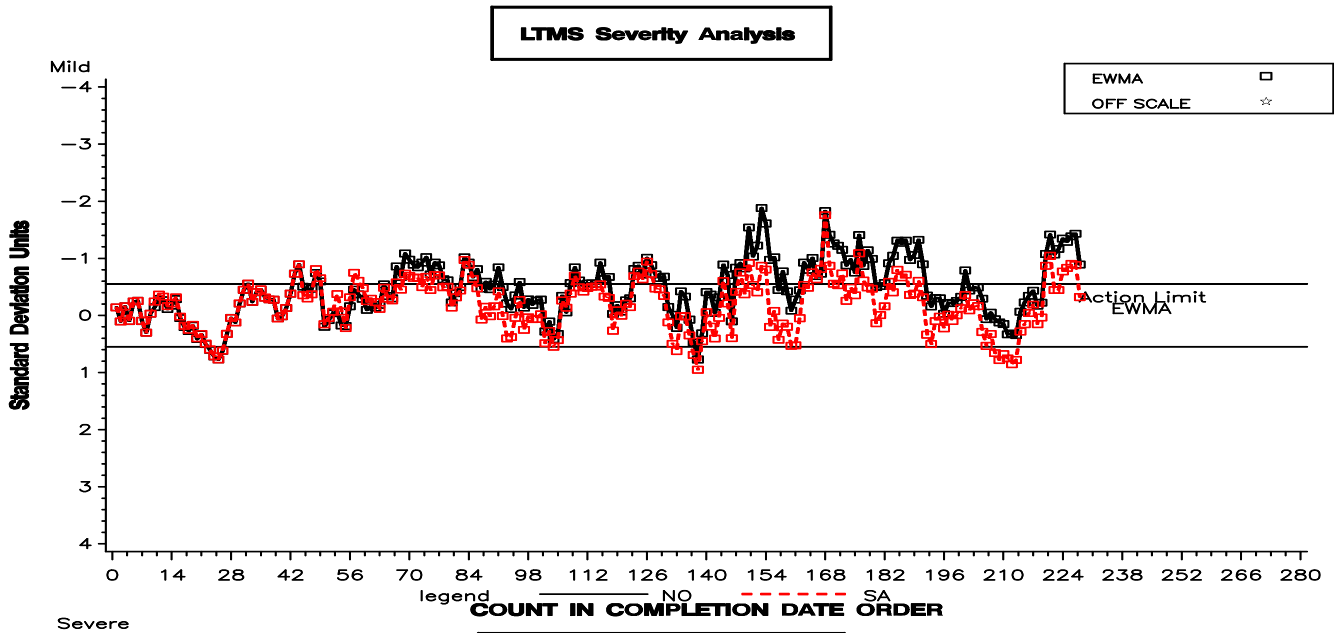
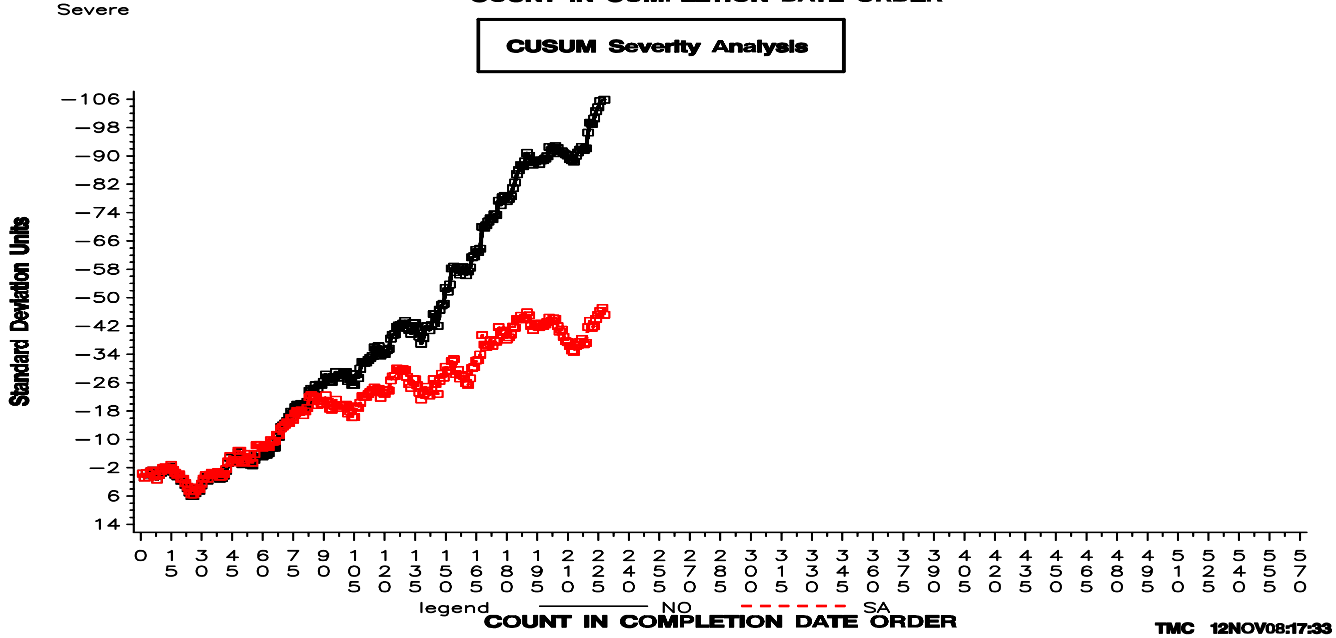
SEQUENCE IIIG LABORATORY OPERATIONALLY VALID DATA

AVERAGE CAM + LIFTER WEAR





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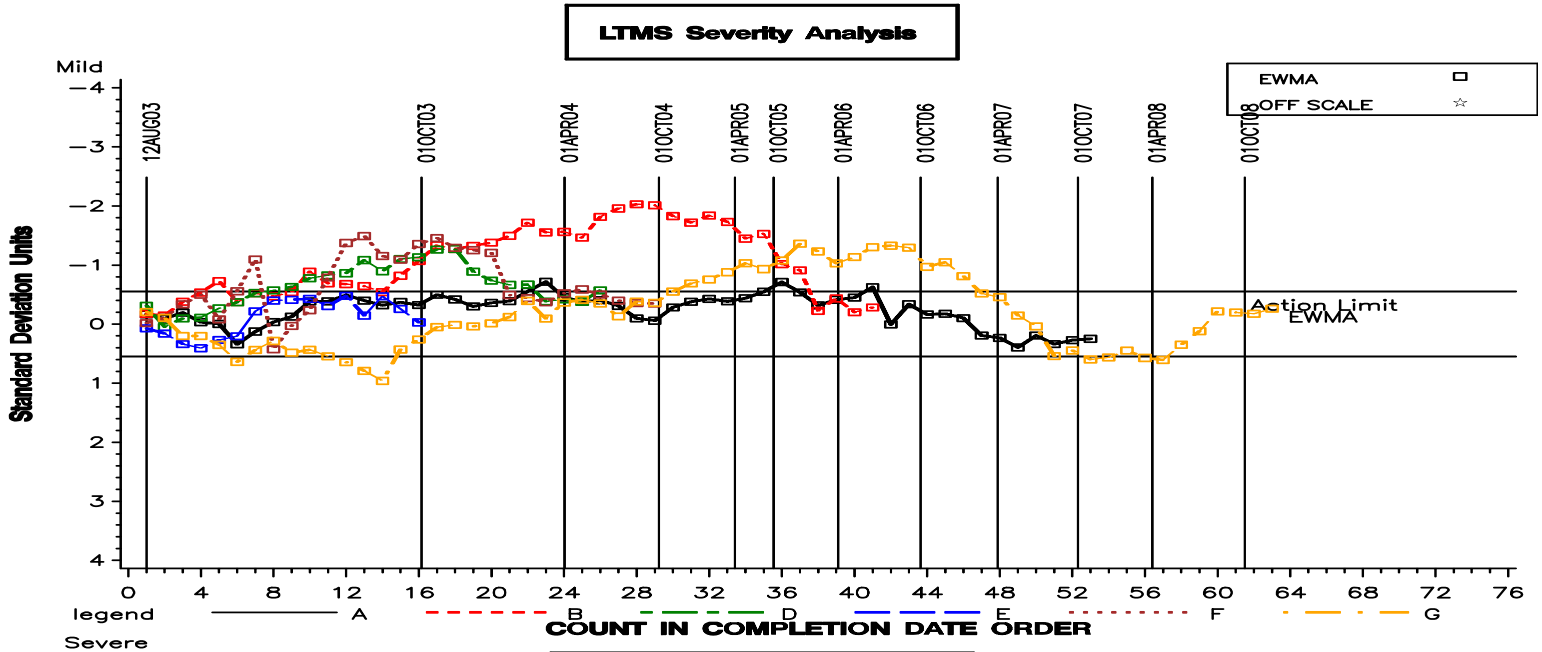
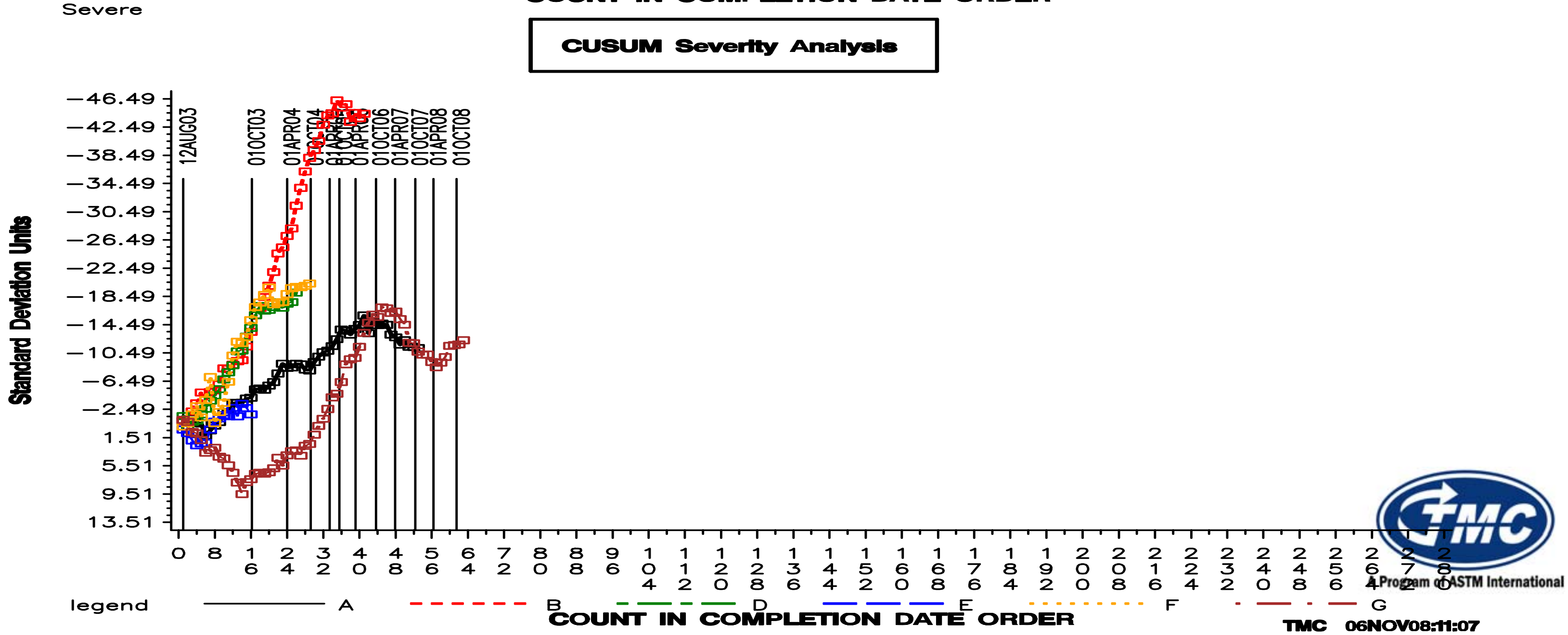
Percent Viscosity Increase

- With the exception of a couple of mild warning alarms, PVIS has been in control since April of 2007
- Some laboratory issues, but overall no real industry problems

SEQUENCE IIIG LABORATORY OPERATIONALLY VALID DATA

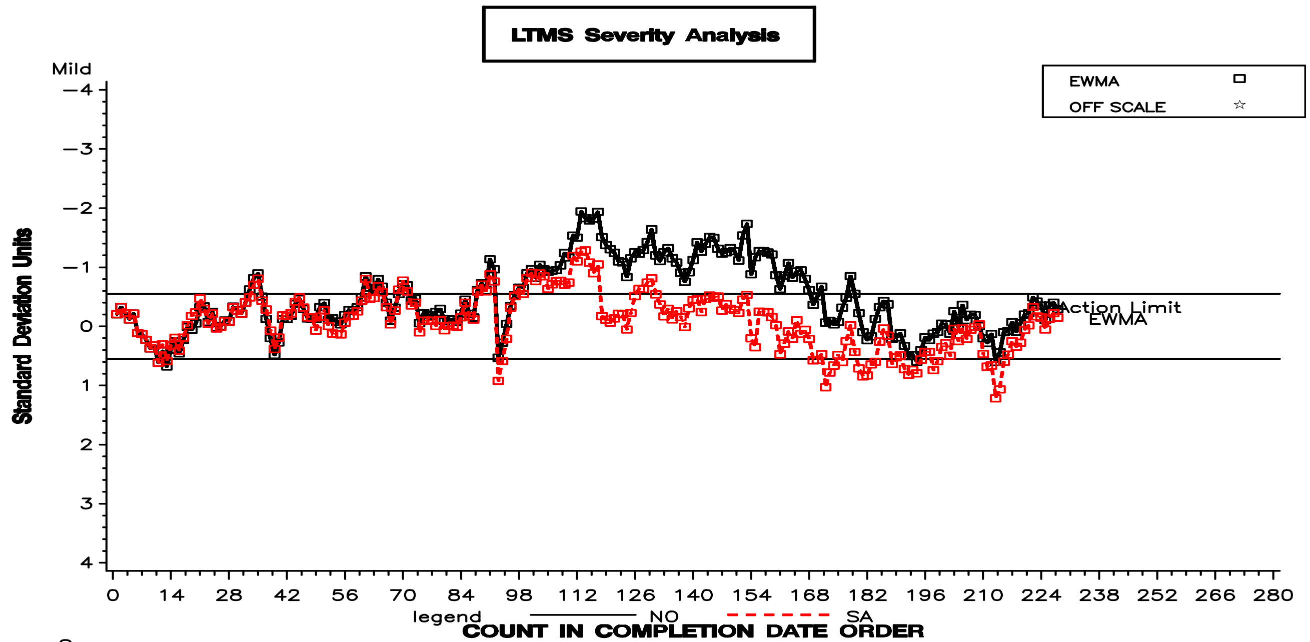
VISCOSITY INCREASE

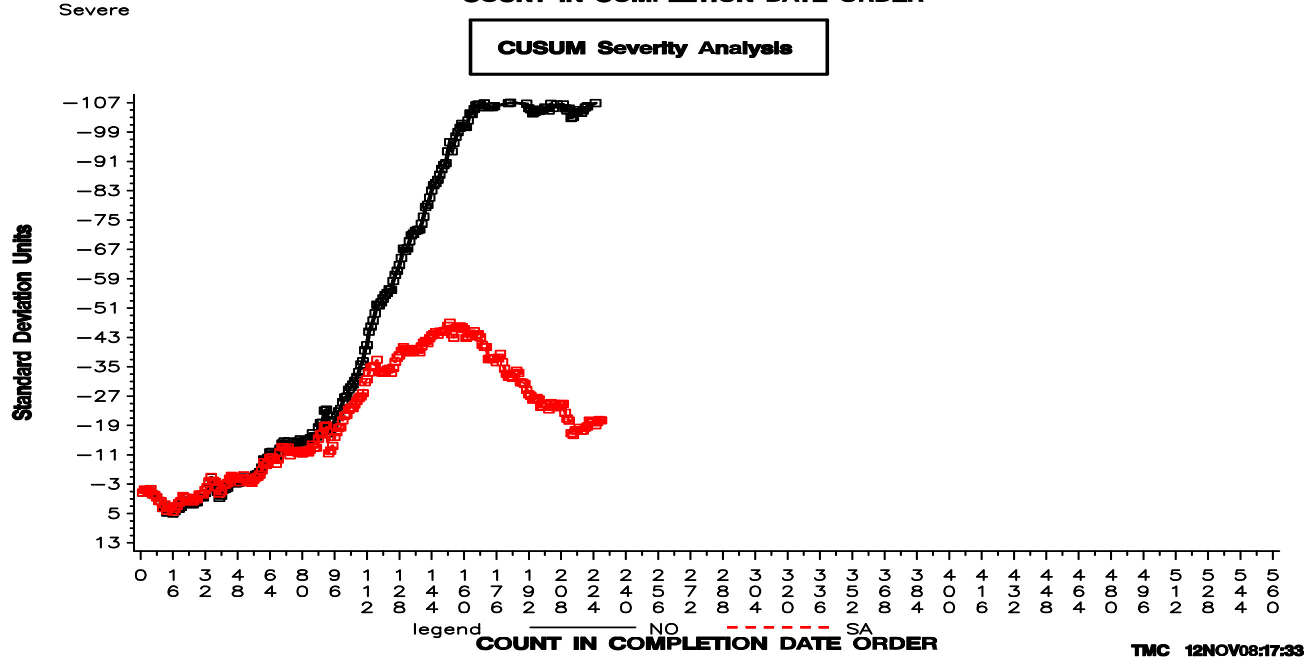




SEQUENCE IIIG LABORATORY OPERATIONALLY VALID DATA

VISCOSITY INCREASE





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WPD Severity

- Currently in Warning alarm
- Not all Ring batches the same
- Not all labs the same
- Not all oils the same

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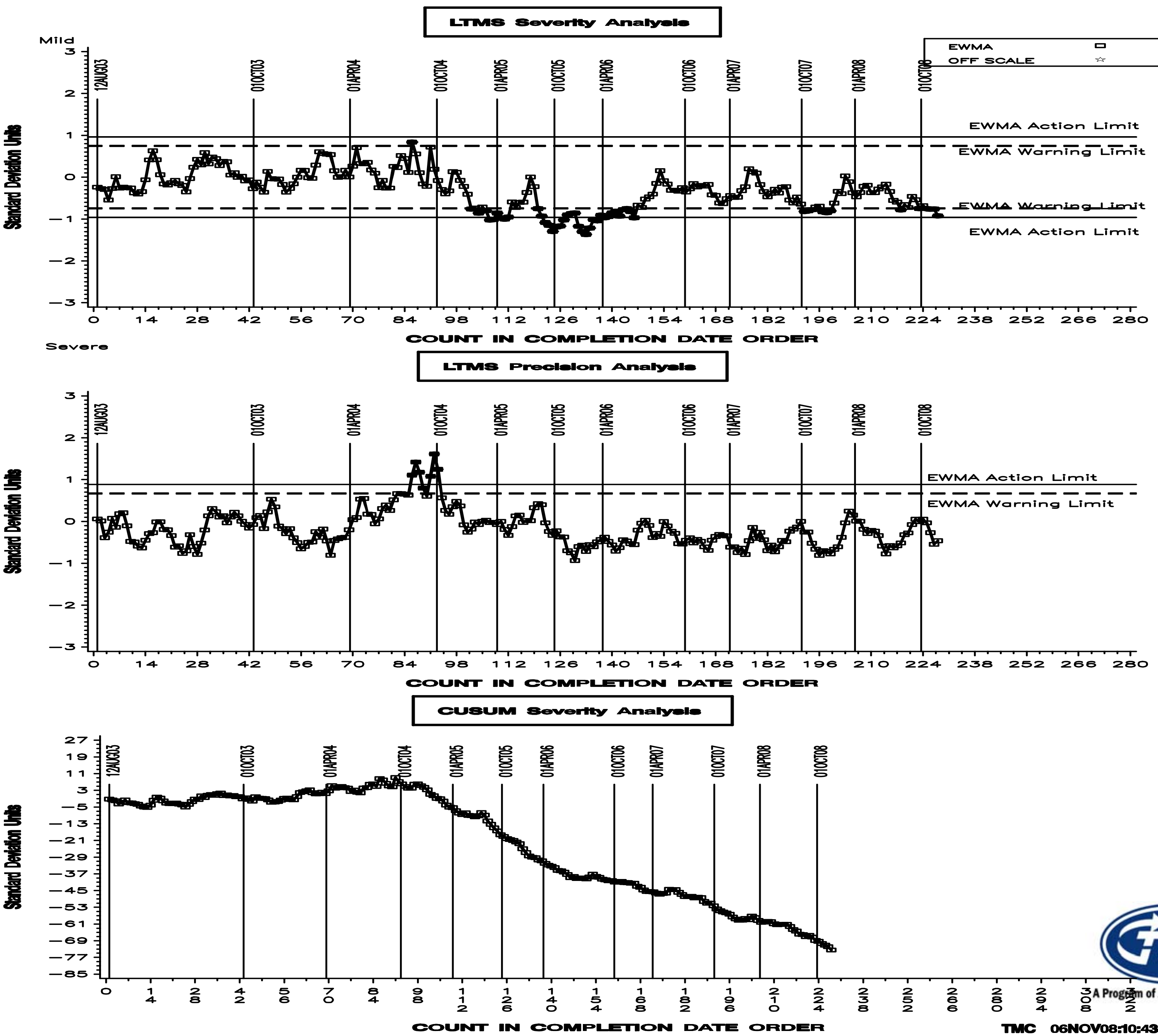
SEQUENCE IIIG INDUSTRY OPERATIONALLY VALID DATA

AVERAGE WEIGHTED PISTON DEPOSITS



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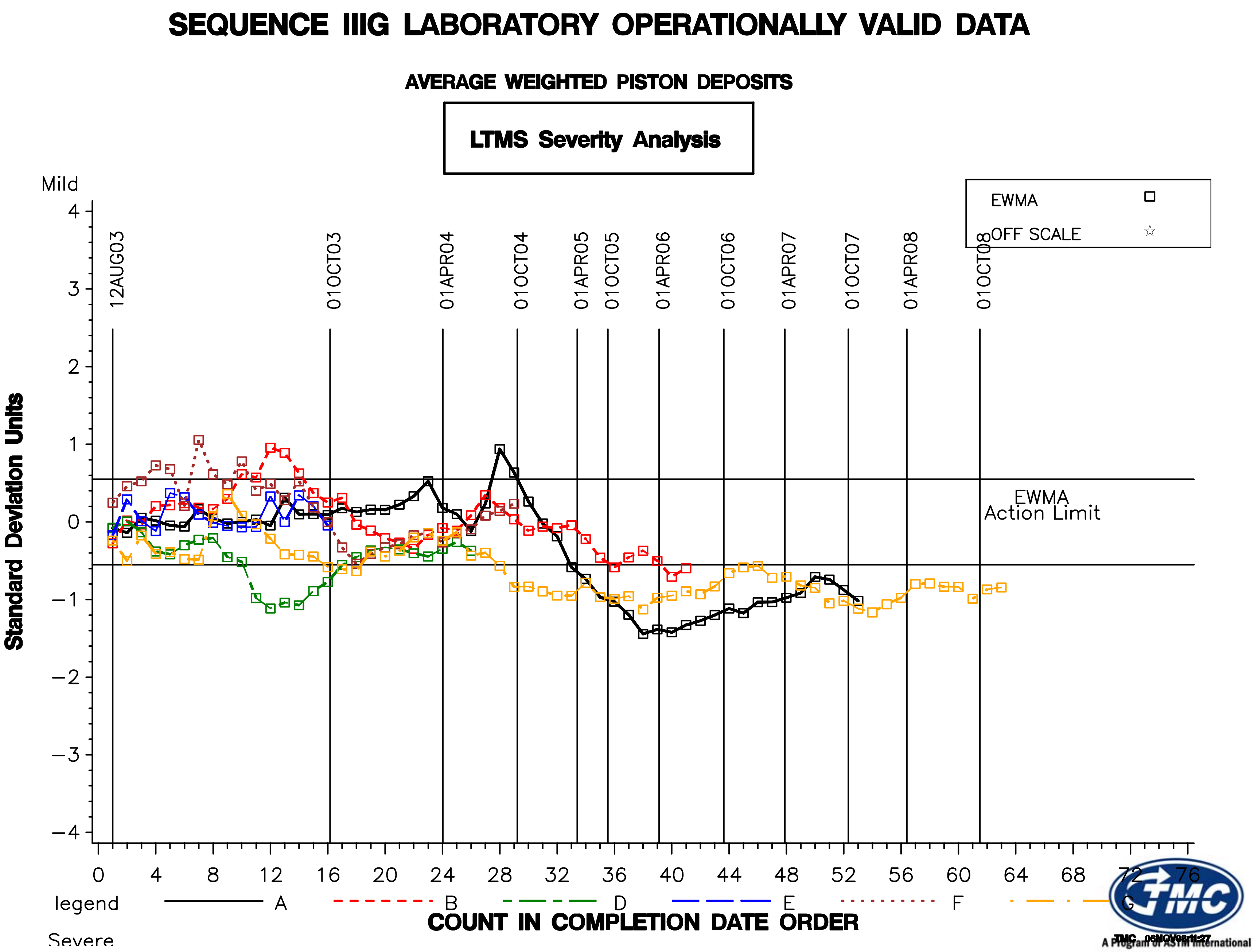
SEQUENCE IIIG LABORATORY OPERATIONALLY VALID DATA
AVERAGE WEIGHTED PISTON DEPOSITS
LTMS Severity Analysis
Mild
Severe
Standard Deviation Units
EWMA
OFF SCALE
12AUG03
01OCT03
01APR04
01OCT04
01APR05
01OCT05
01APR06
01OCT06
01APR07
01OCT07
01APR08
01OCT08
EWMA Action Limit
COUNT IN COMPLETION DATE ORDER
legend
A
B
D
E
F
G
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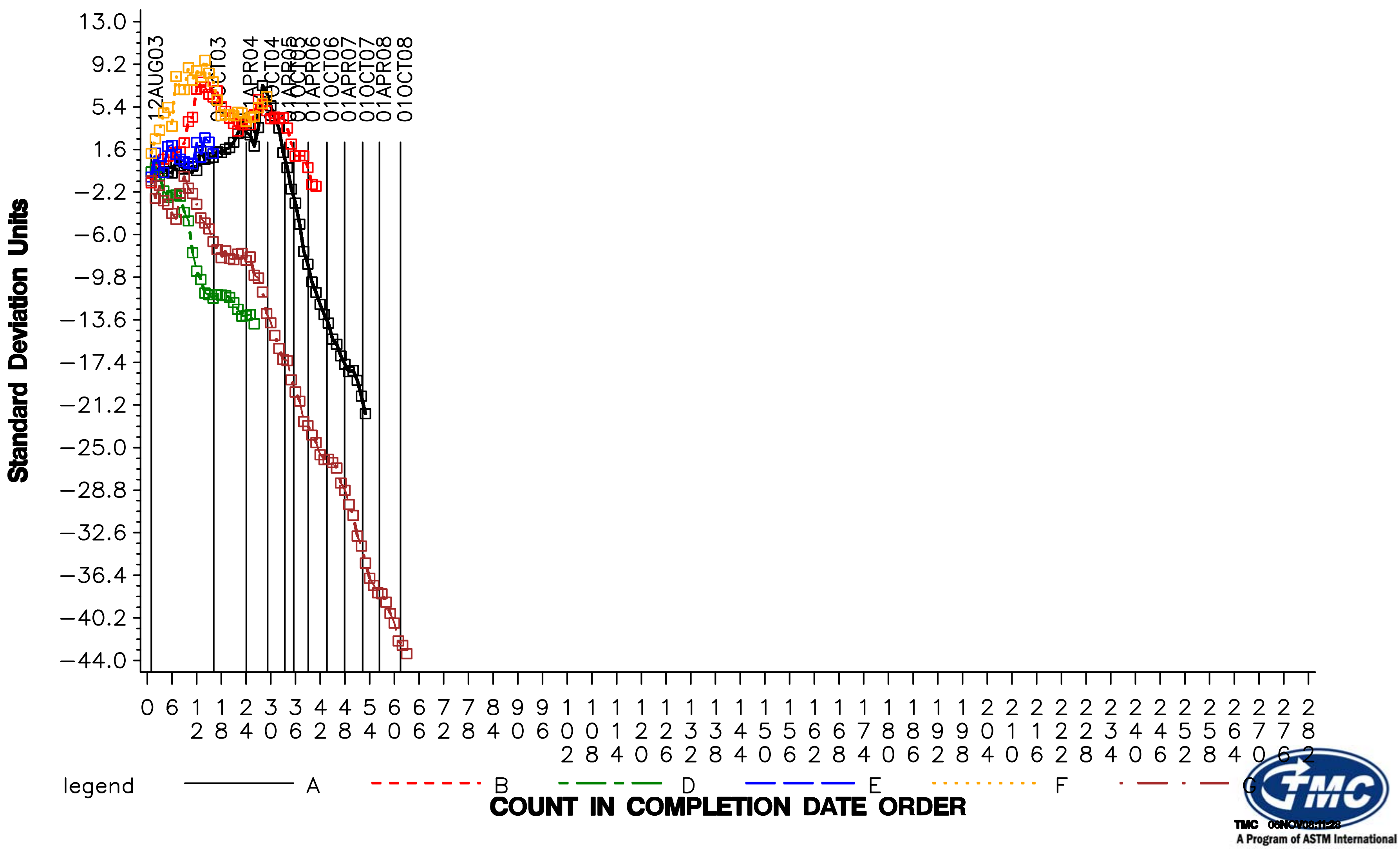
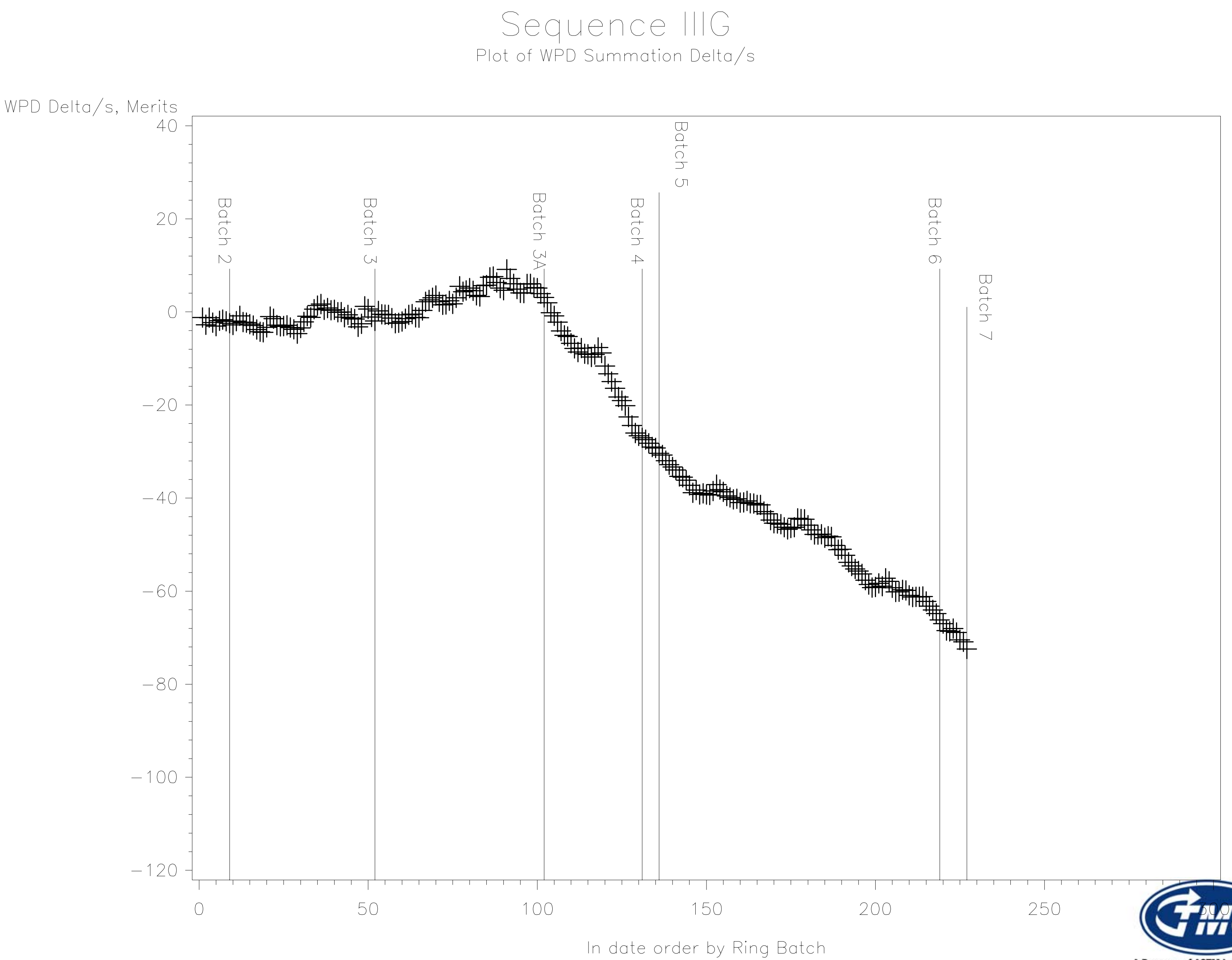
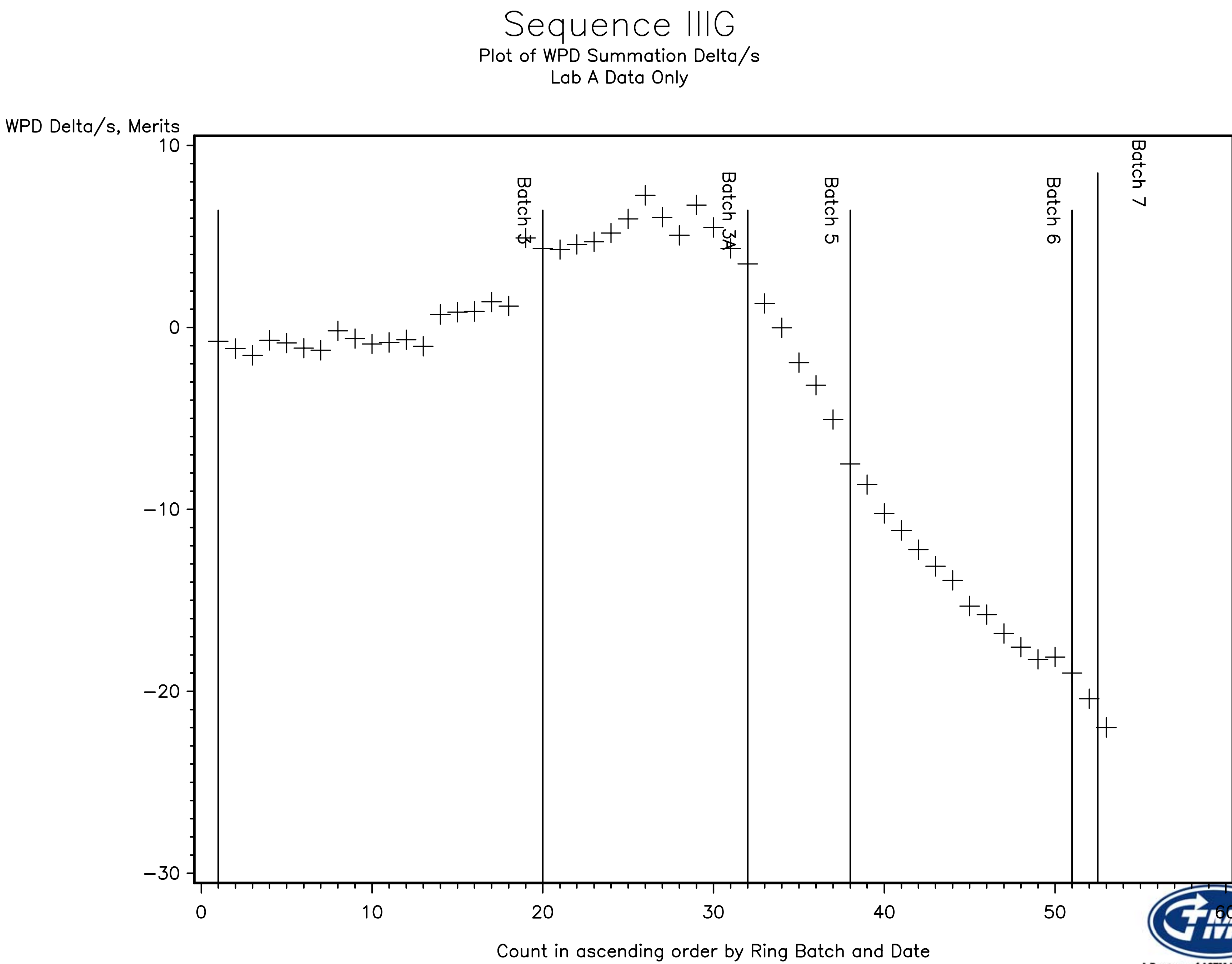
SEQUENCE IIIG LABORATORY OPERATIONALLY VALID DATA

AVERAGE WEIGHTED PISTON DEPOSITS

CUSUM Severity Analysis




Sequence IIIG
Plot of WPD Summation Delta/s
WPD Delta/s, Merits
40
20
0
−20
−40
−60
−80
−100
−120
Batch 2
Batch 3
Batch 3A
Batch 4
Batch 5
Batch 6
Batch 7
0
50
100
150
200
250
300
In date order by Ring Batch



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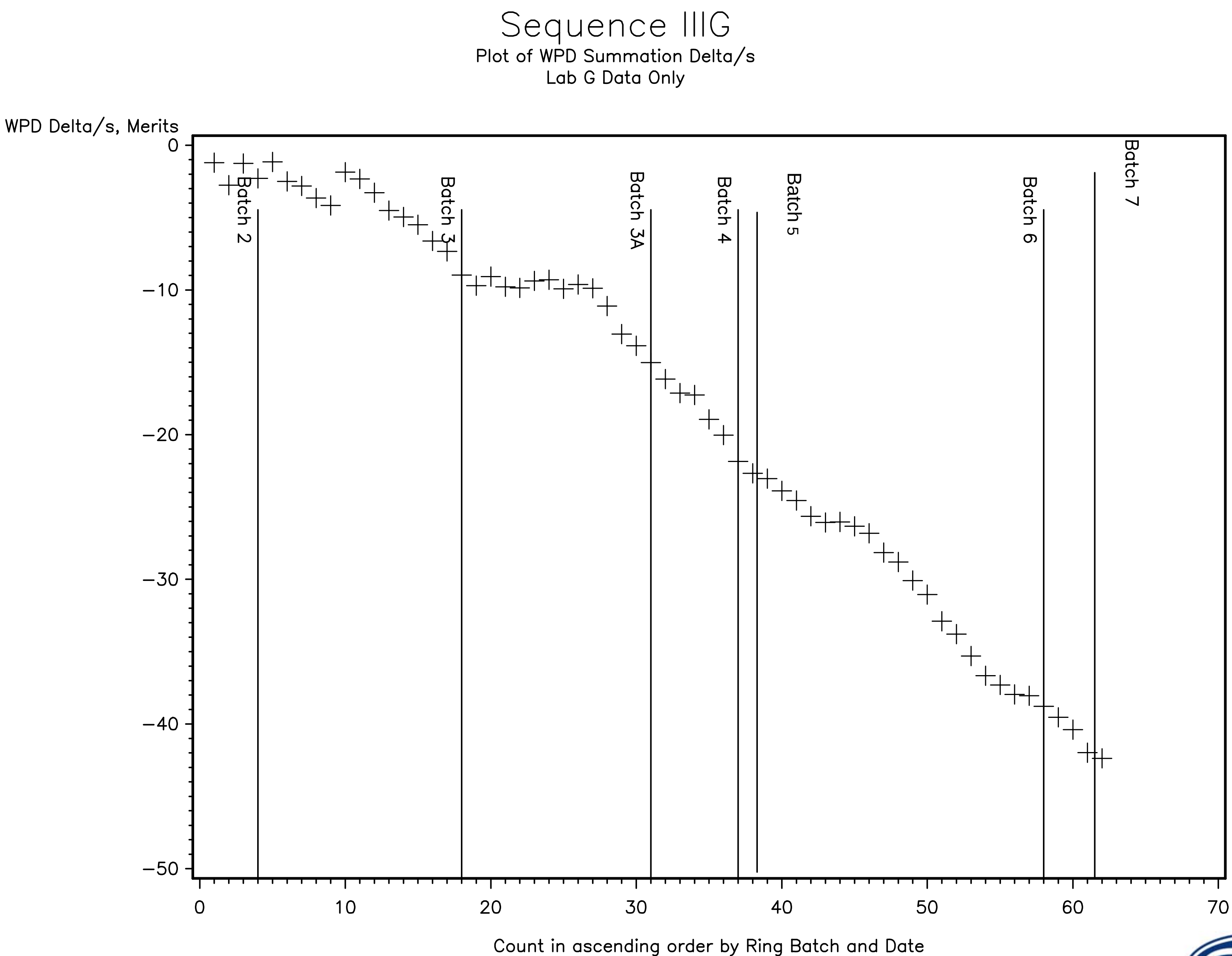

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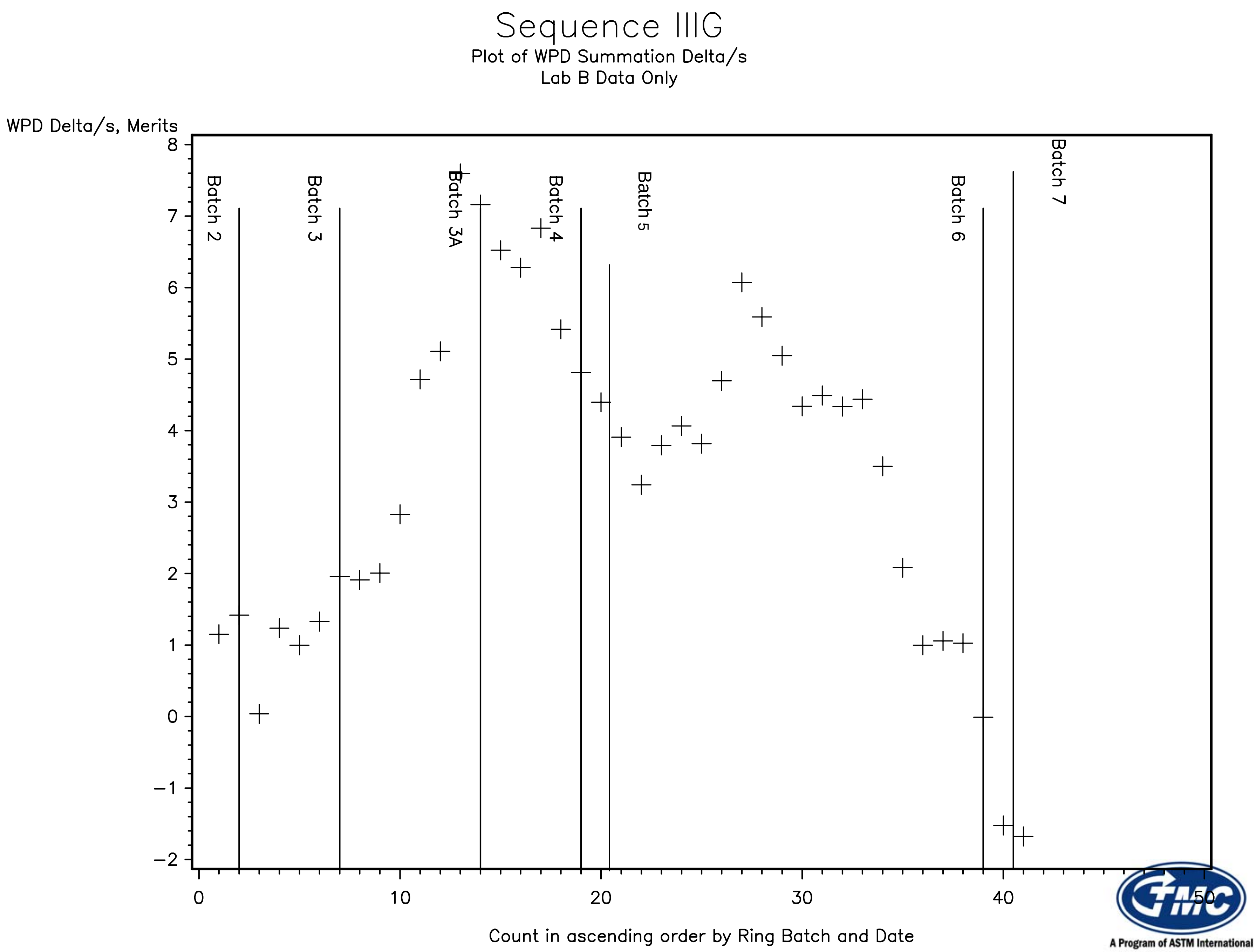
Sequence IIIG
Plot of WPD Summation Delta/s
Lab B Data Only
WPD Delta/s, Merits
Batch 2
Batch 3
Batch 3A
Batch 4
Batch 5
Batch 6
Batch 7
8
7
6
5
4
3
2
1
0
−1
−2
0
10
20
30
40
50
Count in ascending order by Ring Batch and Date
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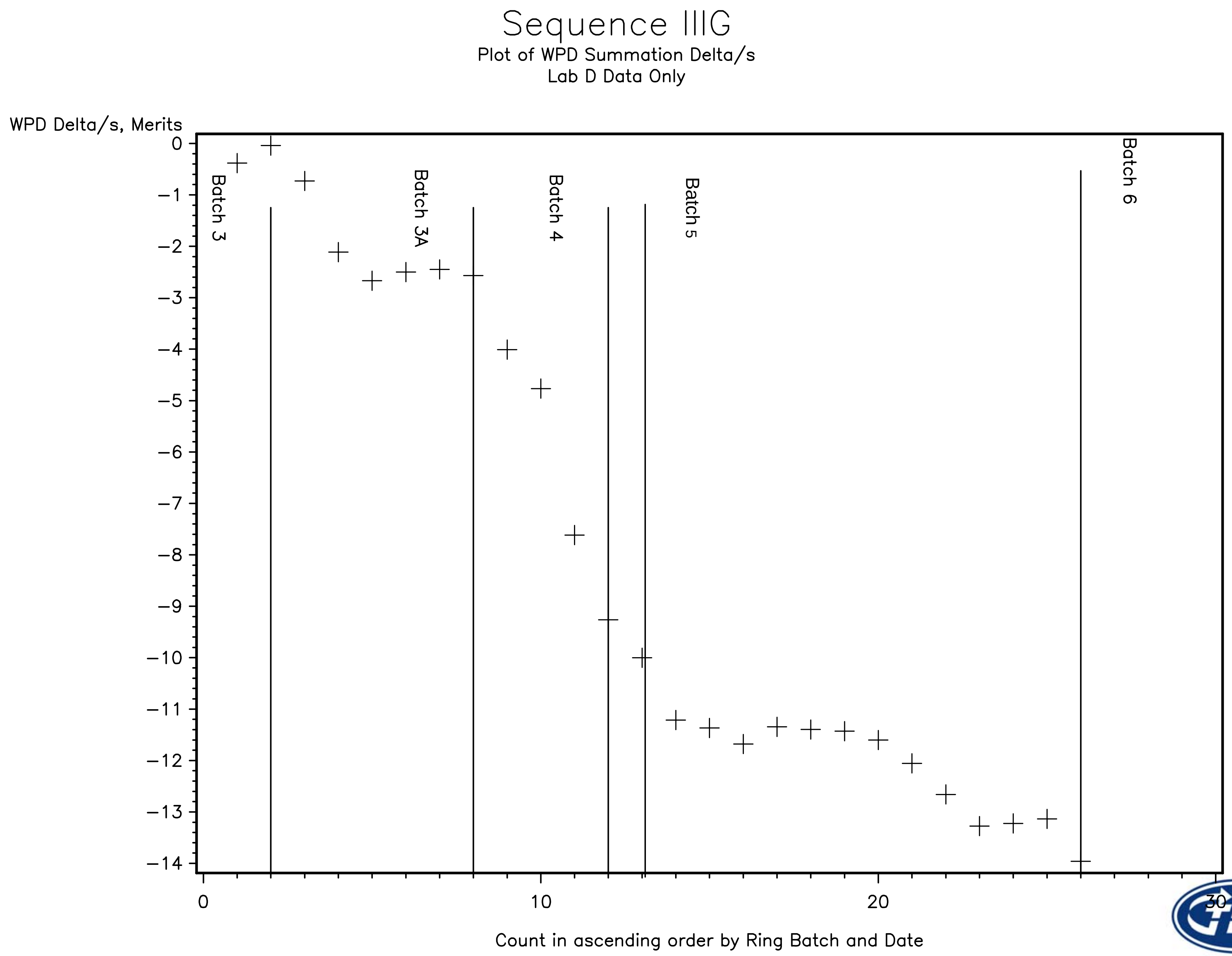
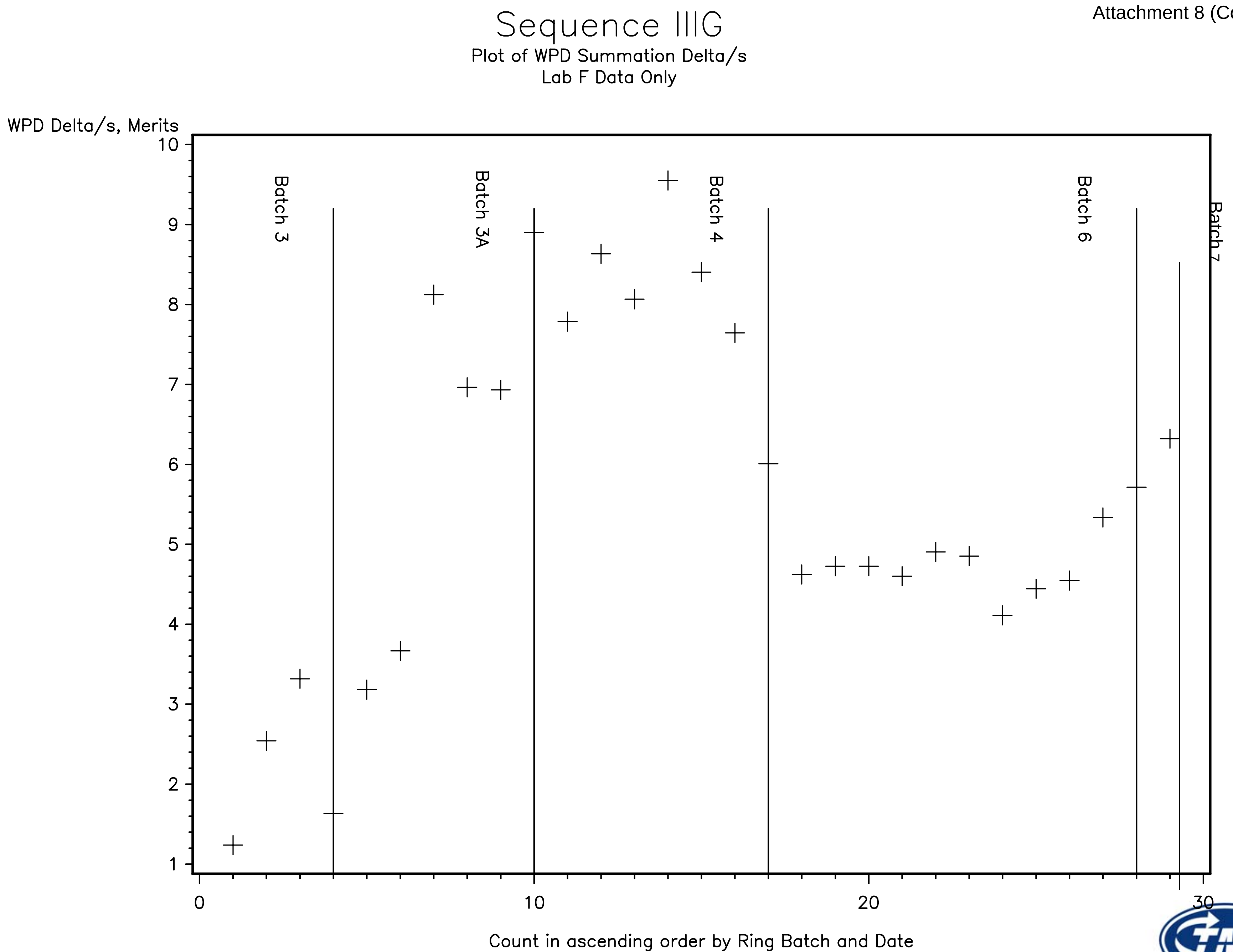
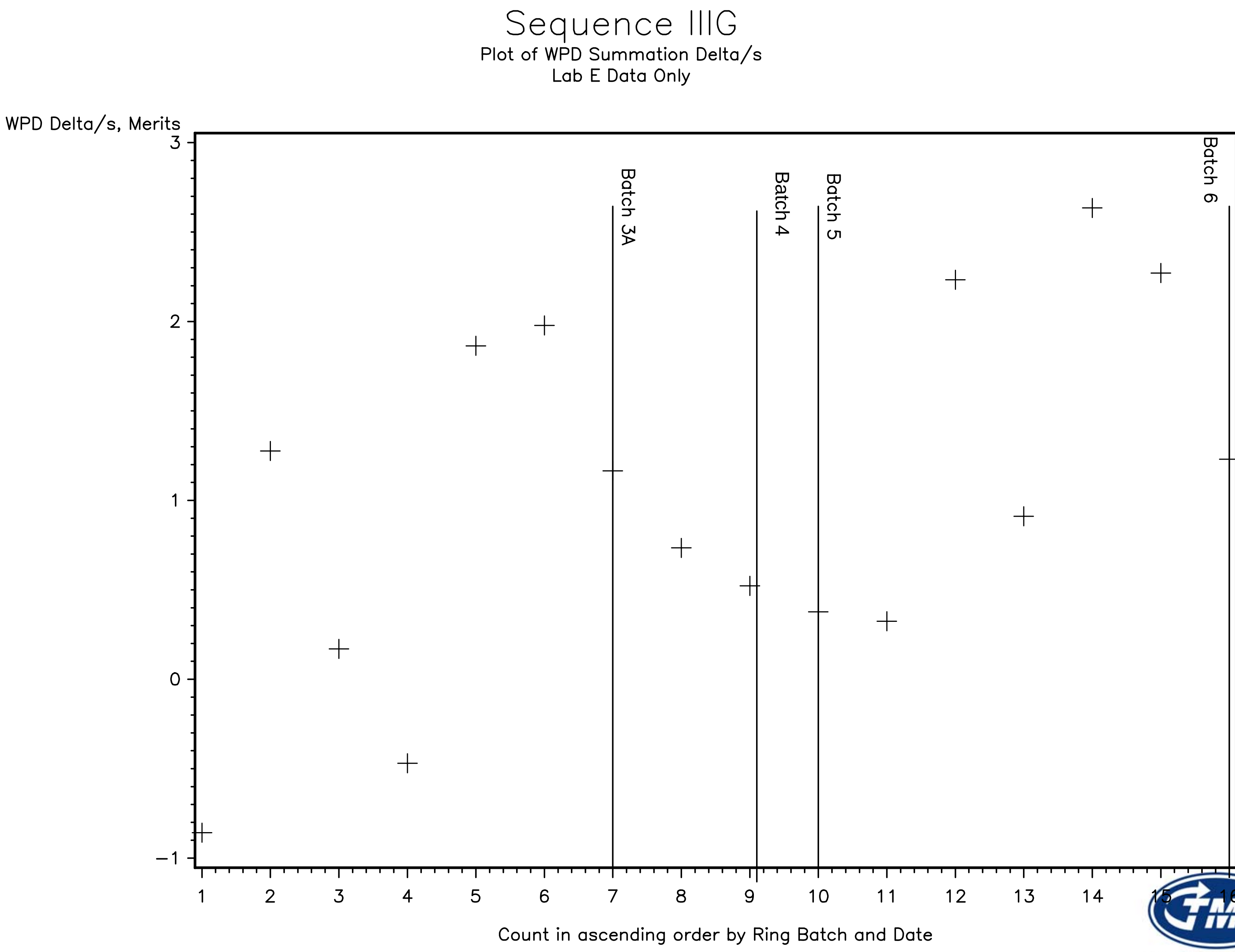

Sequence IIIG
Plot of WPD Summation Delta/s
Lab D Data Only
WPD Delta/s, Merits
0
−1
−2
−3
−4
−5
−6
−7
−8
−9
−10
−11
−12
−13
−14
Batch 3
Batch 3A
Batch 4
Batch 5
Batch 6
0
10
20
30
Count in ascending order by Ring Batch and Date


Sequence IIIG
Plot of WPD Summation Delta/s
Lab F Data Only
WPD Delta/s, Merits
10
9
8
7
6
5
4
3
2
1
Batch 3
Batch 3A
Batch 4
Batch 6
Batch 7
0
10
20
30
Count in ascending order by Ring Batch and Date



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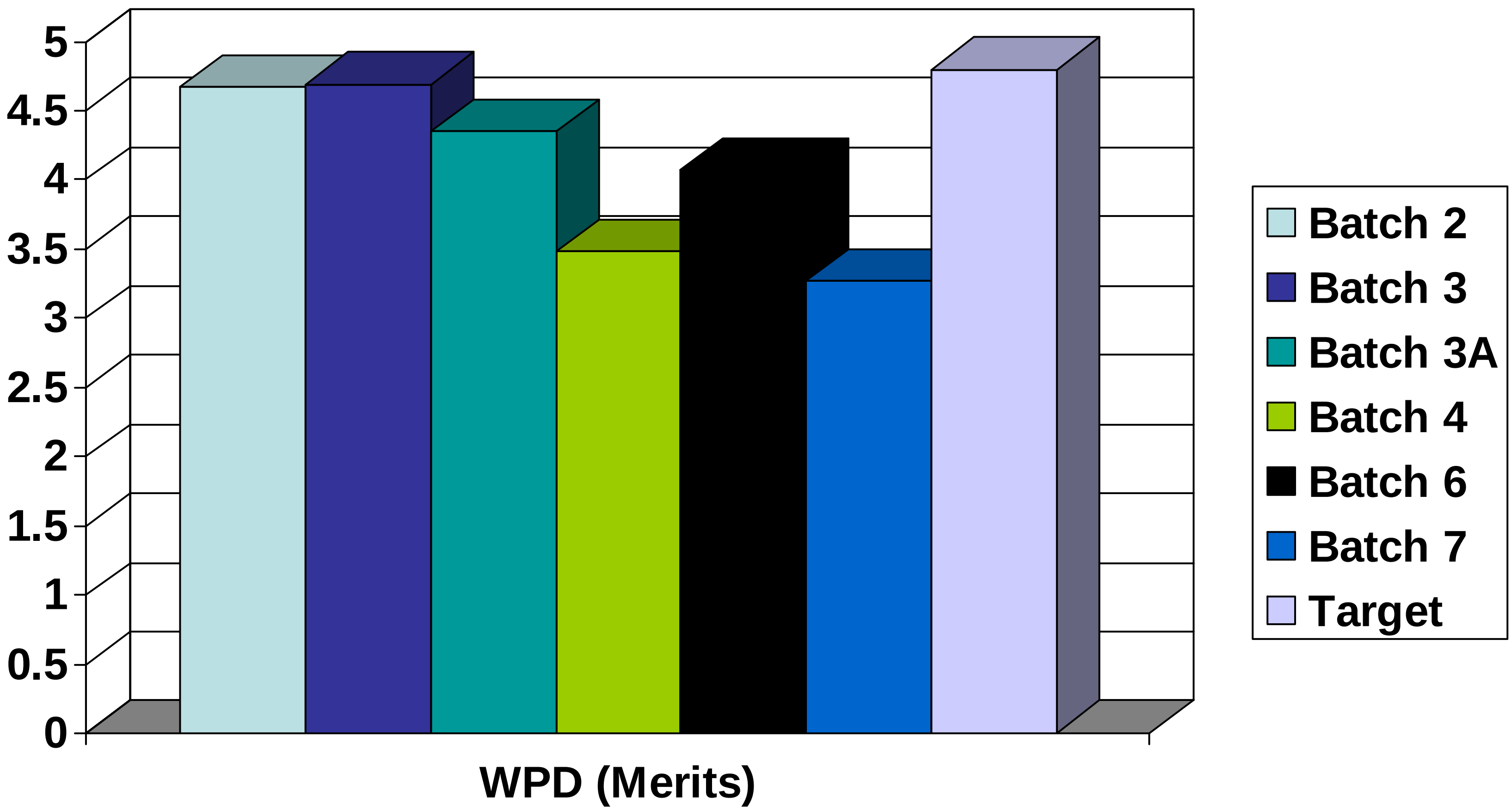
Oil 434 Average Performance by Ring Batch



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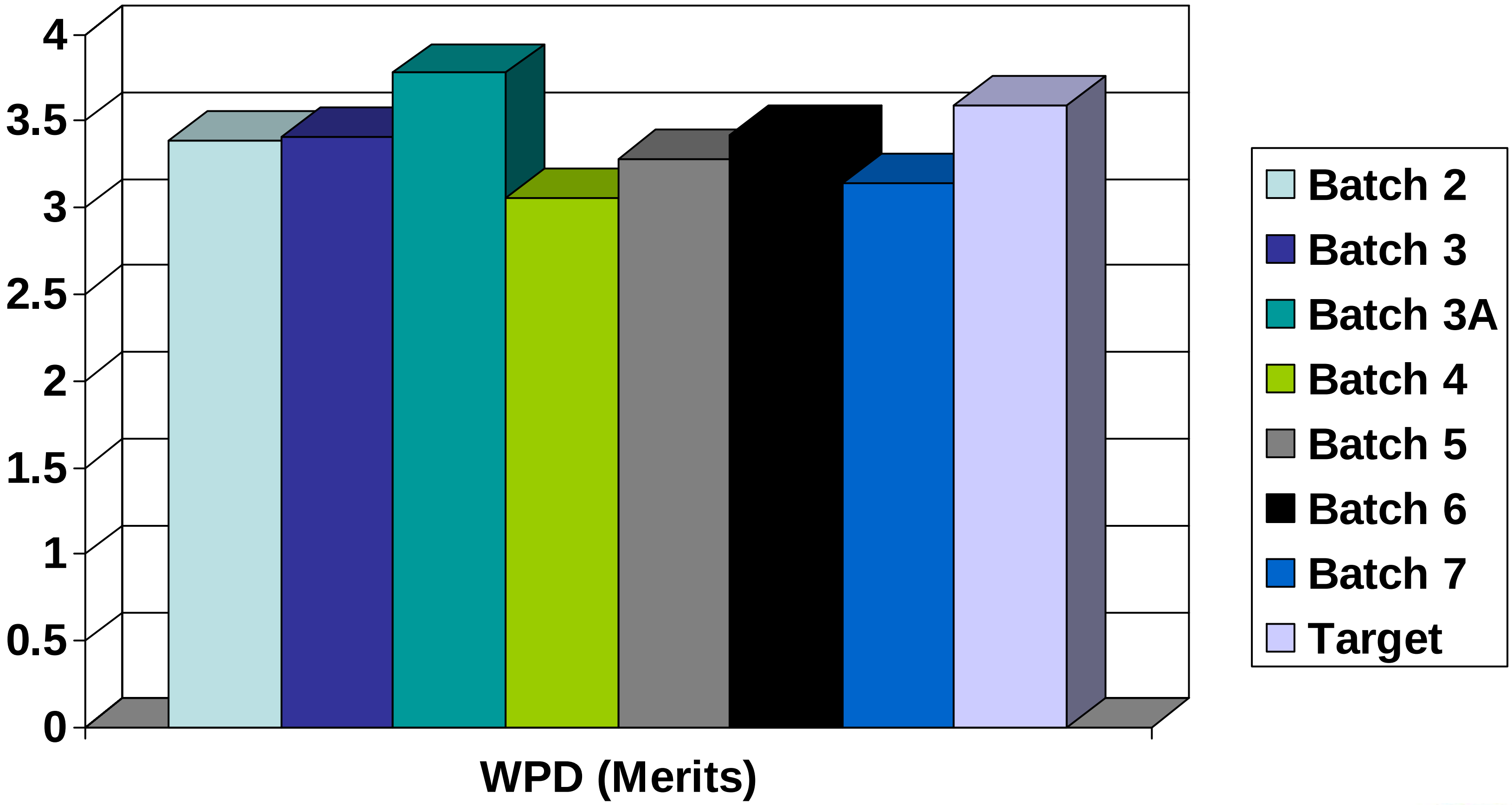
Oil 435 Average Performance by Ring Batch



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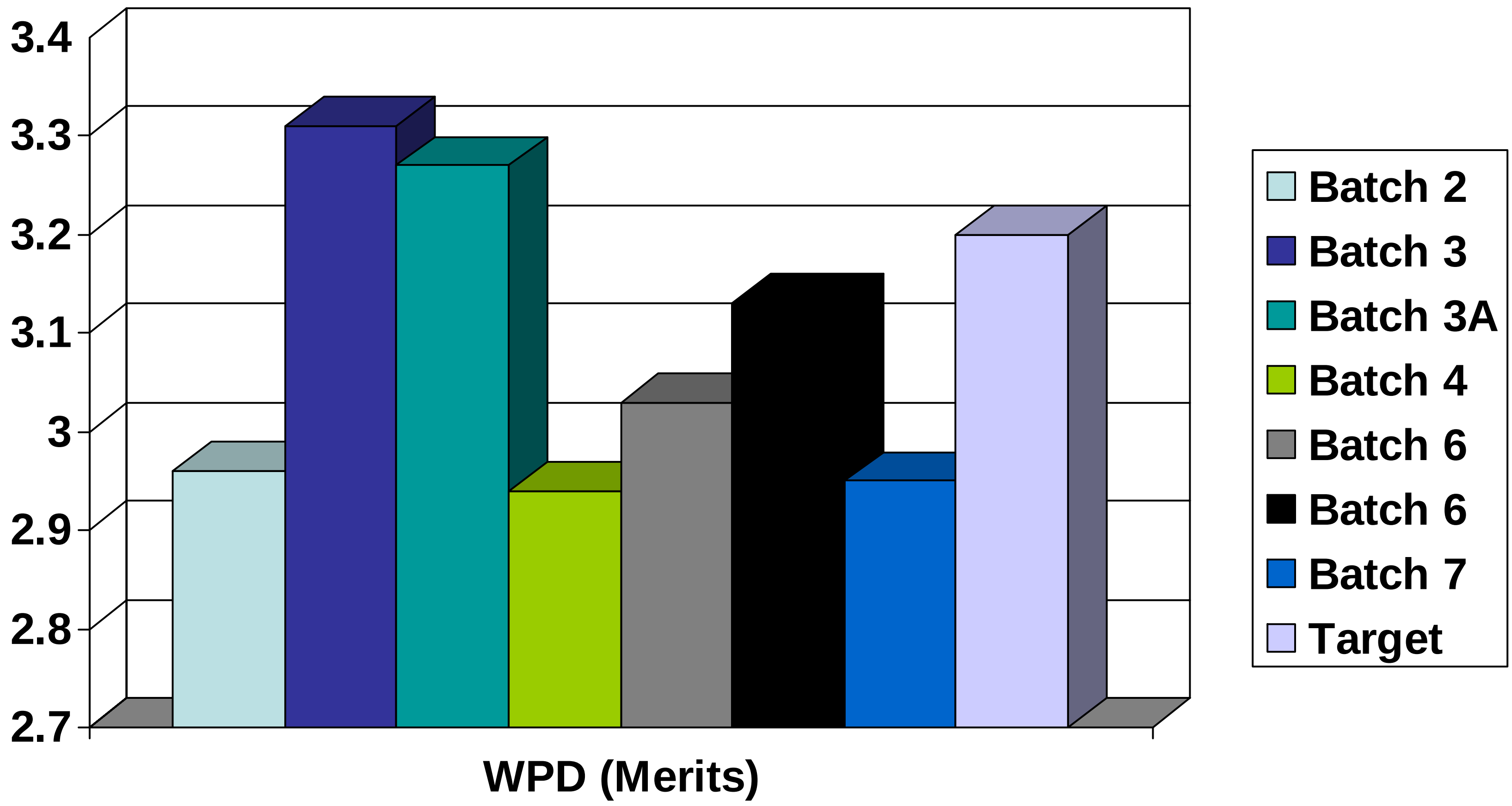
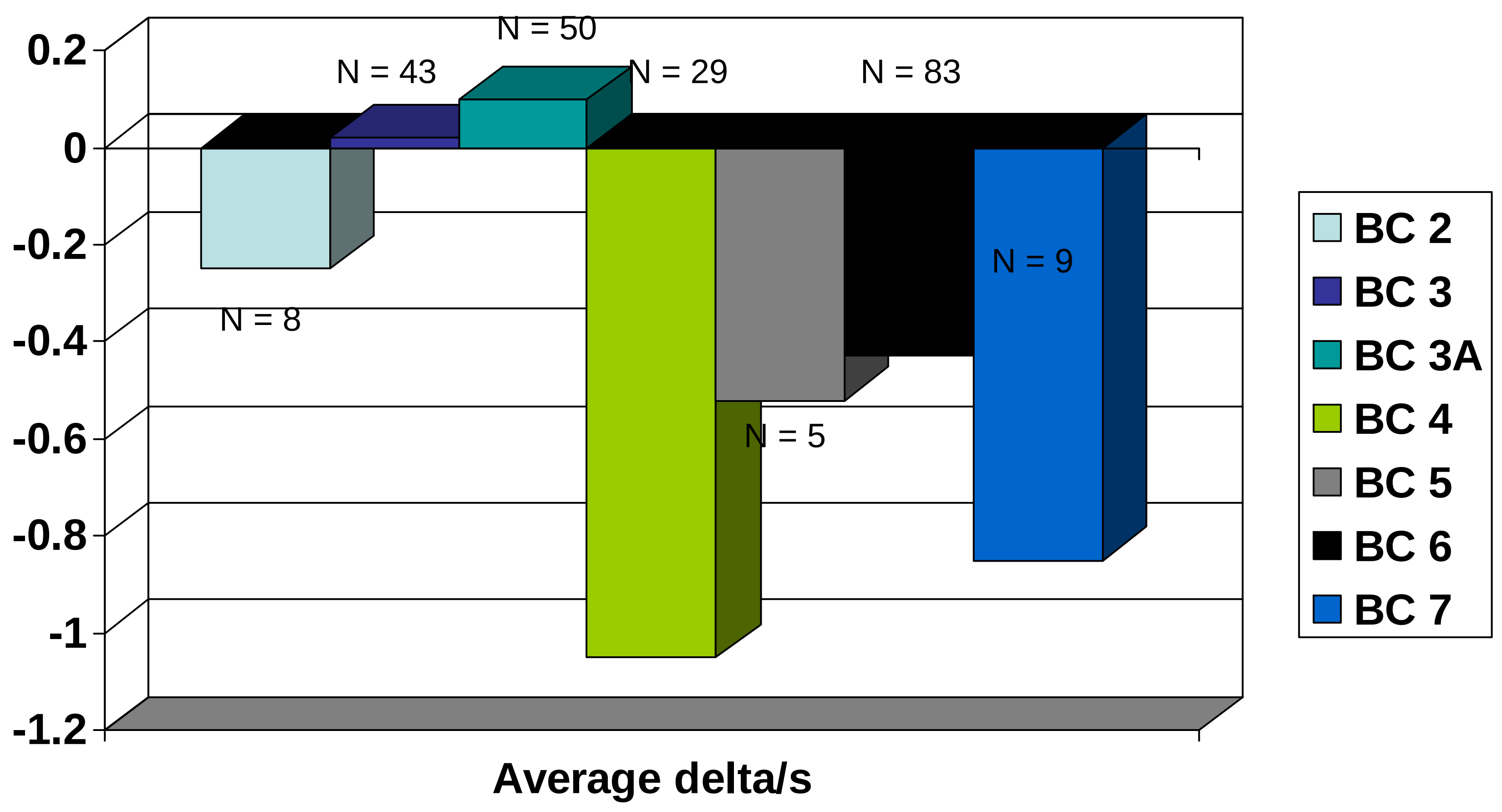
Oil 438 Average Performance by Ring Batch



Average Delta/s by Ring Batch



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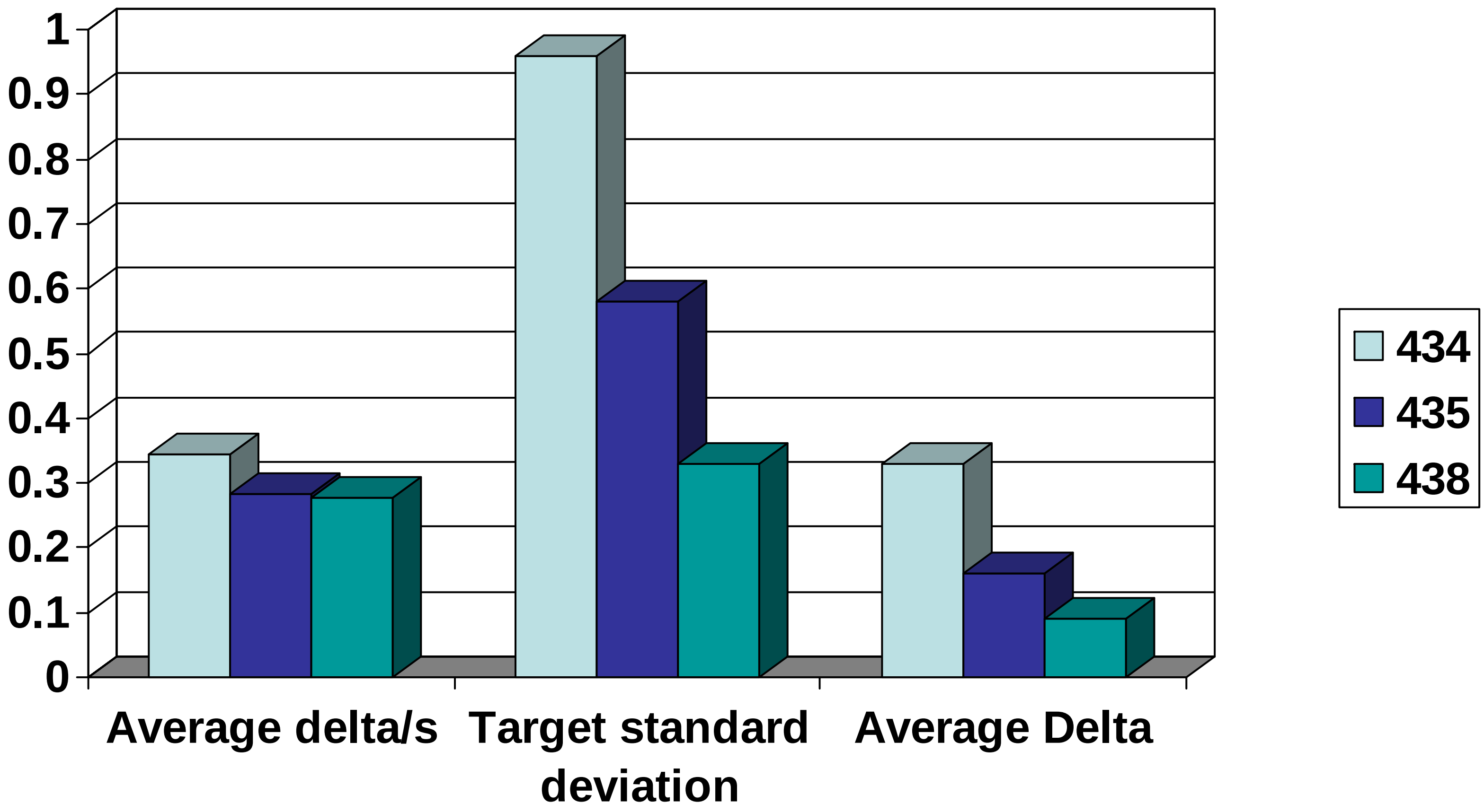
Comparison of Average delta/s with Average Delta and Standard Deviation, By Oil



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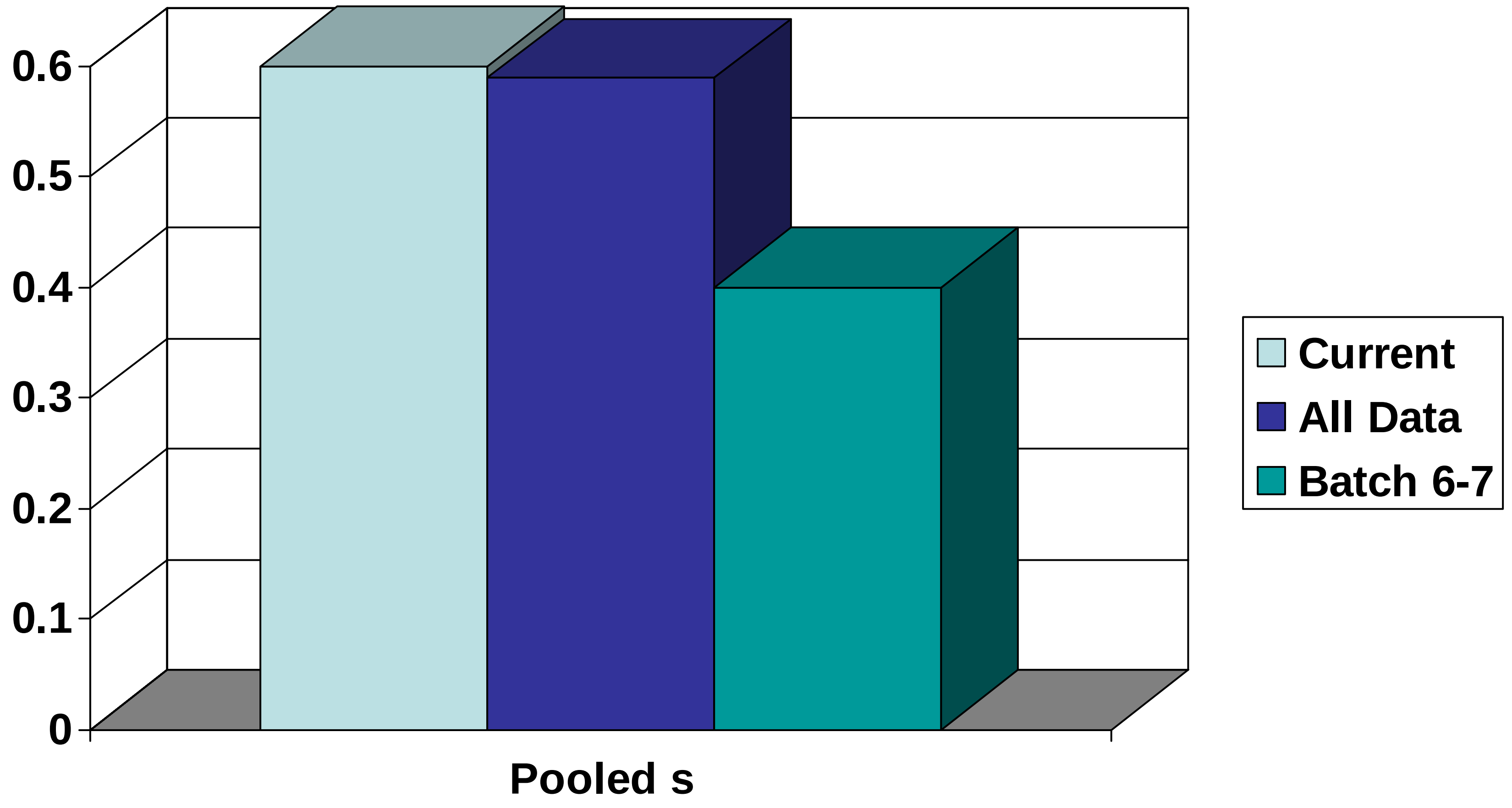
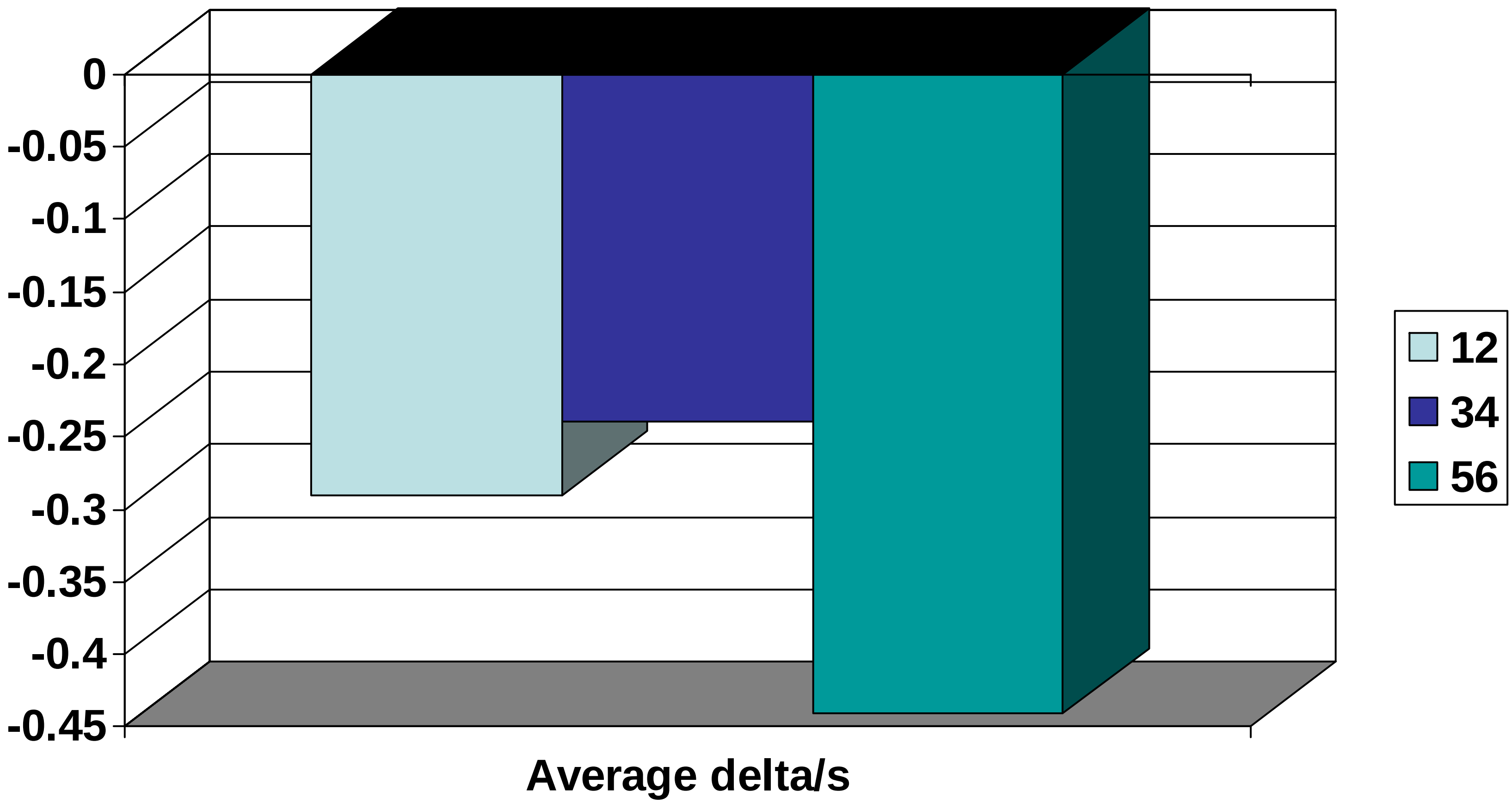
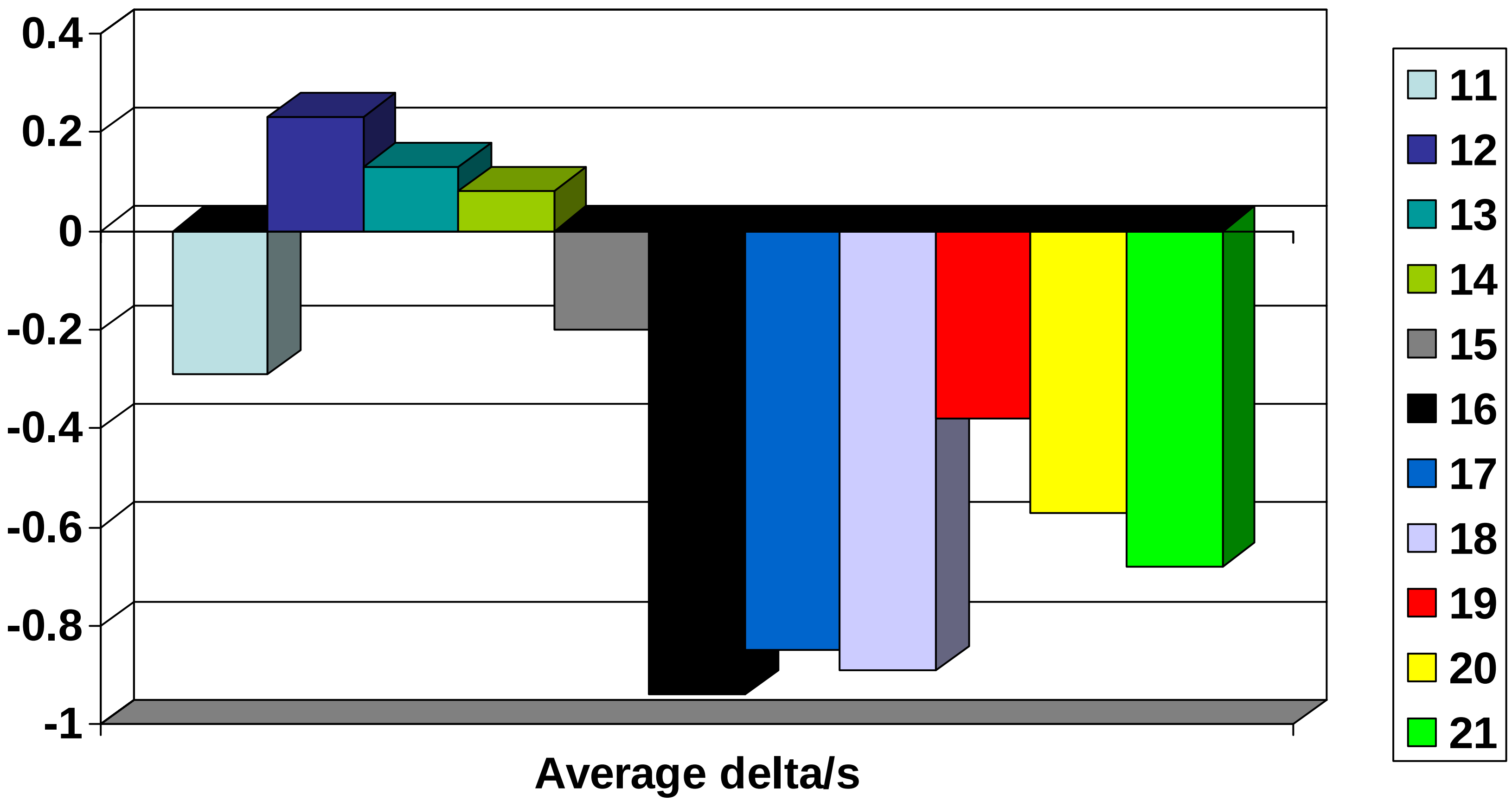
Pooled s for WPD SA Calculations



Average WPD delta/s by Piston Size



Average WPD delta/s by Piston Batch



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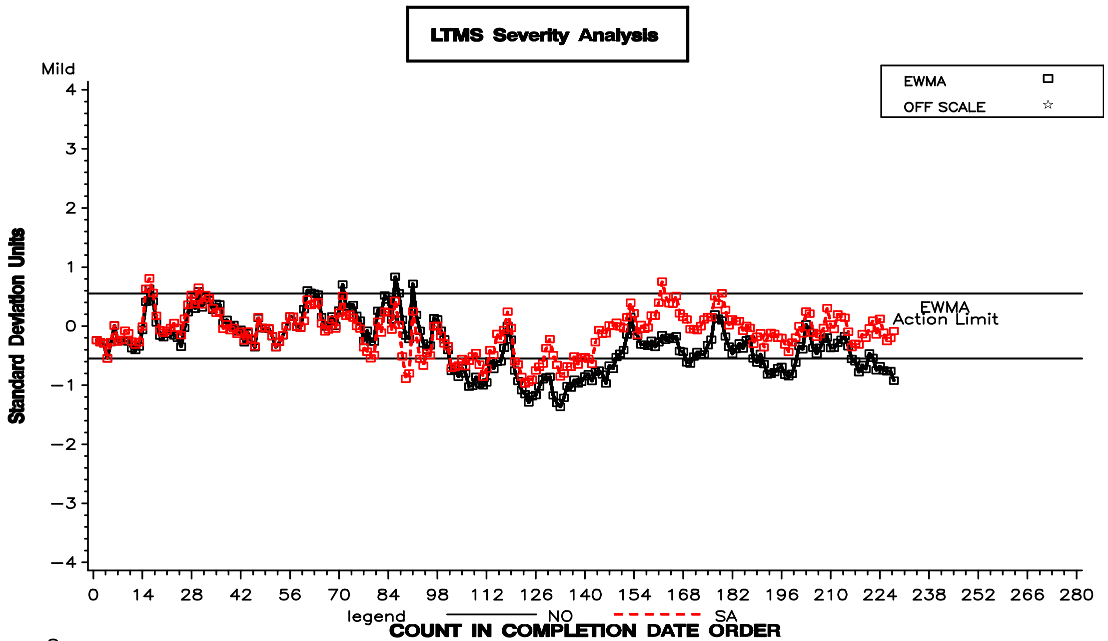
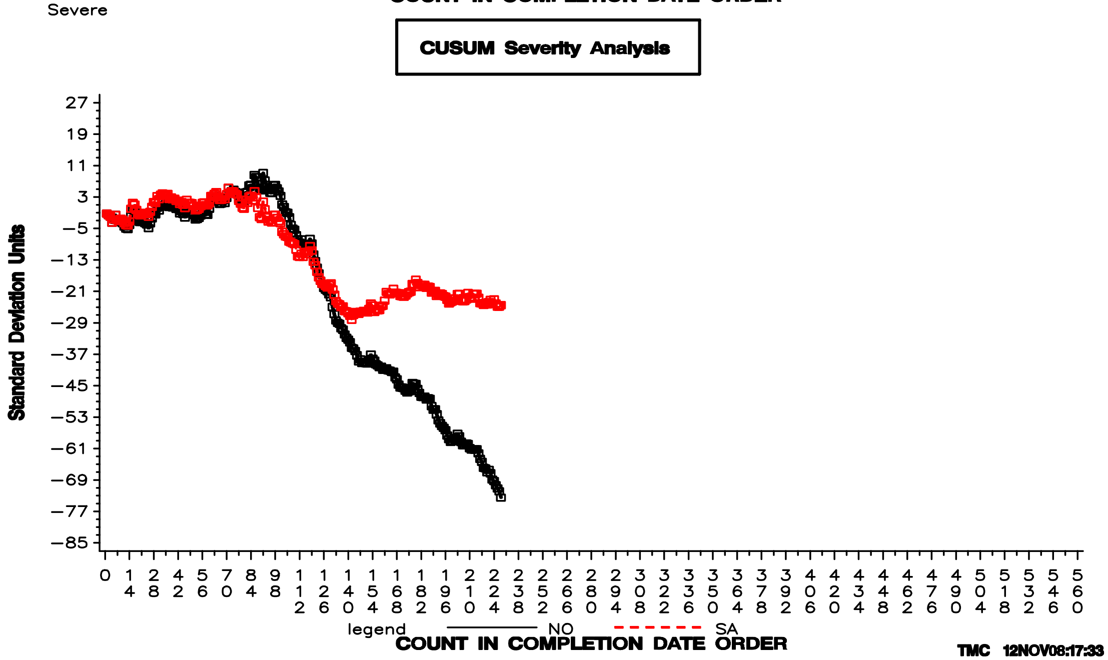
SEQUENCE IIIG LABORATORY OPERATIONALLY VALID DATA

AVERAGE WEIGHTED PISTON DEPOSITS





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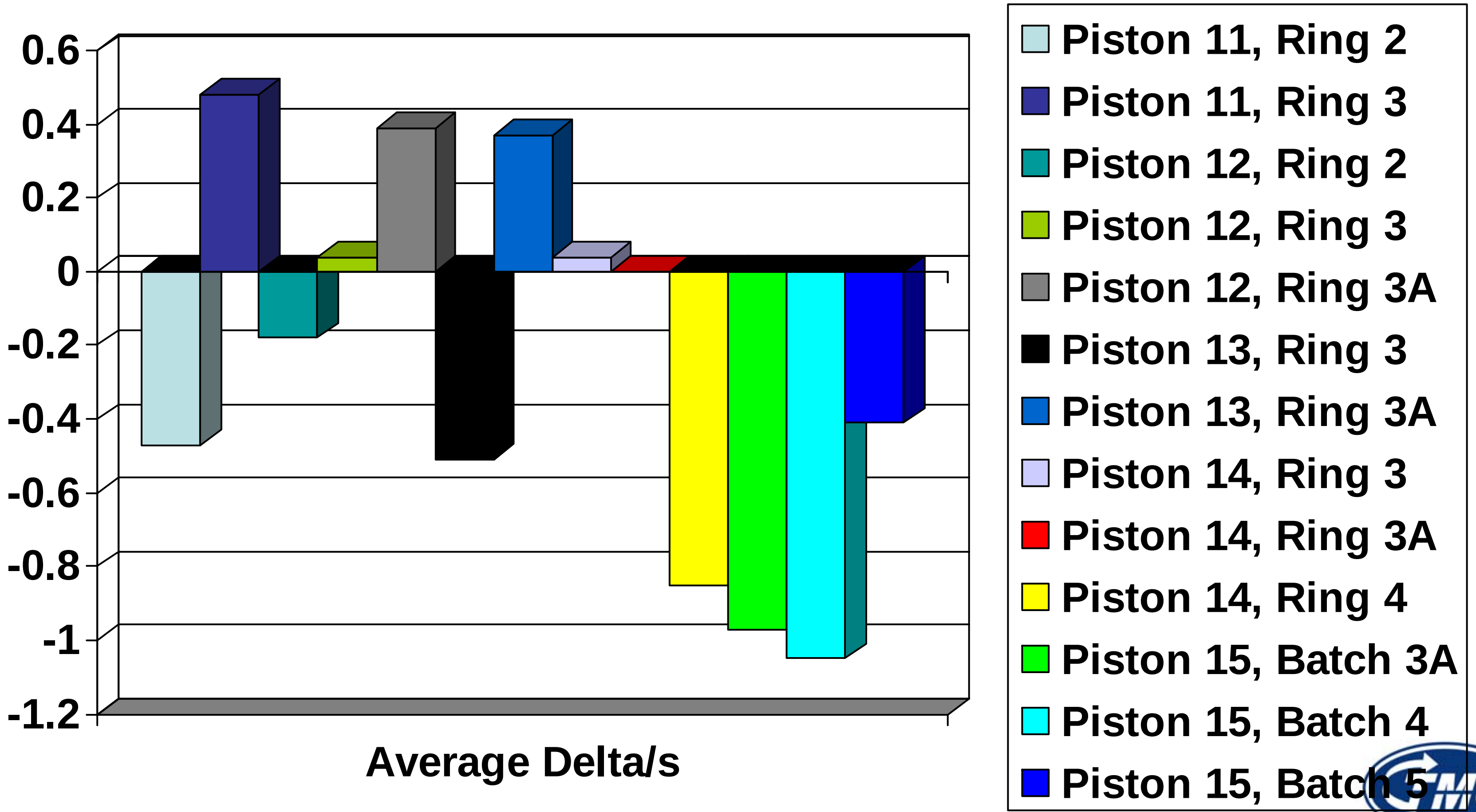
Average WPD Delta/s by Piston and Ring Batch, through Batch 15



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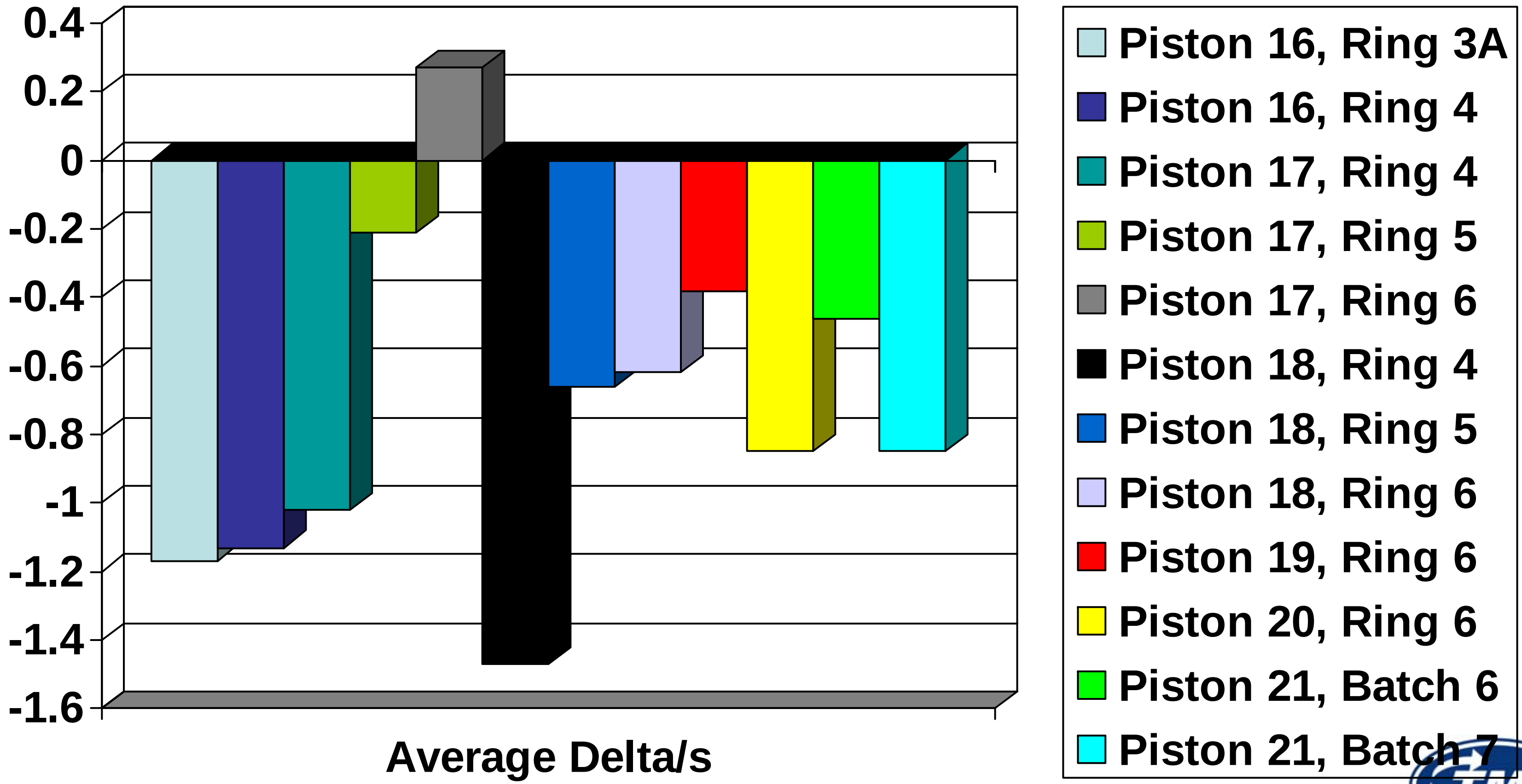
Average WPD Delta/s by Piston and Ring Batch, through Batch 21



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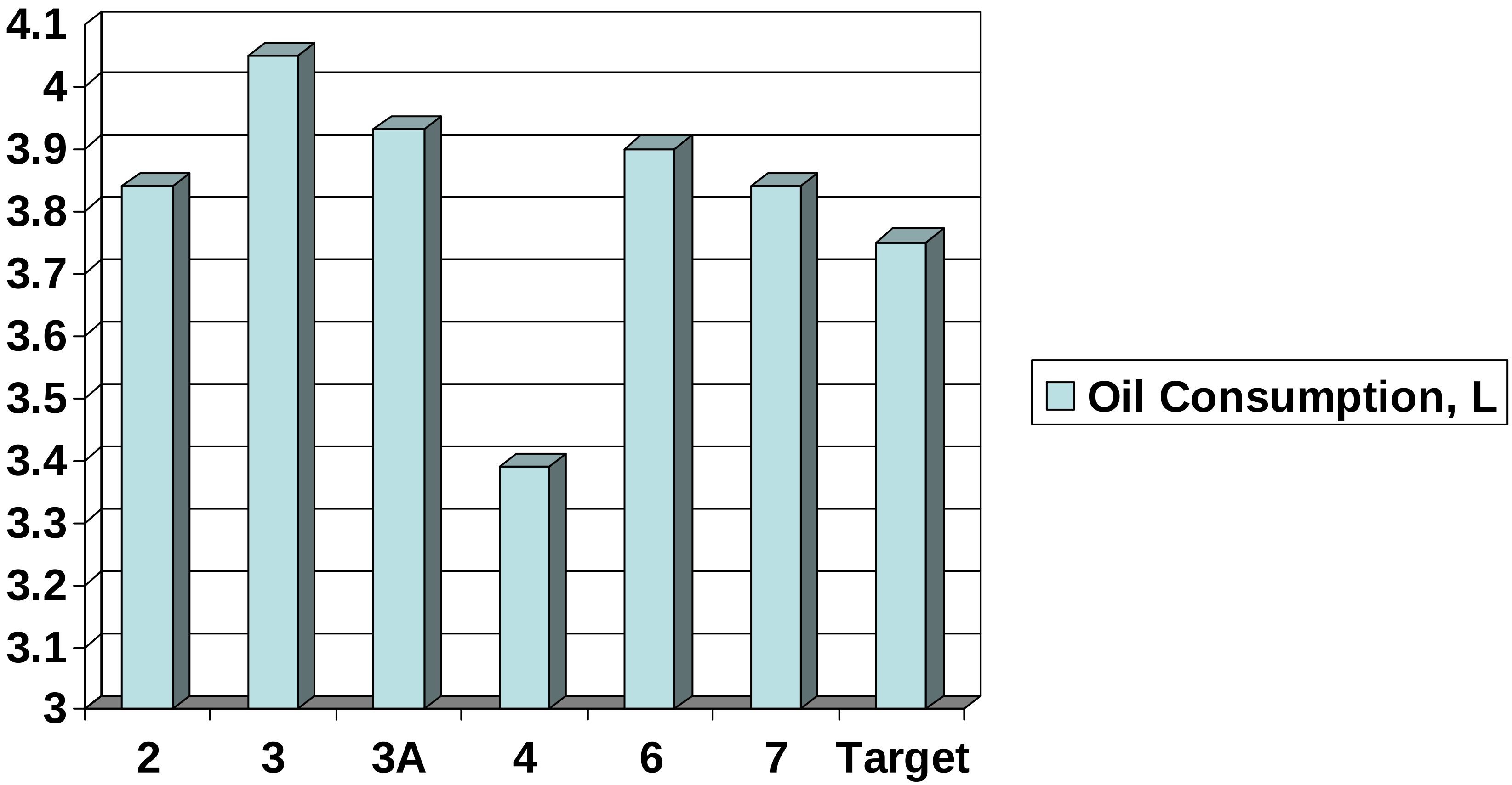
Oil Consumption by Ring Batch, RO 434



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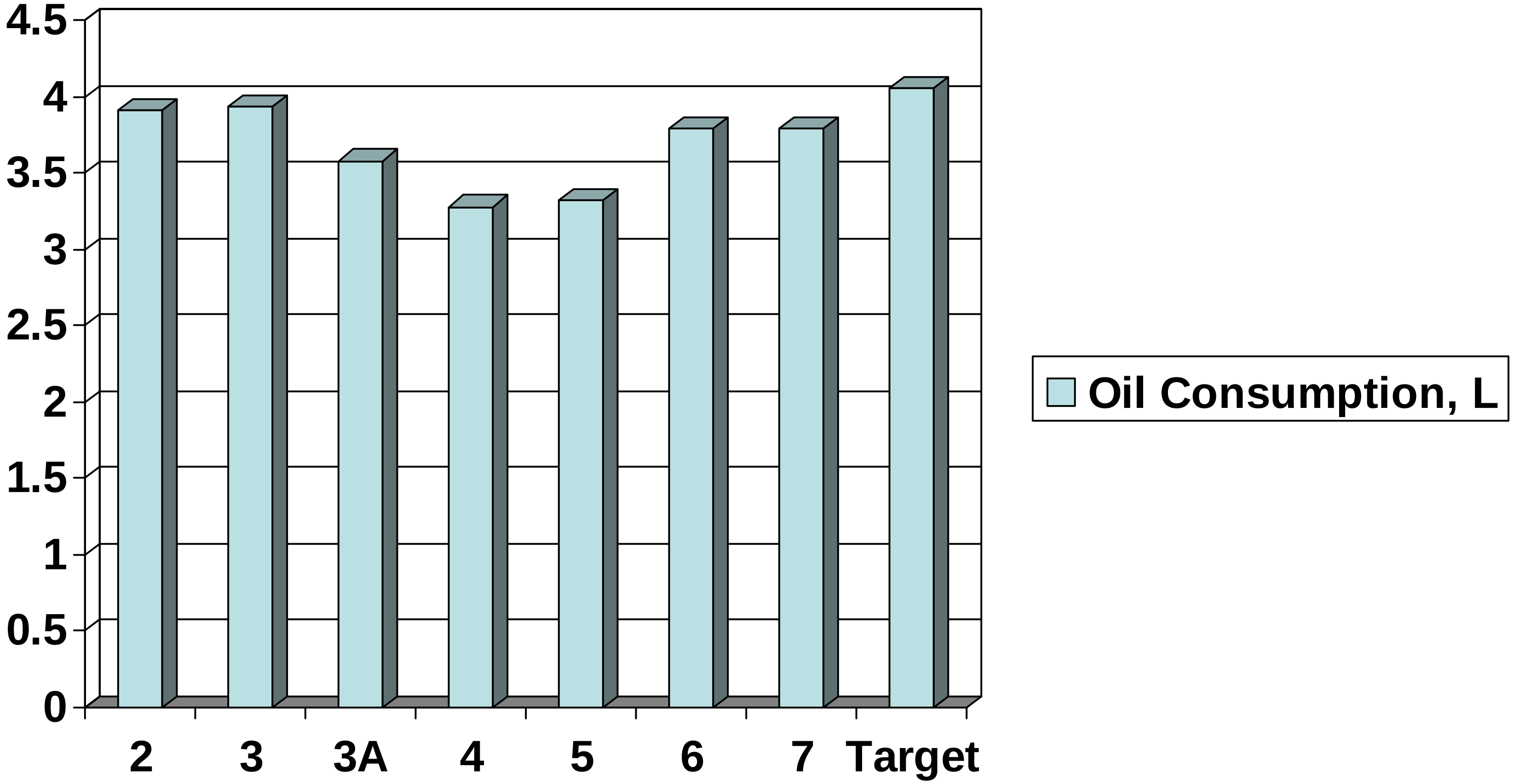
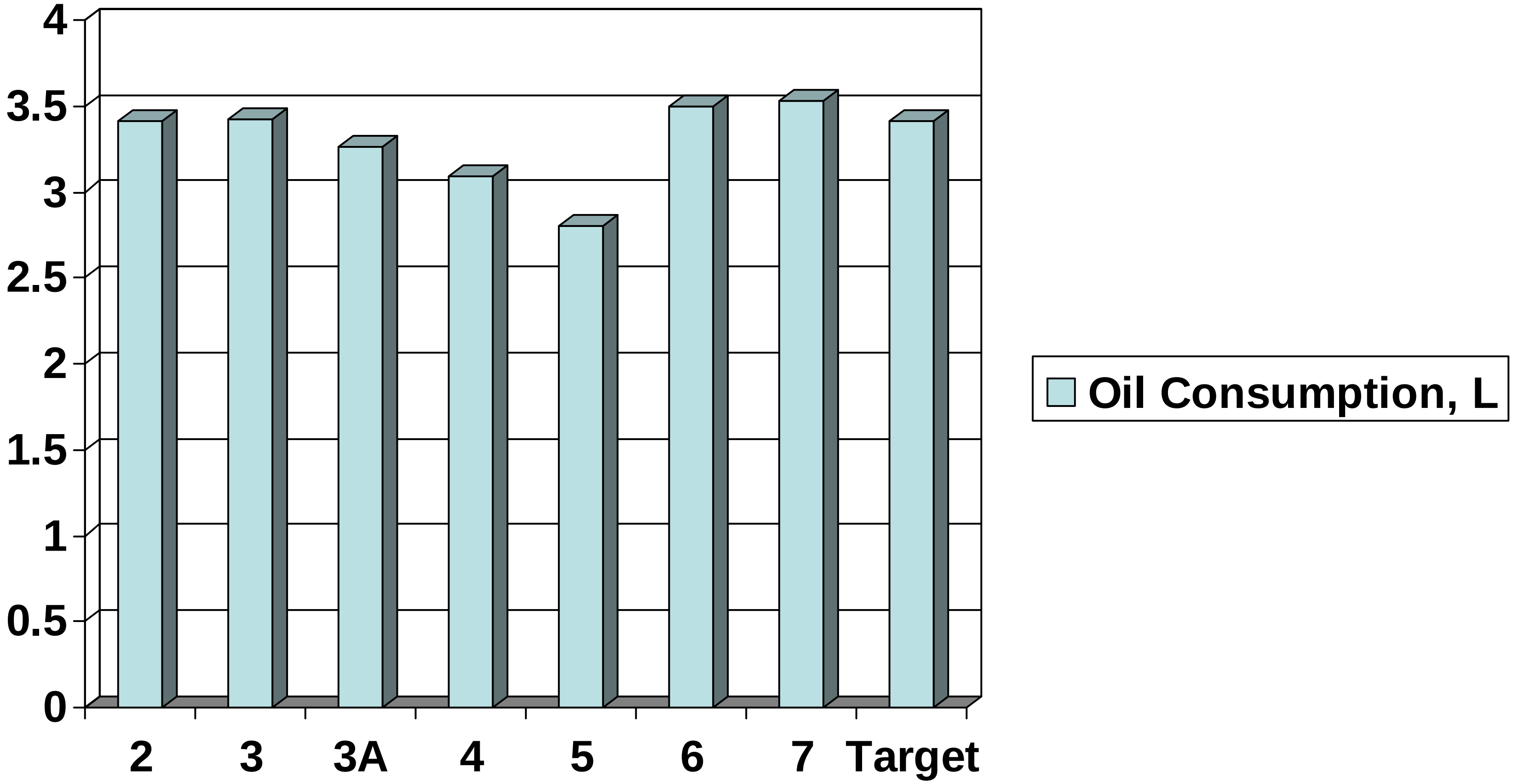


Oil Consumption by Ring Batch, RO 438



IIIG Reference Oil Severity Trends

By: Todd Dvorak

10/31/08

Background

- Sequence IIIG has been used by the testing community since 2003 with the introduction of GF-4.
- As with all tests, it has evolved over time with hardware and procedure changes.
- Continues to be the industry leader in terms of part serialization and hardware accountability.
- Major test hardware has been secured for the life of the test. Labs have been running consistent hardware and build procedures since late 2006.
- It is appropriate at this time to address any severity or precision concerns prior to GF-5 testing.

Background

- A review of TMC WPD and PVIS LTMS Severity Charts suggest that there are 4 mild/severe trend periods.
- Each period includes factors that have been identified as statistically significant (ring batch, honing, etc) and other related hardware and build practices (i.e. UEB) that may have contributed to a change in the IIIG performance.
- The historical periods[1] are represented by their ring batch and connecting rod classification:
  - BC2 - BC3A Ring Period
  - BC4 - BC5 Ring Period
  - BC6 - BC7 Ring with PM Connecting Rod Period
  - BC6 - BC7 Ring with PMNS Connecting Rod Period[2]
- With well established IIIG build practices and the securing of the major test hardware for the life of the test, the emphasis of this analysis will focus on current IIIG performance (BC6-BC7 Ring PMNS period) as compared to the established reference oil targets.

Notes: 1. Historical periods exclude 434-1 reference oil test data.
2. Intake valve seal batch change nearly coincidental with introduction of PMNS connecting rods.

LTMS Overview

LTMS Overview

- For the IIIG, LTMS generates Severity, CUSUM, and Precision charts to monitor the test performance for each of the response parameters.
- All of the charts are based on the metric Y_i, the standard deviation units. The calculation formula for the metric is summarized below:

$$Y_i = \frac{\text{(Actual Test Result)} - \text{(Reference Oil Test Target)}}{\text{(Reference Oil Target Standard Deviation)}}$$

- The difference between successive Y_i metrics is used to estimate the precision.

$$R_i = \frac{(|Y_i - Y_{i-1}|)^{0.5} - 0.969}{0.416}$$

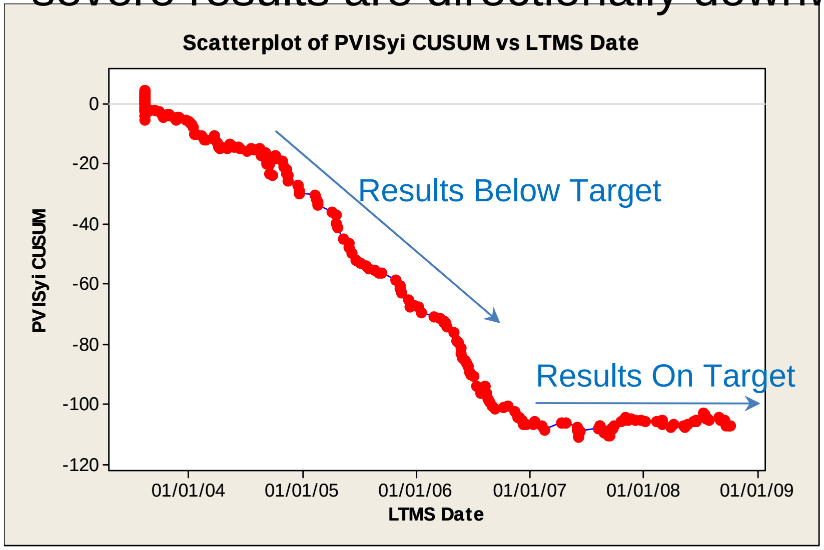
- LTMS applies an exponentially weighted moving average (EWMA) to Y_i and R_i to monitor Severity (Z_i) and Precision (Q_i). *(For the industry control charts λ = 0.2.)*

$$Z_i = \lambda Y_i + (1-\lambda) Z_{i-1}$$

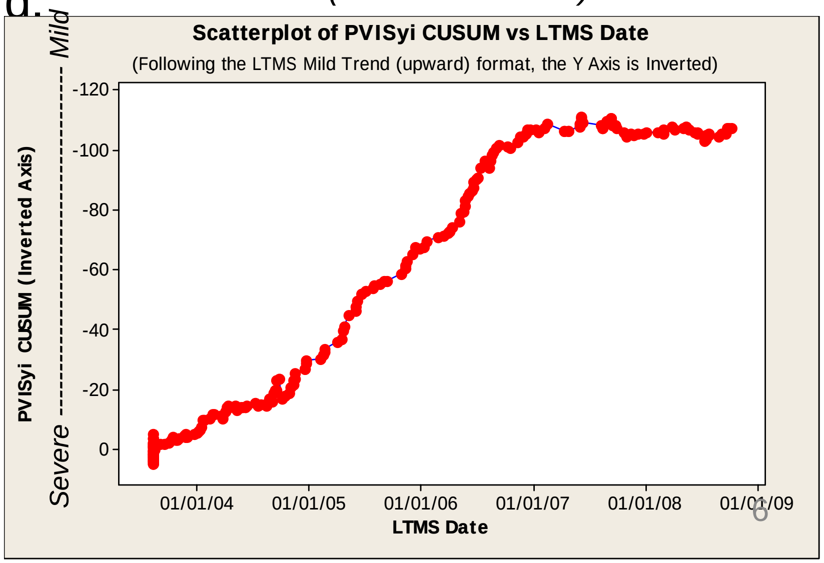
$$Q_i = \lambda R_i + (1-\lambda) Q_{i-1}$$

LTMS Overview

- The Cumulative Sum (CUSUM) control chart is effective tool to determine if the test results are on target ($Y_i = 0$).
- The calculation is based on the cumulative sum of the deviations from the target value.
  - Negative CUSUM deviations indicate that the test results are performing below target values. (The converse is also true.)
  - Horizontal or zero slope CUSUM deviations indicate that the test results are on target.
- LTMS will chart the data such that mild results are directionally up and severe results are directionally downward.



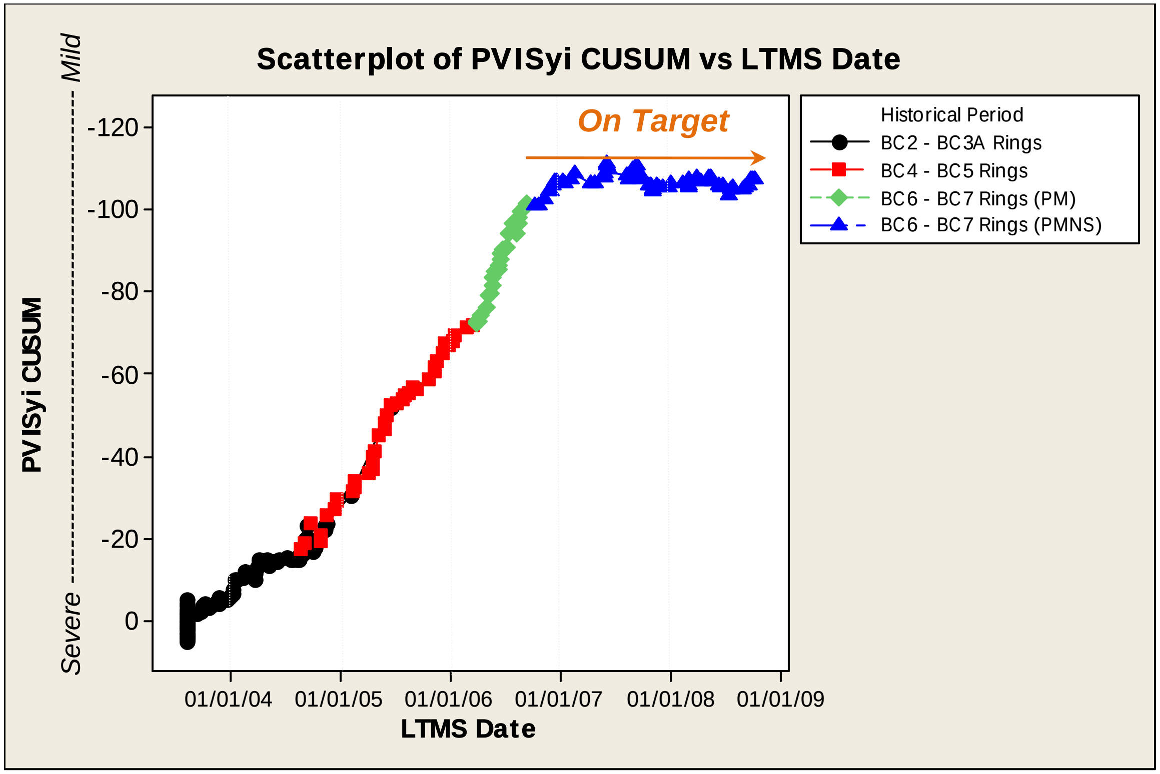
(LTMS Formatted)



%Viscosity Increase Parameter Review

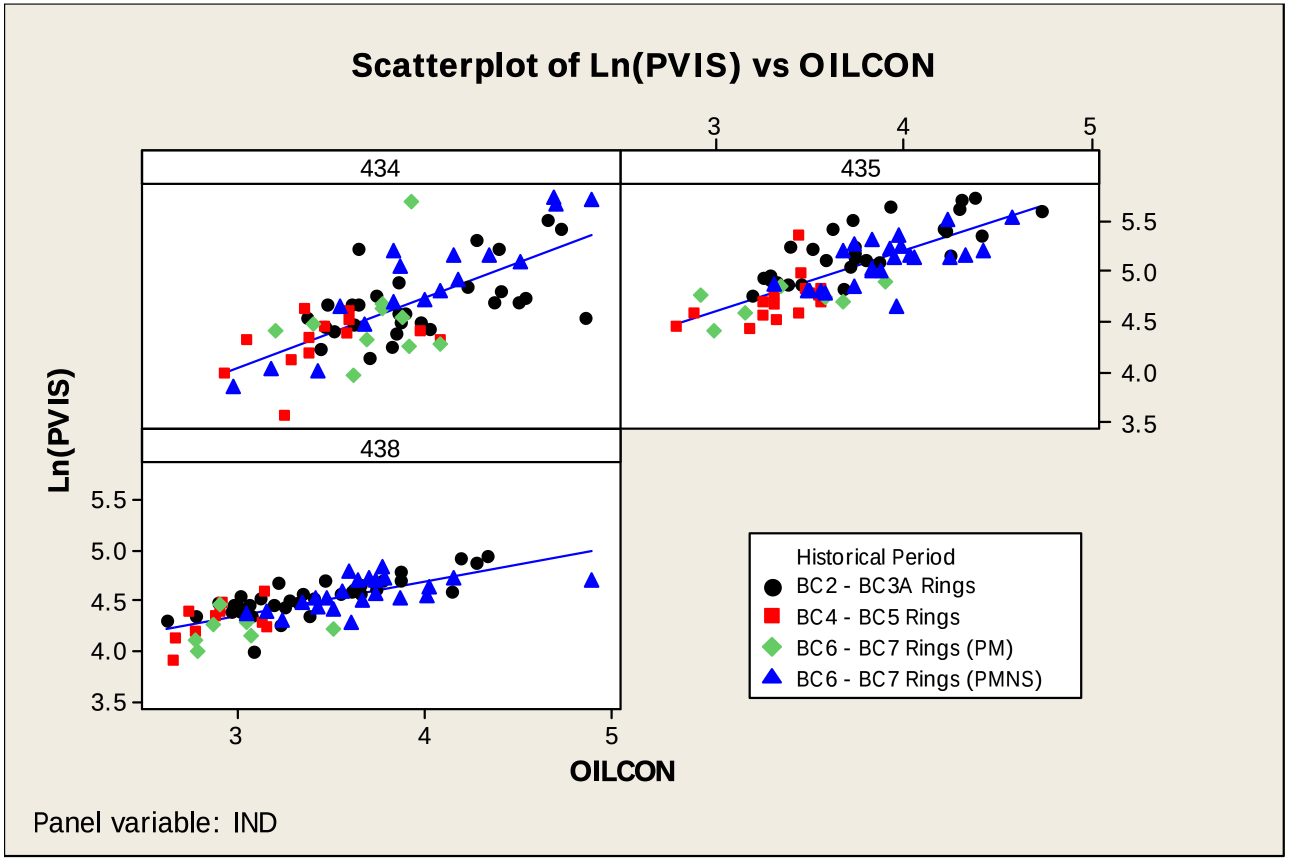
%Viscosity Increase Parameter Review

- CUSUM Plot of PVIS Y_i data suggests that 3 of the 4 test periods have some relationship to the PVIS (mild) result trends.
- PVIS Y_i parameter test results have been near reference oil targets since 2007.



%Viscosity Increase Parameter Review

- Factors affecting Oil Consumption also tend to have a similar effect on PVIS.
  - Total Oil Consumption is the result of volatile and mechanical oil loss

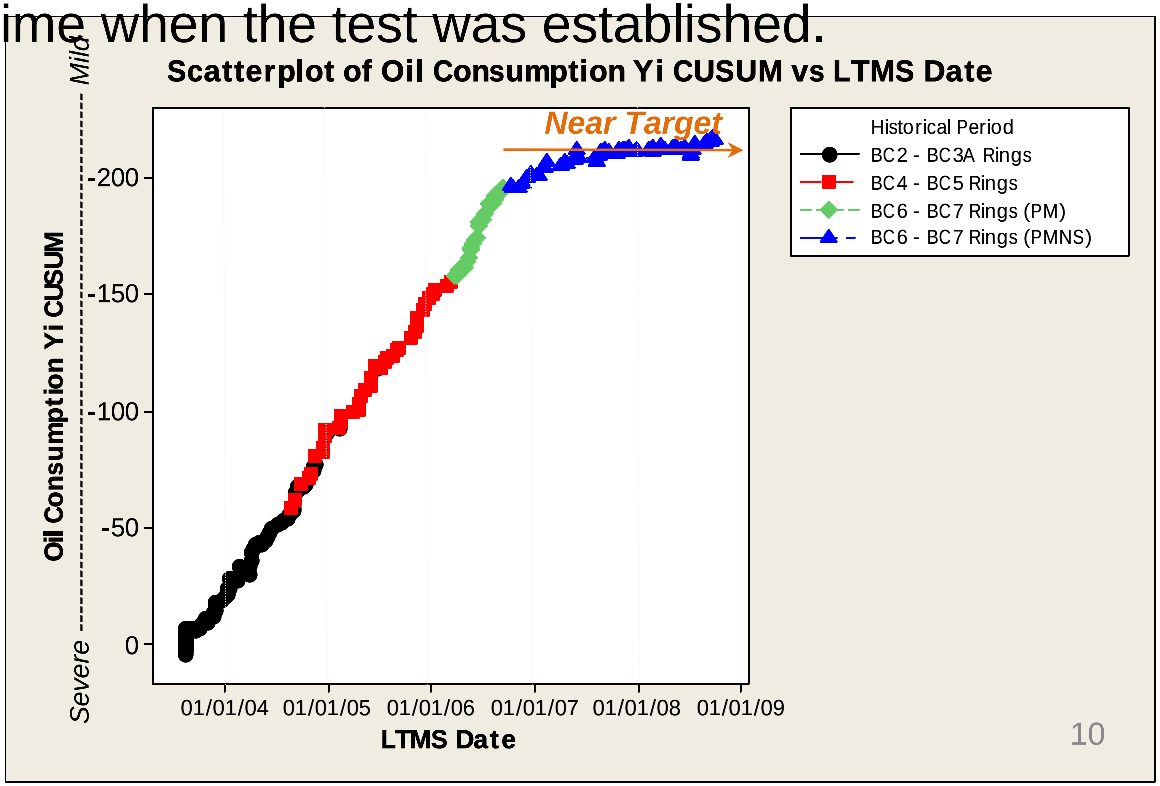


%Viscosity Increase Parameter Review

- Using the initial (24 run) IIIG test matrix data to calculate the Oil Consumption targets, CUSUM Plot of OilCon Y_i data also suggests that the 4 historical periods have some relationship to the (mild result) trends.
- CUSUM plot of Oil Consumption Y_i data suggests that the test is performing similar to time when the test was established.

IIIG Test Matrix Data Summary for OILCON

Variable	IND	Mean	StDev
OILCON	434	4.024	0.381
	435	4.085	0.243
	438	3.696	0.417



%Viscosity Increase Parameter Review

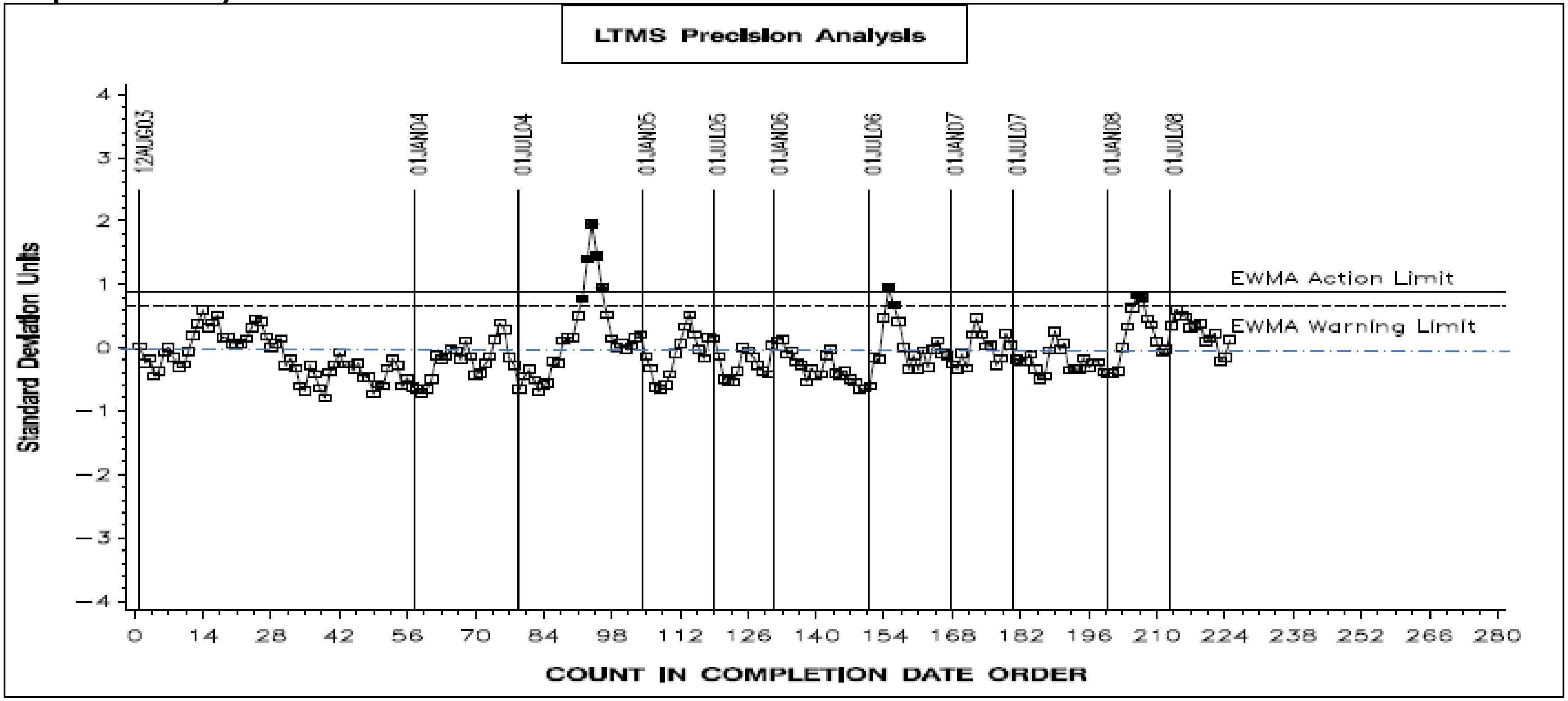
- Analysis of the LTMS Ln(PVIS) data suggests that there is no difference between BC2-BC3A and BC6-BC7 PMNS test periods.

General Linear Model: Ln(PVIS) versus IND, LTMSLAB, Historical Period (Outlier Omitted)

```
Factor             Type   Levels  Values
IND                fixed       3  434, 435, 438
LTMSLAB            fixed       6  A, B, D, E, F, G
Historical Period  fixed       4  BC2-BC3A Rings, BC4-BC5 Rings, BC6-BC7 Rings(PM), BC6-
BC7 Rings(PMNS)

Analysis of Variance for Ln(PVIS), using Adjusted SS for Tests

Source              DF   Seq SS   Adj SS  Adj MS      F      P
IND                  2  11.5760  12.2400  6.1200  73.89  0.000
LTMSLAB              5   2.6402   1.9794  0.3959   4.78  0.000
Historical Period    3   5.2661   5.2661  1.7554  21.19  0.000
Error              211  17.4772  17.4772  0.0828
Total              221  36.9594

S = 0.287802   R-Sq = 52.71%   R-Sq(adj) = 50.47%

Least Squares Means for Ln(PVIS)

Historical Period        Mean  SE Mean
BC2 - BC3A Rings        4.789  0.03243
BC4 - BC5 Rings         4.426  0.04700
BC6 - BC7 Rings (PM)    4.517  0.06031
BC6 - BC7 Rings (PMNS)  4.819  0.03703
IND
434                     4.576  0.03718
435                     4.949  0.03582
438                     4.389  0.03643

Tukey Simultaneous Tests with Ln(PVIS) Response Variable

Historical Period = BC2 - BC3A Rings  subtracted from:
Historical Period       Dif of Means  SE of Dif  T-Value   P-Value
BC4 - BC5 Rings            -0.3634     0.05602   -6.486    0.0000
BC6 - BC7 Rings (PM)       -0.2718     0.06682   -4.068    0.0004
BC6 - BC7 Rings (PMNS)      0.0293     0.04767    0.614    0.9274

Historical Period = BC4 - BC5 Rings  subtracted from:
Historical Period       Dif of Means  SE of Dif  T-Value   P-Value
BC6 - BC7 Rings (PM)       0.09157     0.07571    1.209    0.6216
BC6 - BC7 Rings (PMNS)     0.39264     0.05875    6.683    0.0000

Historical Period = BC6 - BC7 Rings (PM)  subtracted from:
Historical Period       Dif of Means  SE of Dif  T-Value   P-Value
BC6 - BC7 Rings (PMNS)      0.3011     0.06970    4.320    0.0001
```

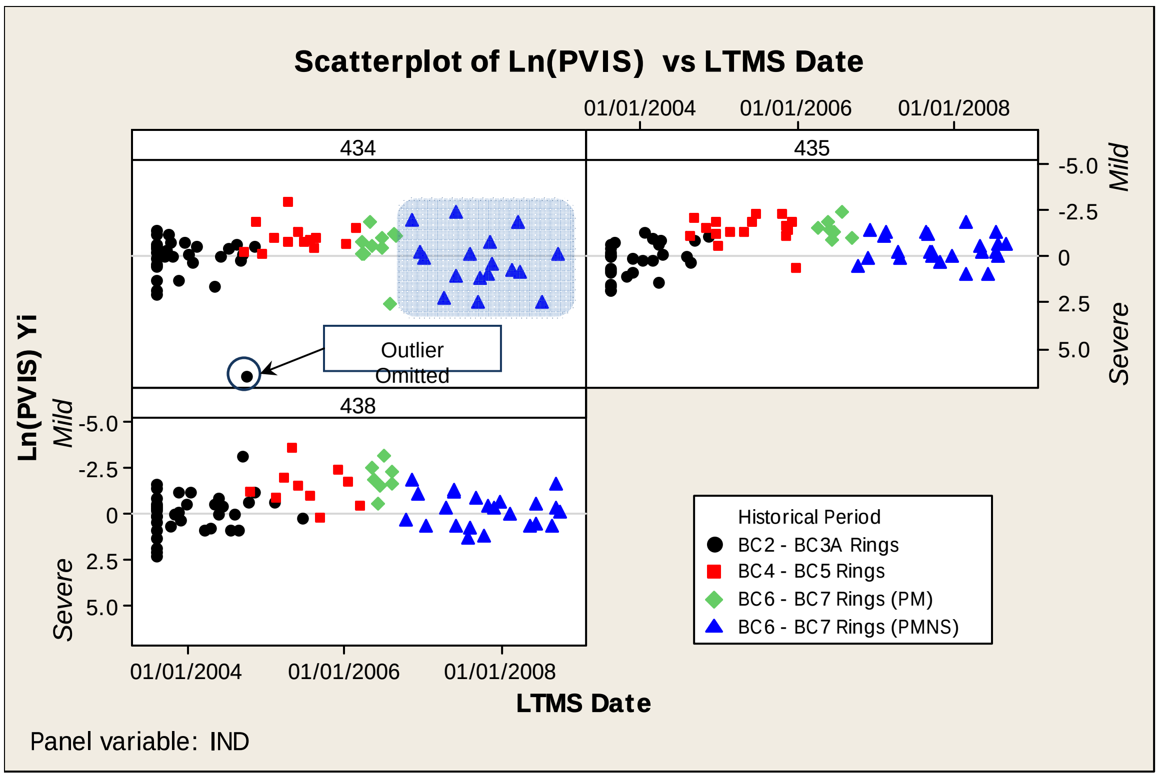
PVIS Parameter Review

- LTMS Precision Chart of Ln(PVIS) parameter indicates that it may be on the increase. (Higher values indicate that the test is less precise.)



PVIS Parameter Review

- Descriptive statistics of the reference oil (grouped by historical period) suggests that the variation for reference oil 434 is on the increase.



Descriptive Statistic Summary (Outlier Omitted)

Results for IND = 434 (Target = 4.7269)

Variable	Historical Period	Count	Mean	StDev
Ln(PVIS)	BC2 - BC3A Rings	30	4.6997	0.3509
	BC4 - BC5 Rings	13	4.3004	0.2877
	BC6 - BC7 Rings (PM)	10	4.5280	0.4630
	BC6 - BC7 Rings (PMNS)	17	4.8580	0.5700

Results for IND = 435 (Target = 5.1838)

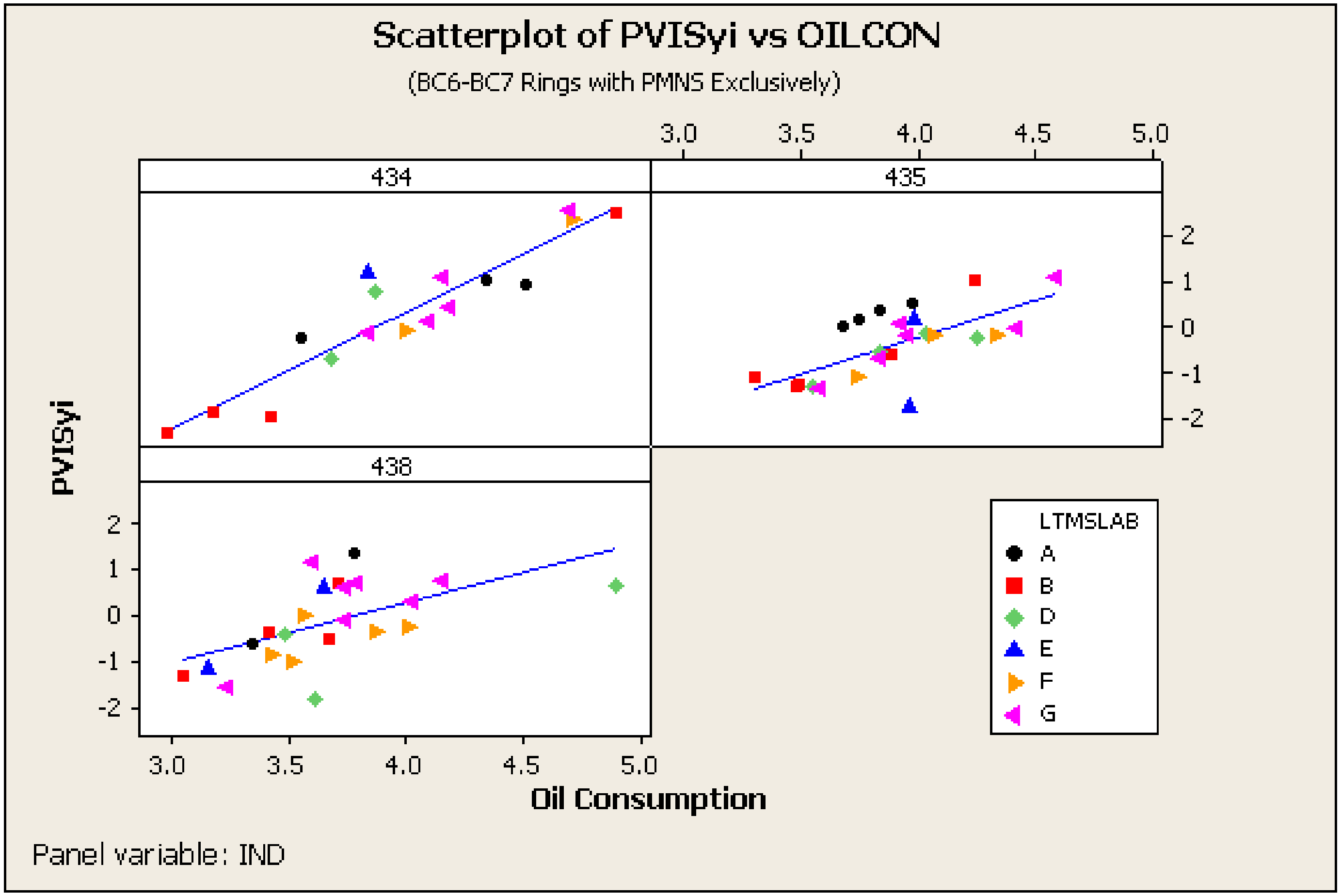
Variable	Historical Period	Count	Mean	StDev
Ln(PVIS)	BC2 - BC3A Rings	30	5.2064	0.2879
	BC4 - BC5 Rings	16	4.7205	0.2267
	BC6 - BC7 Rings (PM)	7	4.7064	0.1688
	BC6 - BC7 Rings (PMNS)	24	5.0740	0.2371

Results for IND = 438 (Target = 4.5706)

Variable	Historical Period	Count	Mean	StDev
Ln(PVIS)	BC2 - BC3A Rings	36	4.5458	0.1945
	BC4 - BC5 Rings	10	4.2986	0.1930
	BC6 - BC7 Rings (PM)	7	4.2167	0.1484
	BC6 - BC7 Rings (PMNS)	23	4.5474	0.1571

PVIS Parameter Review

- Variation in oil consumption could be a factor that is affecting the PVIS test precision.



PVIS Parameter Review

- PVIS Parameter Summary:

  - The Ln(PVIS) Y_i & Oil Consumption CUSUM charts provides no evidence that the current test period is performing differently as compared to when the test was established.

  - An analysis of the Ln(PVIS) parameter data provides no evidence that there is statistical difference in test performance in the current test period as compared to the period when the test was established.

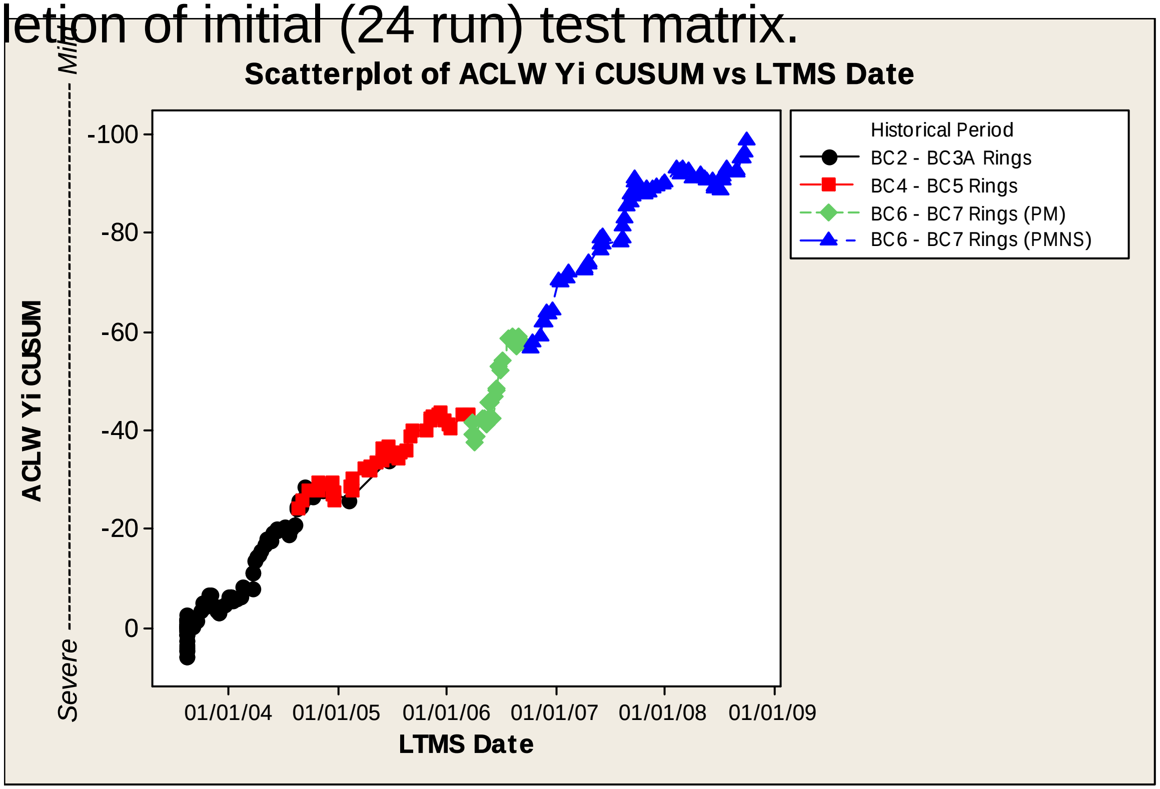
  - The LTMS precision chart indicates that the test variation is increasing. The factors causing the increase in test variation are unknown.

  - Possible Corrective Action:
    - PVIS is currently on target – no corrective action needed for next GF-5 category.
    - It would be advantageous to investigate the factors that could be affecting PVIS and Oil Consumption parameters (i.e. honing).

ACLW Parameter Review

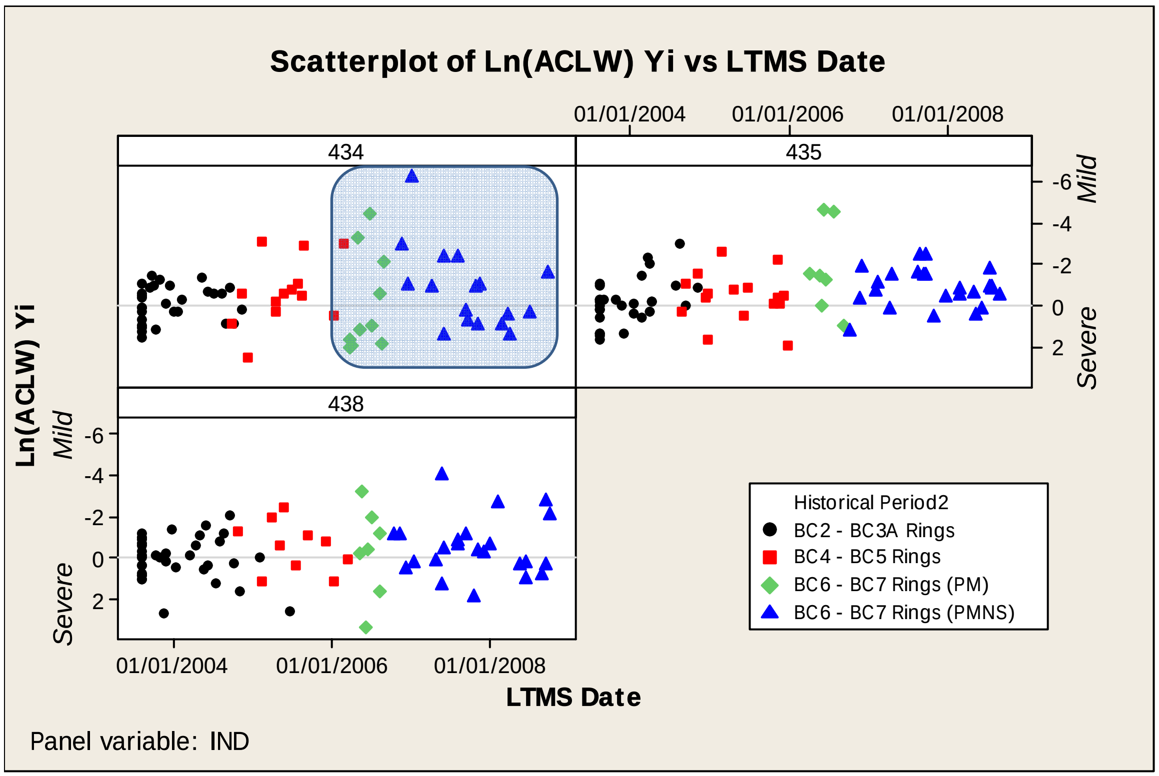
ACLW Parameter Review

- CUSUM plot of Ln(ACLW) Y_i data suggests that the relationship between the 4 historical periods and the Ln(ACLW) parameter is weak.
- CUSUM plot indicates that the trend has been mild shortly after completion of initial (24 run) test matrix.



ACLW Parameter Review

- There are no clear distinct differences in Ln(ACLW) Y_i performance for the 4 different historical test periods.
- Directionally, the descriptive statistics suggests that the test period BC6-BC7 ring PMNS is milder and has more test variation as compared to the BC2-BC3A test period.



Descriptive Statistic Summary

Results for IND = 434 (Target = 3.4657)

Variable	Historical Period	Count	Mean	StDev
Ln(ACLW)	BC2 - BC3A Rings	30	3.4527	0.1723
	BC4 - BC5 Rings	13	3.3418	0.3208
	BC6 - BC7 Rings (PM)	10	3.4560	0.4780
	BC6 - BC7 Rings (PMNS)	17	3.3286	0.3936

Results for IND = 435 (Target = 3.4985)

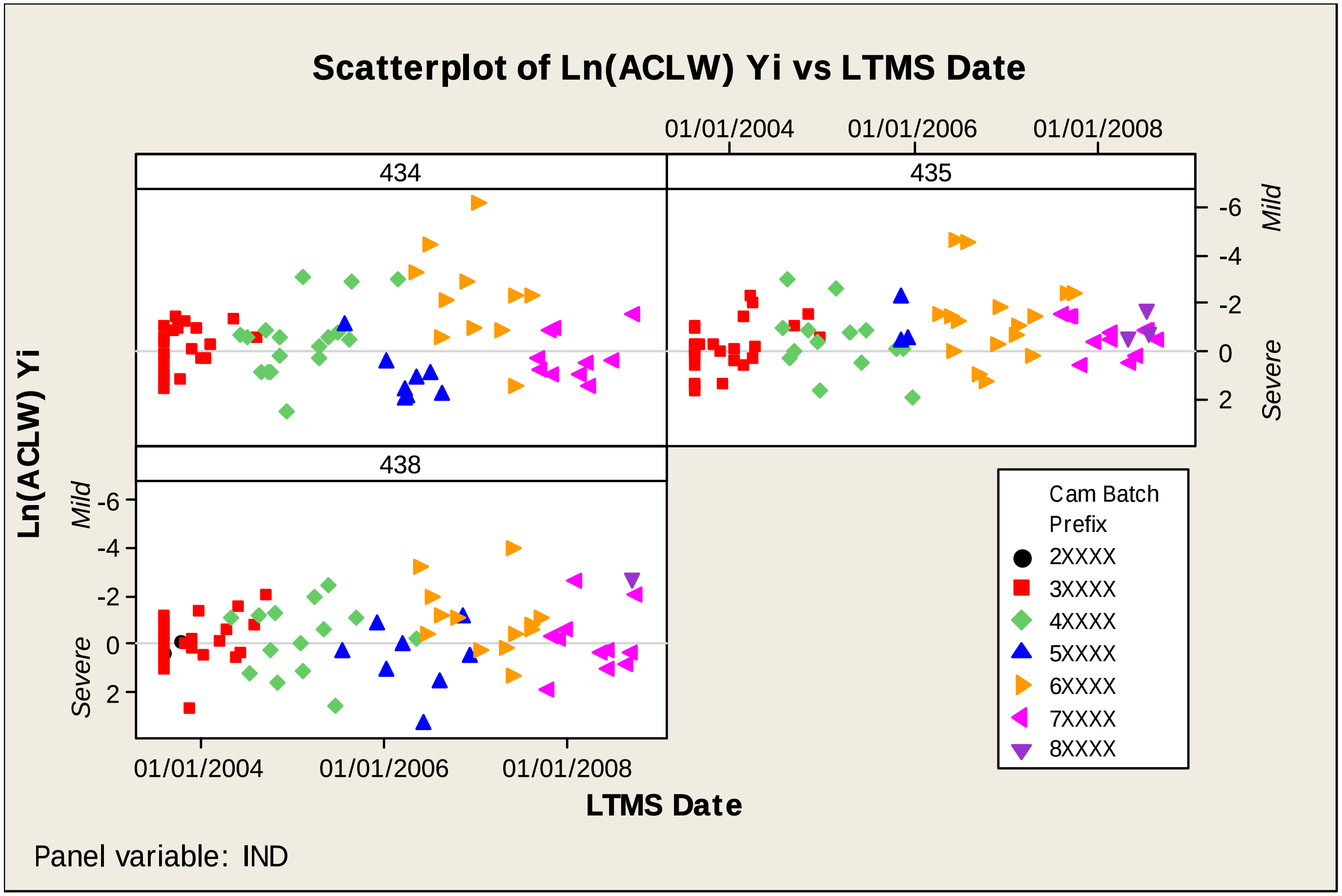
Variable	Historical Period	Count	Mean	StDev
Ln(ACLW)	BC2 - BC3A Rings	30	3.4640	0.2591
	BC4 - BC5 Rings	16	3.4072	0.2811
	BC6 - BC7 Rings (PM)	7	3.0880	0.4940
	BC6 - BC7 Rings (PMNS)	24	3.3206	0.2164

Results for IND = 438 (Target = 2.8814)

Variable	Historical Period	Count	Mean	StDev
Ln(ACLW)	BC2 - BC3A Rings	36	2.8843	0.2207
	BC4 - BC5 Rings	10	2.7678	0.2510
	BC6 - BC7 Rings (PM)	7	2.8190	0.4560
	BC6 - BC7 Rings (PMNS)	23	2.7851	0.2918

ACLW Parameter Review

- Scatter plot of Ln(ACLW) Y_i data suggests that unique camshaft batches may have an effect on the ACLW performance.



ACLW Parameter Review

- Analysis of the LTMS Ln(ACLW) data suggests that there is no difference between BC2-BC3A and BC6-BC7 PMNS test periods.

General Linear Model: Ln(ACLW) versus IND, LTMSLAB, Historical Period

```
Factor             Type   Levels  Values
IND                fixed       3  434, 435, 438
LTMSLAB            fixed       6  A, B, D, E, F, G
Historical Period  fixed       4  BC2-BC3A Rings, BC4-BC5 Rings, BC6-BC7 Rings(PM), BC6-BC7 Rings(PMNS)

Analysis of Variance for Ln(ACLW), using Adjusted SS for Tests

Source              DF   Seq SS   Adj SS  Adj MS      F      P
IND                  2  15.4183  15.4951  7.7475  93.58  0.000
LTMSLAB              5   0.9760   0.7687  0.1537   1.86  0.103
Historical Period    3   0.5071   0.5071  0.1690   2.04  0.109
Error              212  17.5522  17.5522  0.0828
Total              222  34.4536

S = 0.287738   R-Sq = 49.06%   R-Sq(adj) = 46.65%

Least Squares Means for Ln(ACLW)

Historical P             Mean  SE Mean
BC2 - BC3A Rings        3.269  0.03215
BC4 - BC5 Rings         3.191  0.04699
BC6 - BC7 Rings (PM)    3.163  0.06029
BC6 - BC7 Rings (PMNS)  3.163  0.03702
IND
434                     3.396  0.03693
435                     3.370  0.03582
438                     2.822  0.03642

Tukey Simultaneous Tests of LN(ACLW) Response Variable
Historical Period = BC2 - BC3A Rings  subtracted from:
Historical Period       Dif of Means  SE of Dif  T-Value   P-Value
BC4 - BC5 Rings            -0.0772     0.05581   -1.383    0.5111
BC6 - BC7 Rings (PM)       -0.1059     0.06670   -1.587    0.3880
BC6 - BC7 Rings (PMNS)     -0.1056     0.04751   -2.223    0.1205

Historical Period = BC4 - BC5 Rings  subtracted from:
Historical Period       Dif of Means  SE of Dif  T-Value   P-Value
BC6 - BC7 Rings (PM)      -0.02867     0.07569  -0.3788    0.9814
BC6 - BC7 Rings (PMNS)    -0.02837     0.05873  -0.4831    0.9628

Historical Period = BC6 - BC7 Rings (PM)  subtracted from:
Historical Period       Dif of Means  SE of Dif  T-Value   P-Value
BC6 - BC7 Rings (PMNS)    0.000299     0.06968  0.004290    1.000
```

ACLW Parameter Review

- ACLW Parameter Summary:
  - LTMS CUSUM and Severity Plots of Ln(ACLW) data suggests that the test is currently in a Mild trend test period.
  - An analysis of the Ln(ACLW) parameter data provides no evidence that there is statistical difference in test performance in the current test period as compared to the period when the test was established.
  - Some of the mild and severe trends could be the result of different Cam & Lifter hardware.
  - Possible Corrective Action:
    - The LN(ACLW) parameter is currently in a period that is mild of target. It is possible that factors such as new camshaft batches may lead to new severe or mild trends. As a result, no corrective action needed at this time for next GF-5 category.

WPD Parameter Review

WPD Parameter Review

- Overview of IIIG Weighted Piston Deposit merit weighting system by location:

Groove 1: Weight Factor = 0.05

Land 2: Weight Factor = 0.15

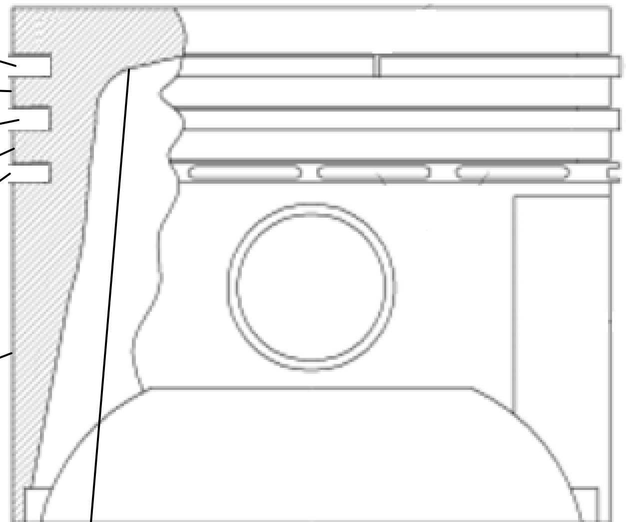
Groove 2: Weight Factor = 0.10

Land 3 (ORL): Weight Factor = 0.30

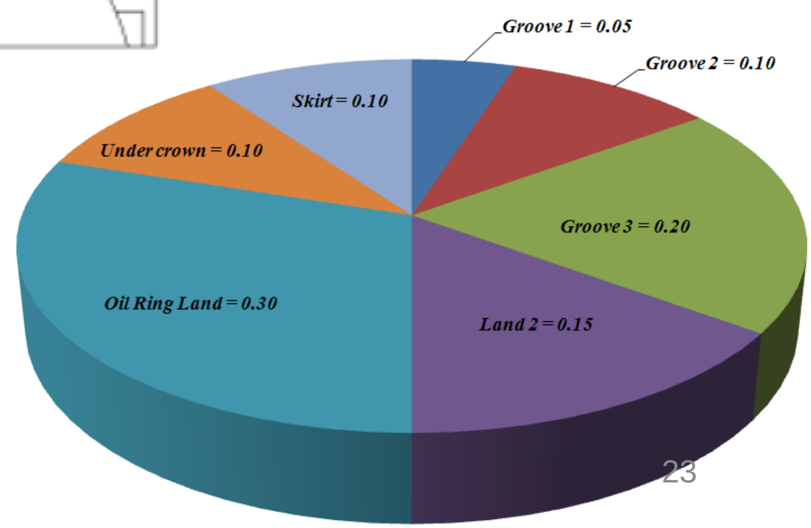
Groove 3: Weight Factor = 0.20

Piston Skirt: Weight Factor = 0.10

Under Crown: Weight Factor = 0.10

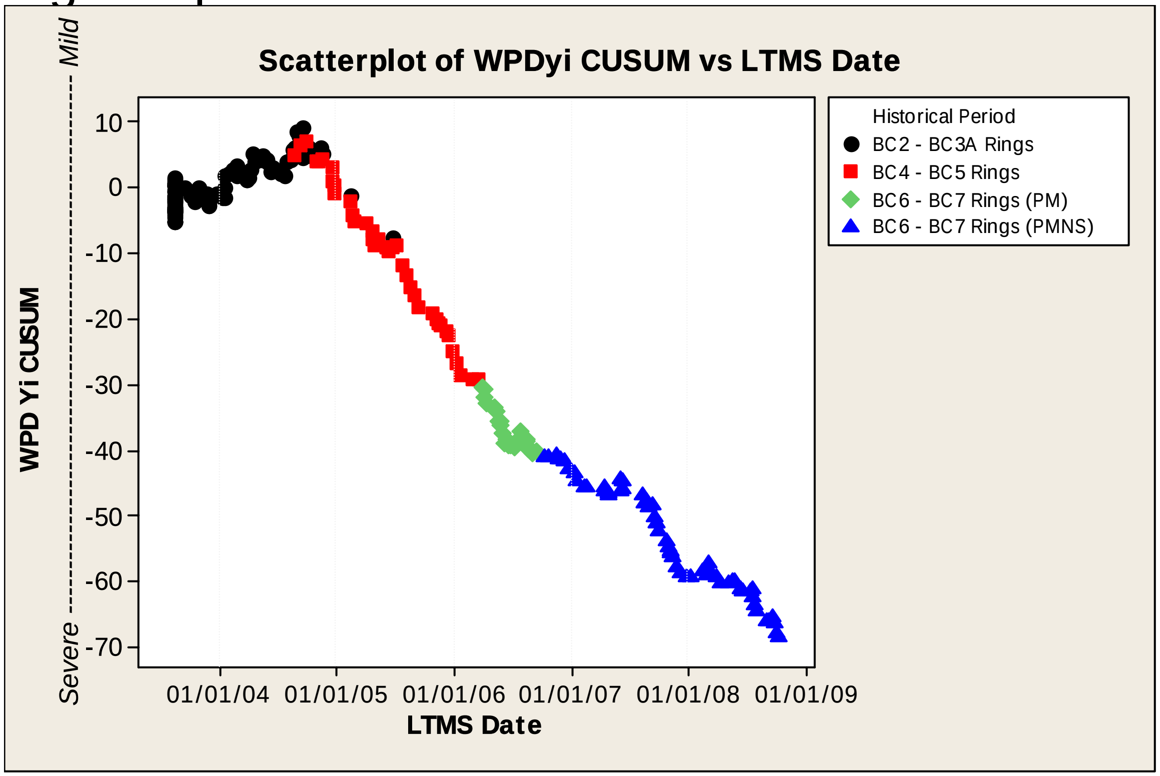


Piston Deposit Weight Factor Summary



WPD Parameter Review

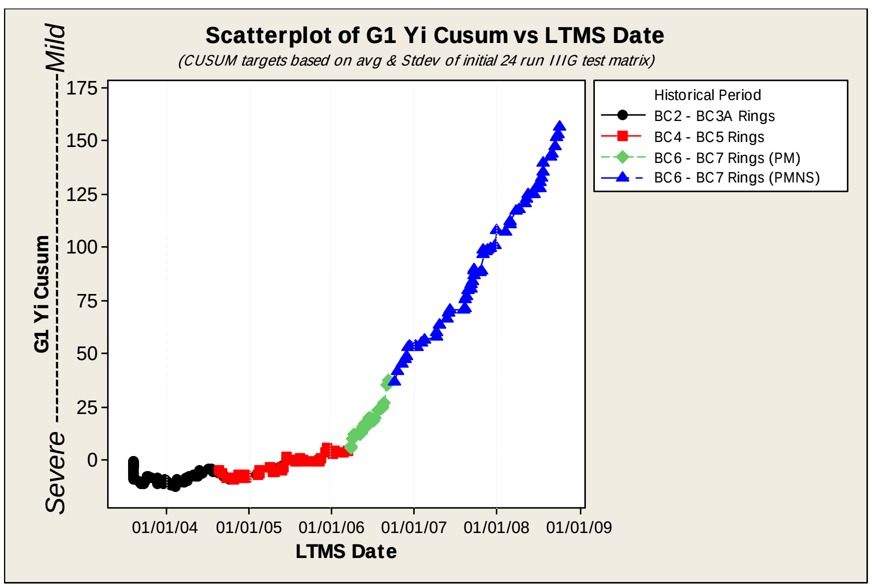
- CUSUM Plot of WPD Y_i data suggests that the 4 historical periods have some relationship to the severe WPD trend.
- The CUSUM WPD Y_i parameter plot also suggests that the results have been severe of the reference oil targets following the BC2 – BC3A Ring test period.

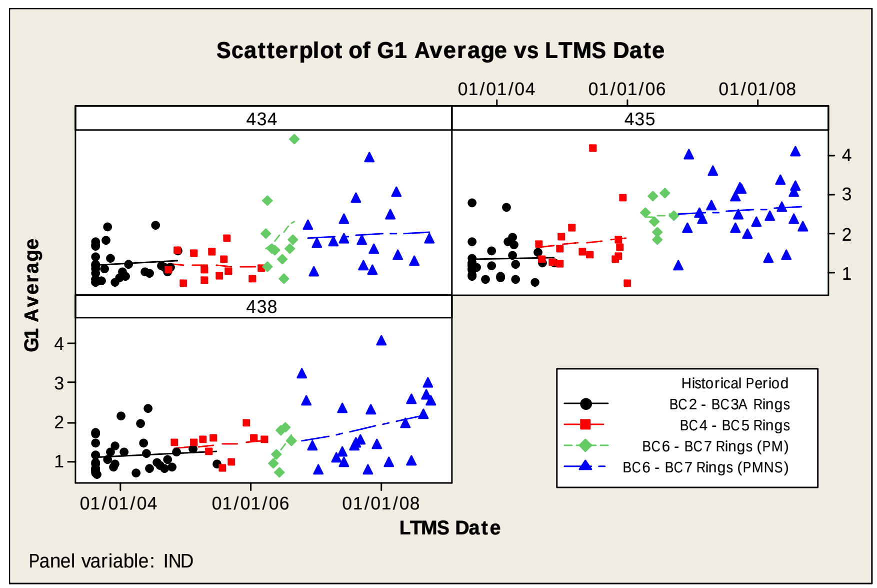


WPD Parameter Review

- CUSUM plot of Groove 1 Y_i data shows that the top piston grooves are getting cleaner. *(The Y_i targets based on initial 24 run test matrix.)*
- Plots of Groove 1 deposit ratings also shows that the top piston grooves are cleaner - since the introduction of BC6 Piston Rings.

(Groove 1 weight factor = 0.05)

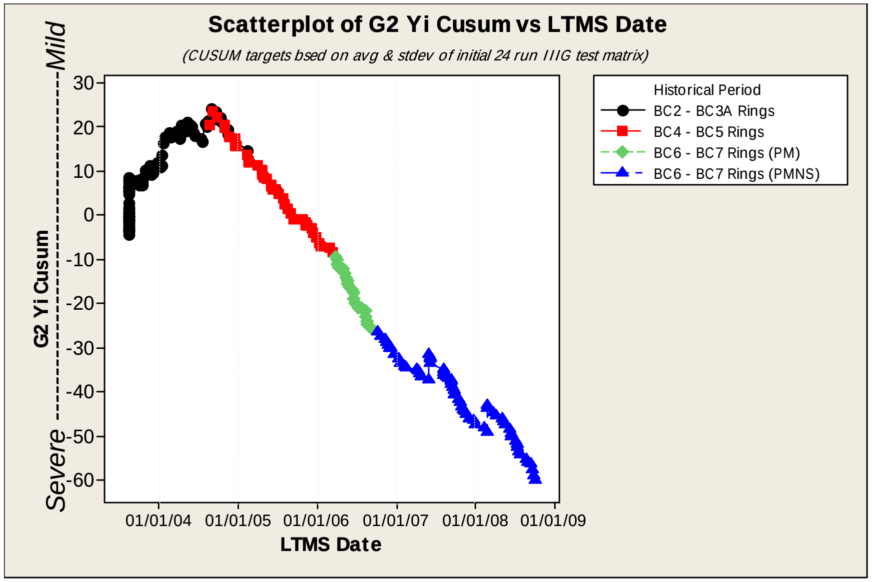


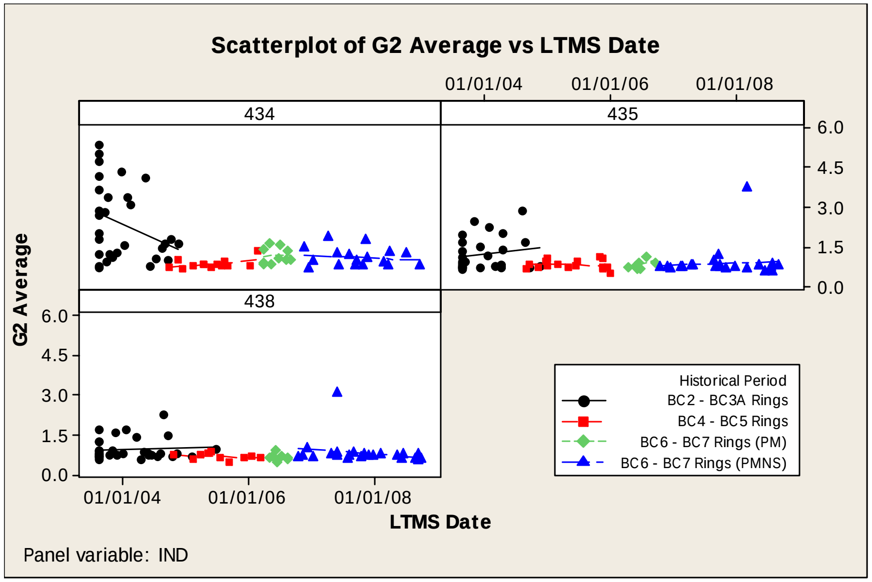


WPD Parameter Review

- CUSUM plot of Groove 2 deposits indicates a directionally severe trend since the introduction of BC4 Piston Rings. *(The Y_i targets based on initial 24 run test matrix.)*
- Plots of Groove 2 deposit ratings show that it was cleaner during the BC2 – BC3A ring test period.

(Groove 2 weight factor = 0.10)

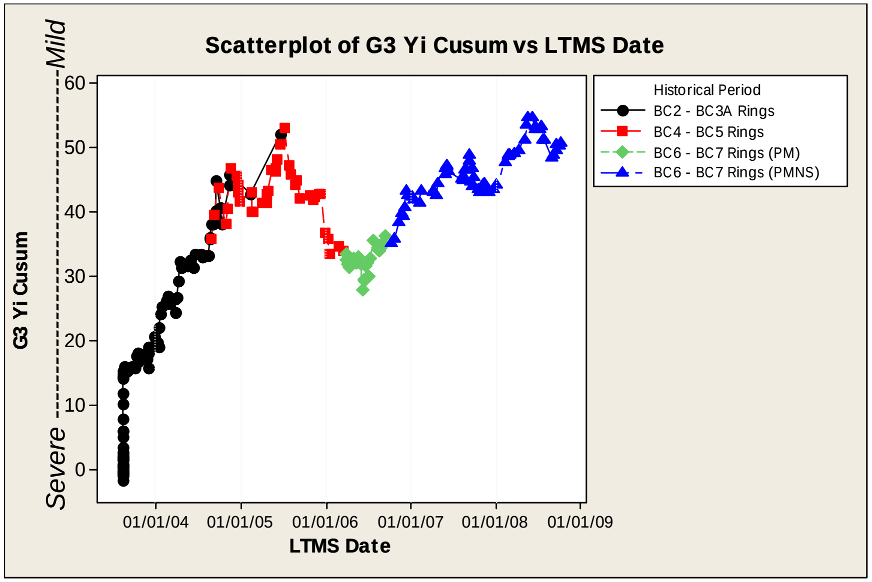


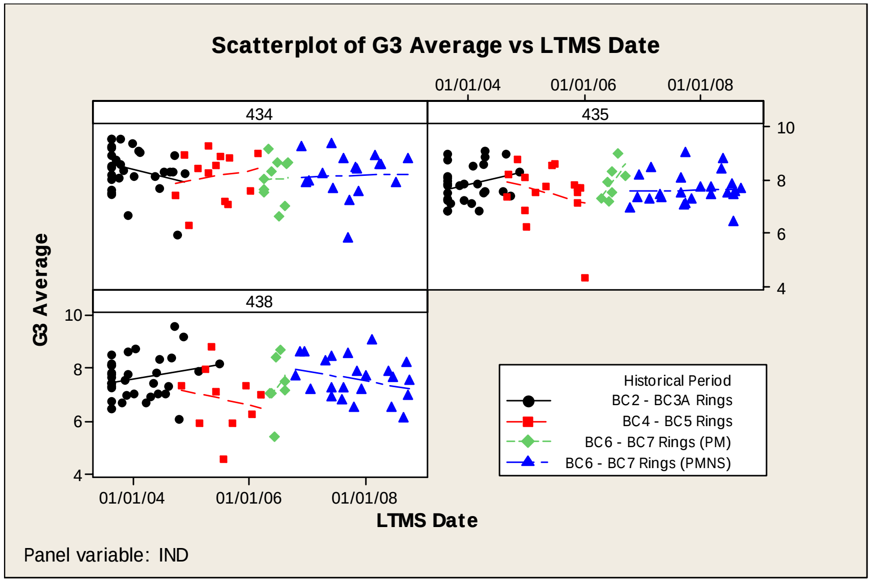


WPD Parameter Review

- CUSUM plot of Groove 3 deposits show a directionally mild trend since the BC6 & BC7 Piston Ring test period. *(The Y_i targets based on initial 24 run test matrix.)*

(Groove 3 weight factor = 0.20)

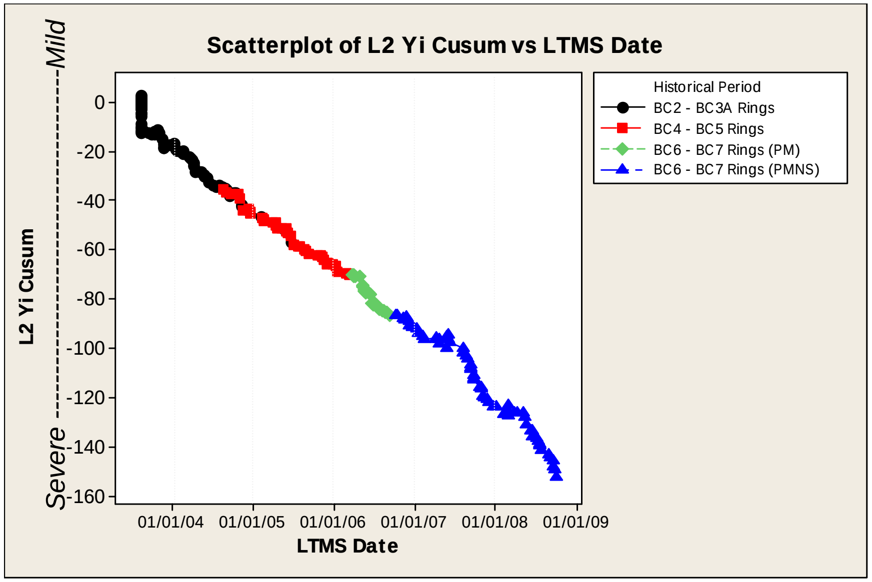


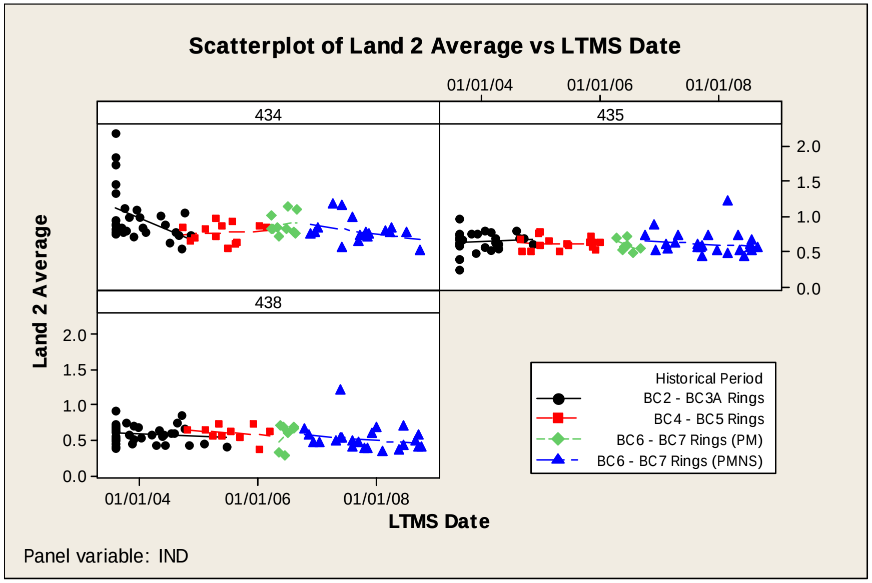


WPD Parameter Review

- CUSUM plot of Land 2 deposits show a directionally severe trend since the start of the test. *(The Y_i targets based on initial 24 run test matrix.)*

(Land 2 weight factor = 0.15)

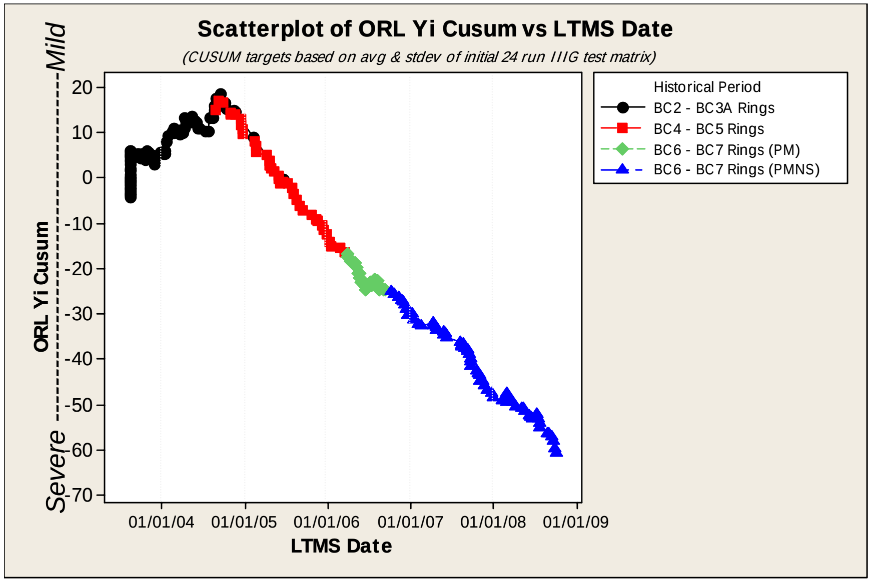


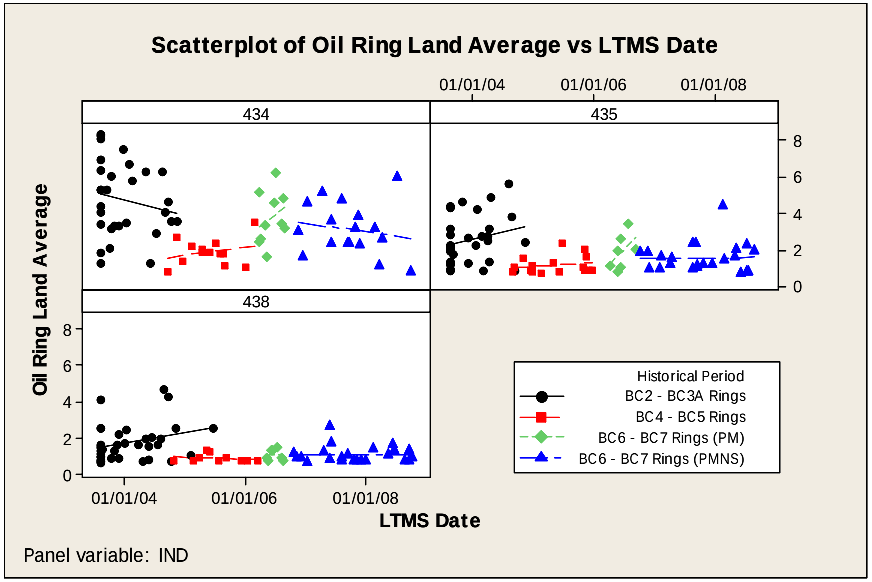


WPD Parameter Review

- Plots of the Oil Ring Land (Land 3) deposits by reference oil show a directionally severe trend since the introduction of BC4 Piston Rings. *(The Y_i targets based on initial 24 run test matrix.)*
- Plots of Oil Ring Land (Land 3) deposit ratings also show that it was cleaner during the BC2 – BC3A ring period.

(Oil Ring Land weight factor = 0.30)

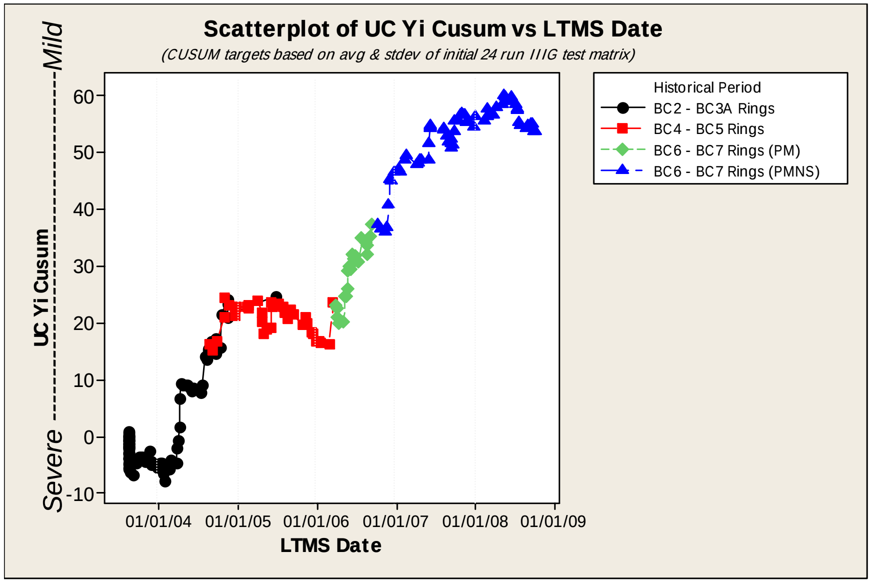


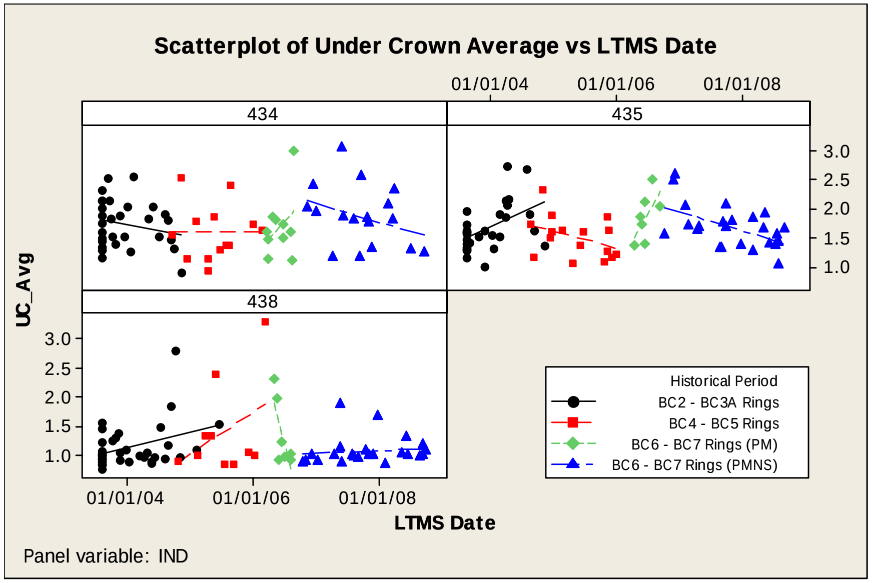


WPD Parameter Review

- Plots of the Under Crown piston deposits indicate a directionally mild trend since the introduction of BC6 Piston Rings. *(Y_i targets based on initial 24 run test matrix)*

(Under Crown weight factor = 0.10)

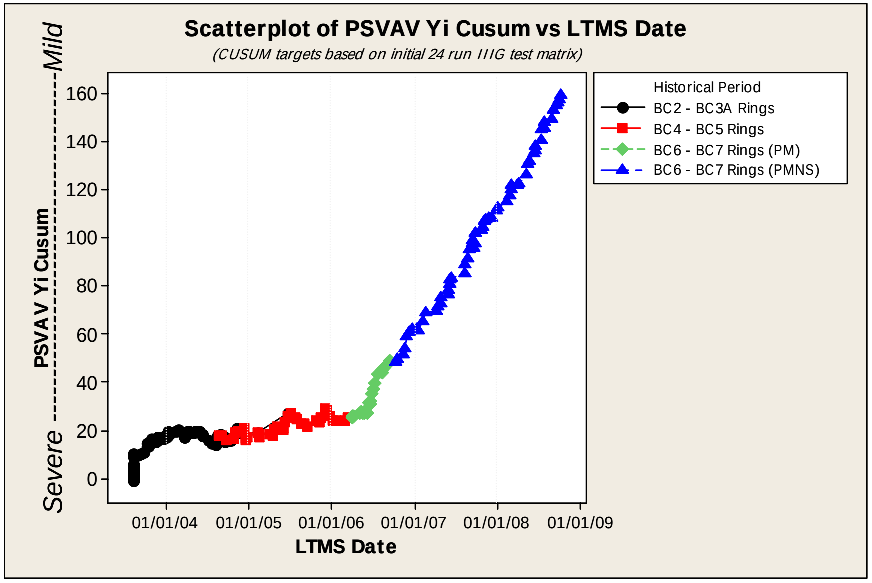


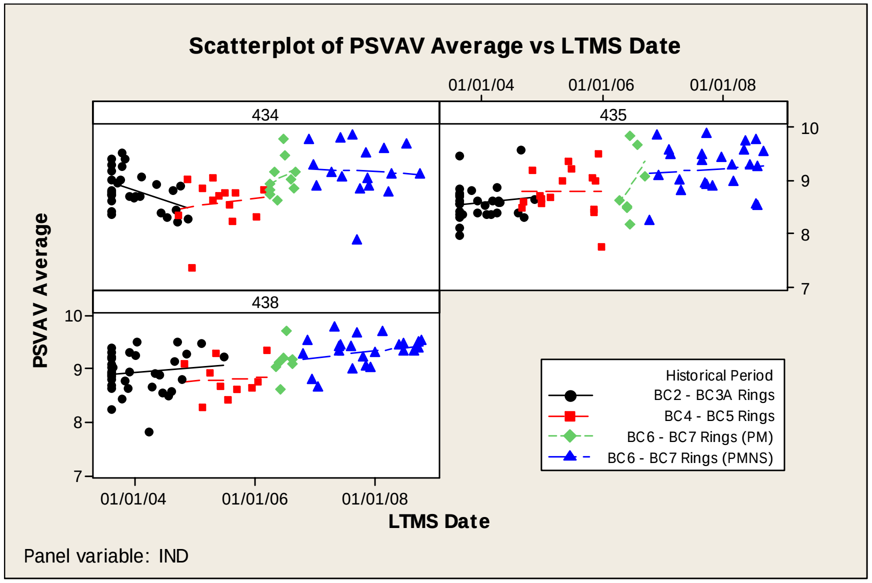


WPD Parameter Review

- Plots of the Piston Skirt Varnish results indicate a directionally mild trend since the introduction of BC6 Piston Rings. *(Y_i targets based on initial 24 run test matrix)*

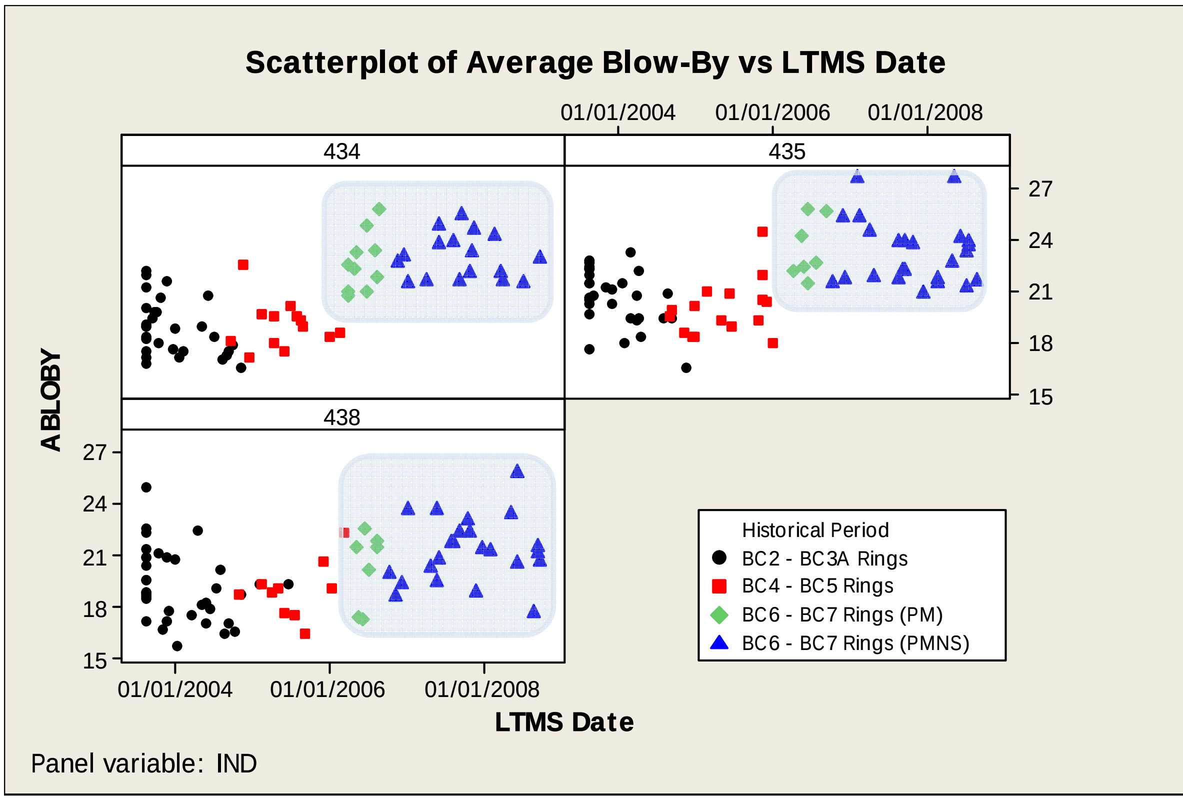
(Skirt weight factor = 0.10)





WPD Parameter Review

- Even though the mechanism is unclear, it is believed that Blow-by gases affect piston deposits (and possibly PVIS).
- A scatter plot of the data and descriptive statistics show that a step change occurred with the introduction of the BC6 & BC7 rings.



Descriptive Statistic Summary

Results for IND = 434

Variable	Historical Period	Count	Mean	StDev
ABLOBY	BC2 - BC3A Rings	30	18.830	1.607
	BC4 - BC5 Rings	13	19.015	1.387
	BC6 - BC7 Rings (PM)	10	22.650	1.684
	BC6 - BC7 Rings (PMNS)	17	22.965	1.294

Results for IND = 435

Variable	Historical Period	Count	Mean	StDev
ABLOBY	BC2 - BC3A Rings	30	20.590	1.639
	BC4 - BC5 Rings	16	19.975	1.615
	BC6 - BC7 Rings (PM)	7	23.486	1.759
	BC6 - BC7 Rings (PMNS)	24	23.204	1.865

Results for IND = 438

Variable	Historical Period	Count	Mean	StDev
ABLOBY	BC2 - BC3A Rings	36	19.214	2.069
	BC4 - BC5 Rings	10	18.950	1.665
	BC6 - BC7 Rings (PM)	7	20.343	2.166
	BC6 - BC7 Rings (PMNS)	23	21.287	1.912

WPD Parameter Review

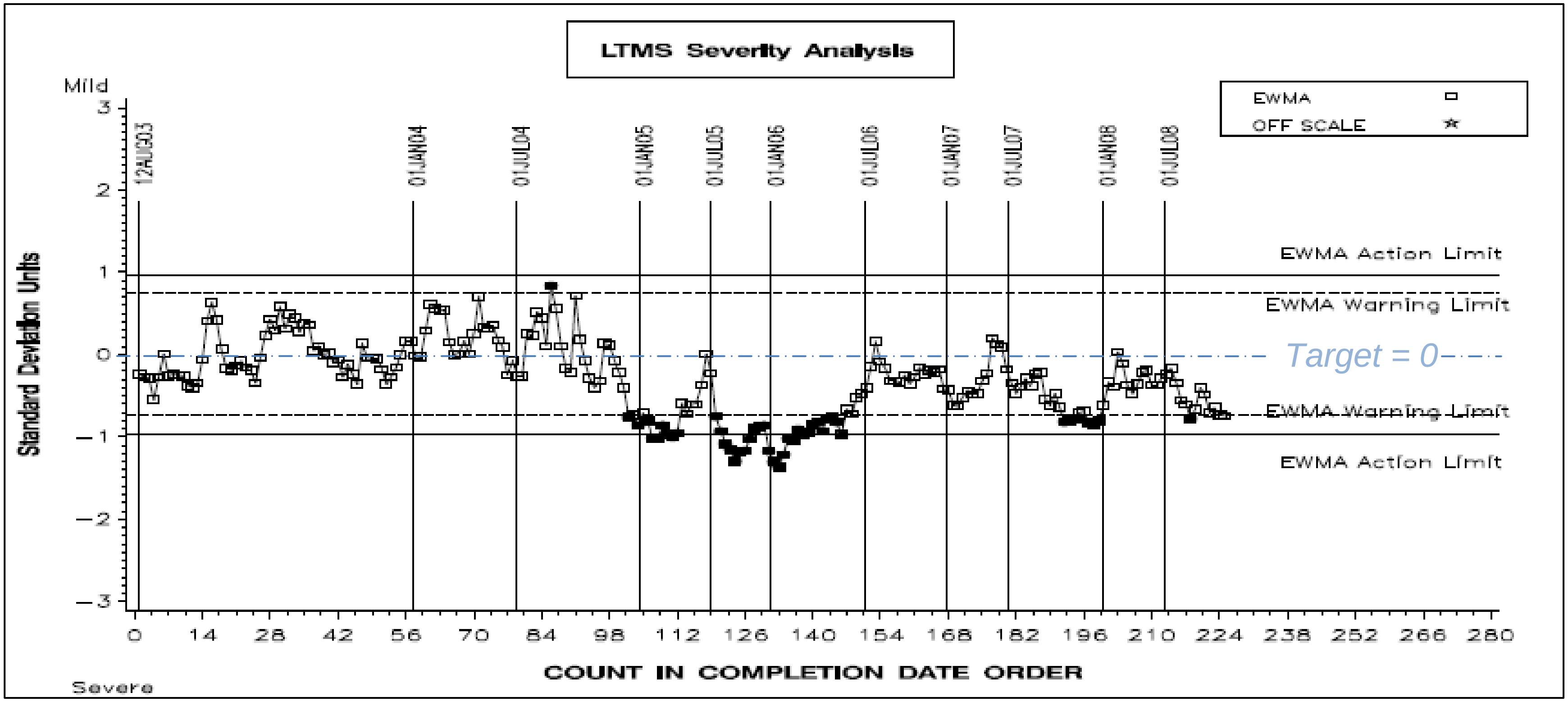
- Analysis of LTMS WPD data suggests that there is a statistical difference in test severity between BC2-BC3A and BC6-BC7 PMNS test periods.

General Linear Model: WPD versus IND, LTMSLAB, Historical Period

```
Factor             Type   Levels  Values
IND                fixed       3  434, 435, 438
LTMSLAB            fixed       6  A, B, D, E, F, G
Historical Period  fixed       4  BC2-BC3A Rings, BC4-BC5 Rings, BC6-BC7 Rings (PM), BC6-BC7 Rings (PMNS)

Analysis of Variance for WPD, using Adjusted SS for Tests

Source              DF    Seq SS   Adj SS   Adj MS      F      P
IND                  2   40.1747  43.4467  21.7234  87.03  0.000
LTMSLAB              5    8.7372  11.1267   2.2253   8.92  0.000
Historical Period    3   16.8331  16.8331   5.6110  22.48  0.000
Error              212   52.9188  52.9188   0.2496
Total              222  118.6638

S = 0.499617   R-Sq = 55.40%   R-Sq(adj) = 53.30%

Least Squares Means for WPD

Historical P             Mean  SE Mean
BC2 - BC3A Rings        3.944  0.05583
BC4 - BC5 Rings         3.177  0.08158
BC6 - BC7 Rings (PM)    3.591  0.10469
BC6 - BC7 Rings (PMNS)  3.549  0.06428
IND
434                     4.169  0.06413
435                     3.440  0.06219
438                     3.087  0.06323

Tukey Simultaneous Tests with WPD Response Variable
Historical Period = BC2 - BC3A Rings  subtracted from:
Historical Period       Dif of Means  SE of Dif  T-Value   P-Value
BC4 - BC5 Rings            -0.7674     0.09691   -7.919    0.0000
BC6 - BC7 Rings (PM)       -0.3534     0.11582   -3.051    0.0136
BC6 - BC7 Rings (PMNS)     -0.3954     0.08249   -4.793    0.0000

Historical Period = BC4 - BC5 Rings  subtracted from:
Historical Period       Dif of Means  SE of Dif  T-Value   P-Value
BC6 - BC7 Rings (PM)        0.4140      0.1314    3.150    0.0100
BC6 - BC7 Rings (PMNS)      0.3720      0.1020    3.648    0.0019

Historical Period = BC6 - BC7 Rings (PM)  subtracted from:
Historical Period       Dif of Means  SE of Dif  T-Value   P-Value
BC6 - BC7 Rings (PMNS)    -0.04200      0.1210  -0.3471    0.9856
```

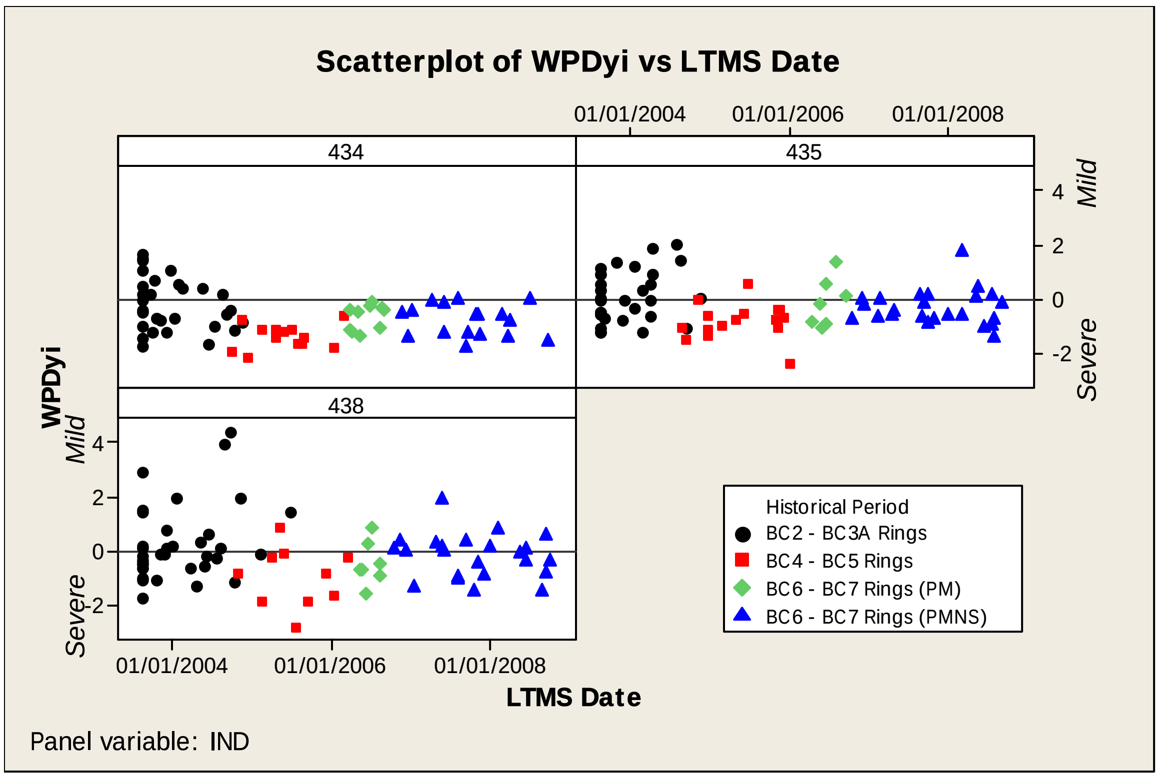
WPD Parameter Review

- LTMS Severity Chart indicates that the test has been severe of target and is at the EWMA warning limit.



WPD Parameter Review

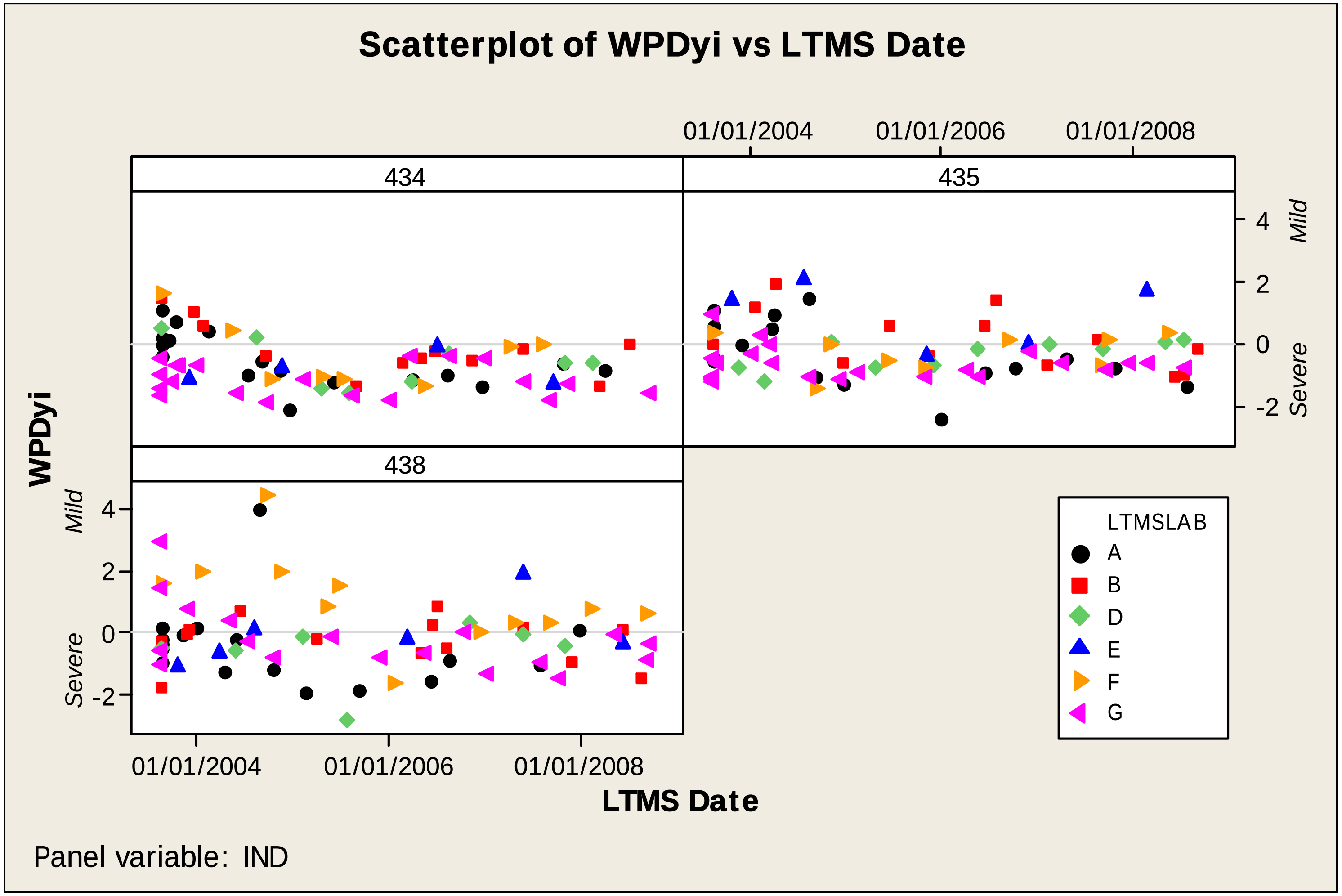
- The below Y_i plots for each of the reference oils suggests that the WPD parameter is operating below the established performance targets.
- The descriptive statistics also suggest that the performance difference is a function of the reference oil target rather than a constant difference.




```
Descriptive Statistic Summary

Results for IND = 434 (LTMS target WPD = 4.80)
Variable  Historical Period    Count   Mean    StDev
WPD      BC2 - BC3A Rings        30   4.6250  0.9270
         BC4 - BC5 Rings         13   3.4550  0.4300
         BC6 - BC7 Rings (PM)    10   4.1480  0.4450
         BC6 - BC7 Rings (PMNS)  17   3.9880  0.5640

Results for IND = 435 (LTMS target WPD = 3.59)
Variable  Historical Period    Count   Mean    StDev
WPD      BC2 - BC3A Rings        30   3.6360  0.5530
         BC4 - BC5 Rings         16   3.1069  0.3817
         BC6 - BC7 Rings (PM)     7   3.5070  0.5240
         BC6 - BC7 Rings (PMNS)  24   3.3758  0.3700

Results for IND = 438 (LTMS target WPD = 3.20)
Variable  Historical Period    Count   Mean     StDev
WPD       BC2 - BC3A Rings       36   3.2939  0.4624
          BC4 - BC5 Rings        10   2.8820  0.3620
          BC6 - BC7 Rings (PM)    7   3.0510  0.2650
          BC6 - BC7 Rings (PMNS) 23   3.1304  0.2674
```

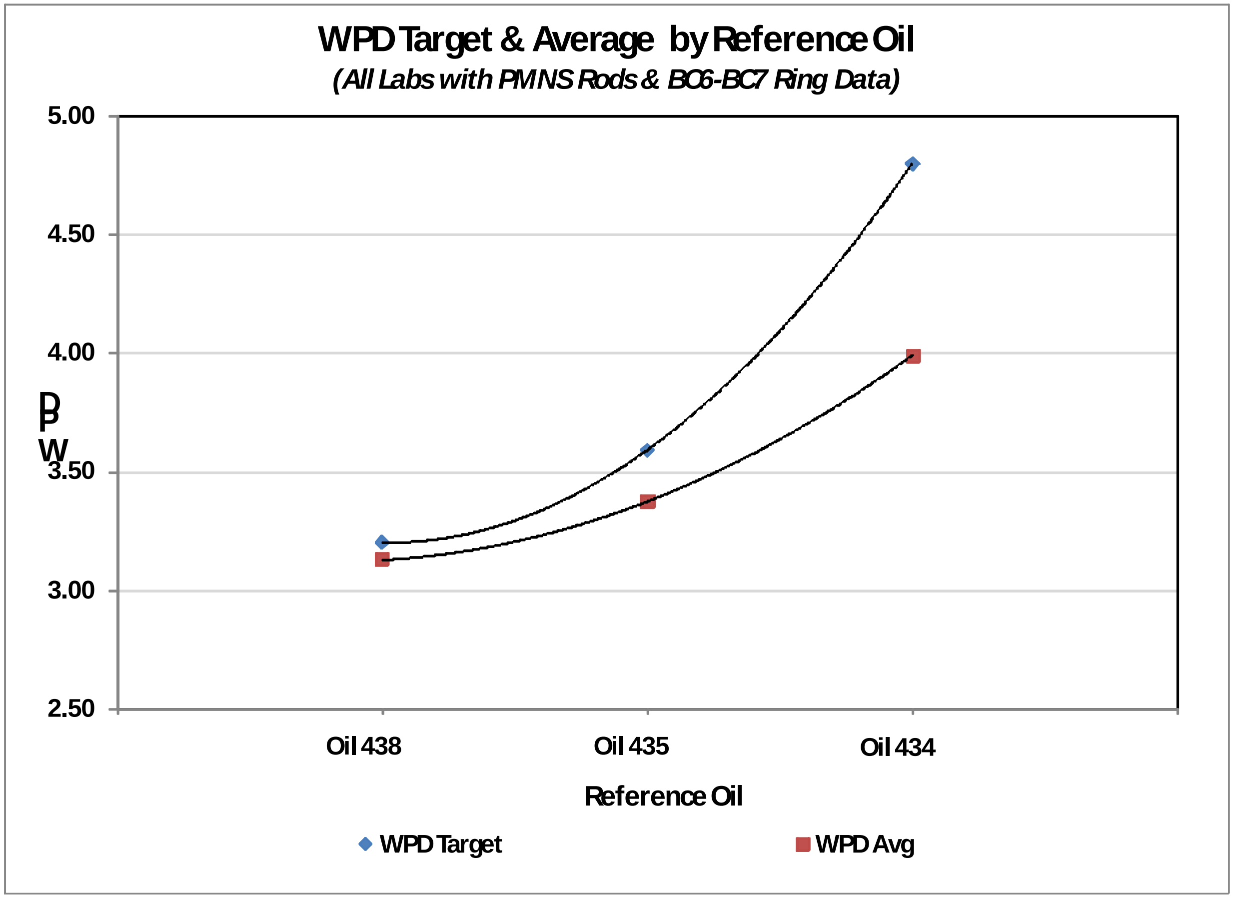
WPD Parameter Review

- Similar plot except grouped by test laboratory.



WPD Parameter Review

- A plot of the WPD means by reference oil also suggests that the WPD parameter is operating below the established performance targets. *(Data means based on PMNS & BC6-BC7 ring hardware.)*



WPD Parameter Review

- WPD Parameter Summary:

  – The LTMS CUSUM and Severity charts indicate that the test is severe and at the warning limit.

  – CUSUM plots of the deposit location parameters indicate that the test is performing both mild and severe – as compared to when the test was established.

  – An analysis of the WPD parameter data provides evidence that there is statistical difference in test performance in the current test period as compared to the period when the test was established.

  – Possible Corrective Action:

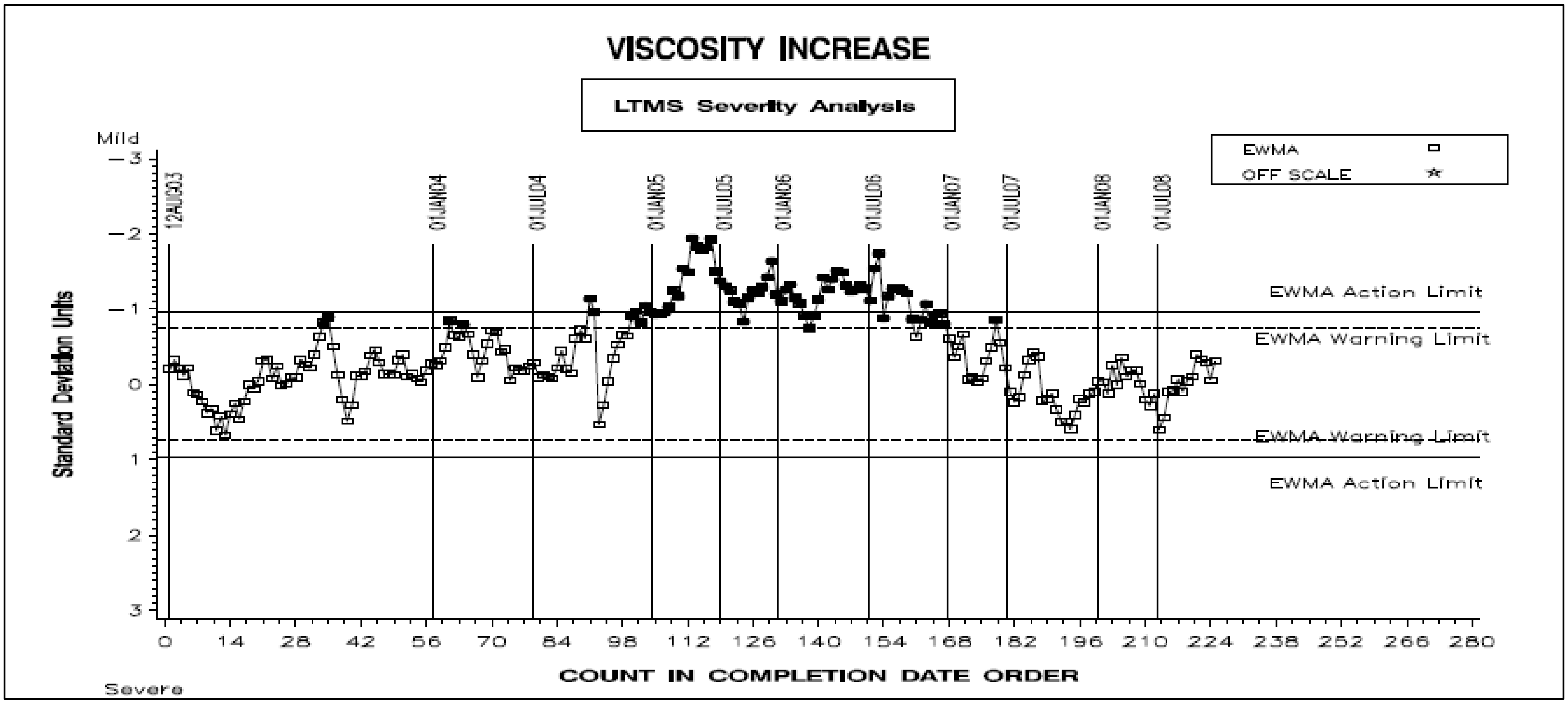
    - Recommend to explore options to return the test to target and/or increase the speed of earning SA's

WPD Parameter Review

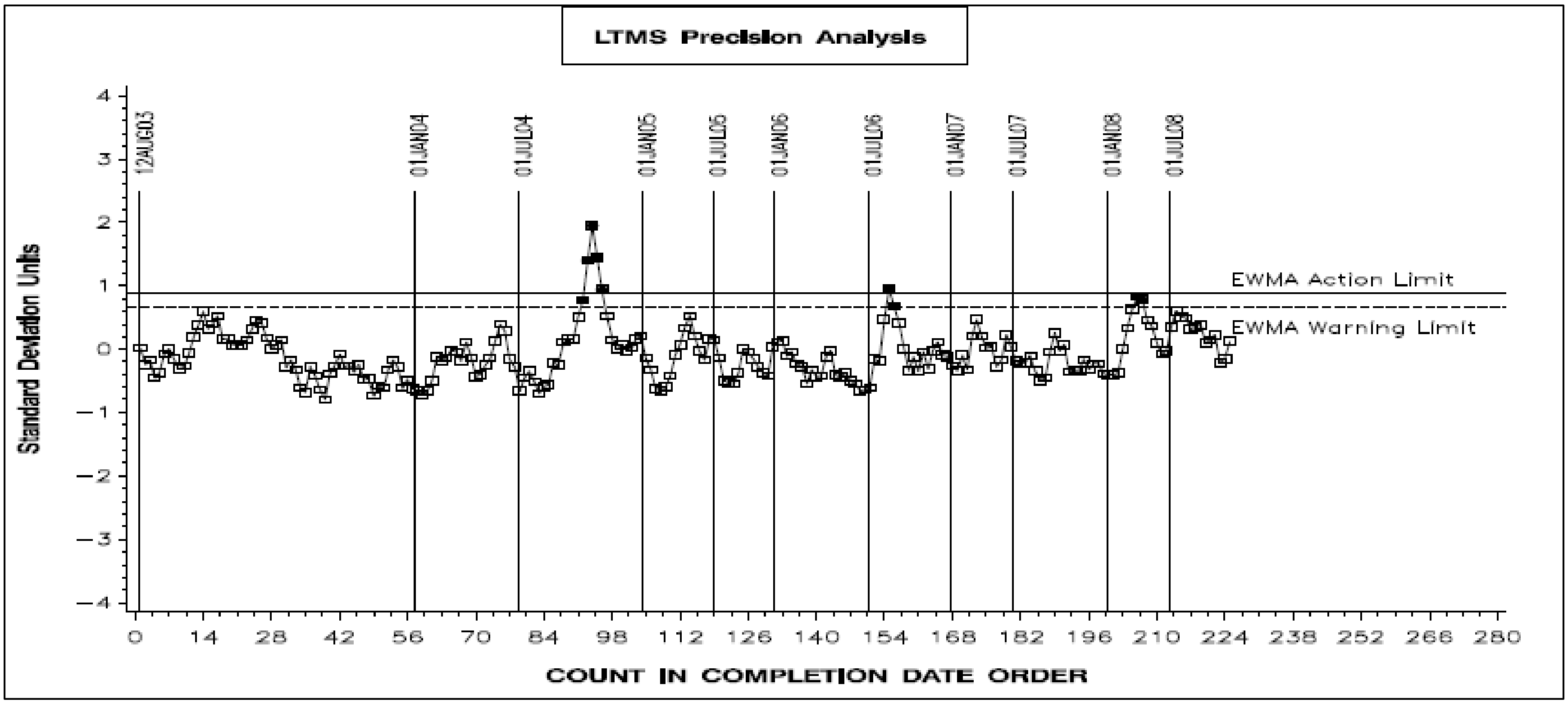
- Options to bring test back to target values:
  - Option 1: Apply a correction factor to return the test back to target values
    - If special cause for the severity trend can be identified, then it may be possible to apply a correction factor.
    - Concern with correction approach is that the severity trend may drift back to a mild condition with new hardware, fuel batches, and/or build procedures. If it does trend in a mild direction, then a correction will no longer be applicable.
  - Option 2: Modify LTMS
    - The data shows that the test is more severe with reference oils 434 and 435. Thus, it may be advantageous to eliminate the 438 reference oil.
    - Revise the Lambda and/or K values to increase the speed of earning a severity adjustment.

Appendix A
LTMS Charts of PVIS Parameter

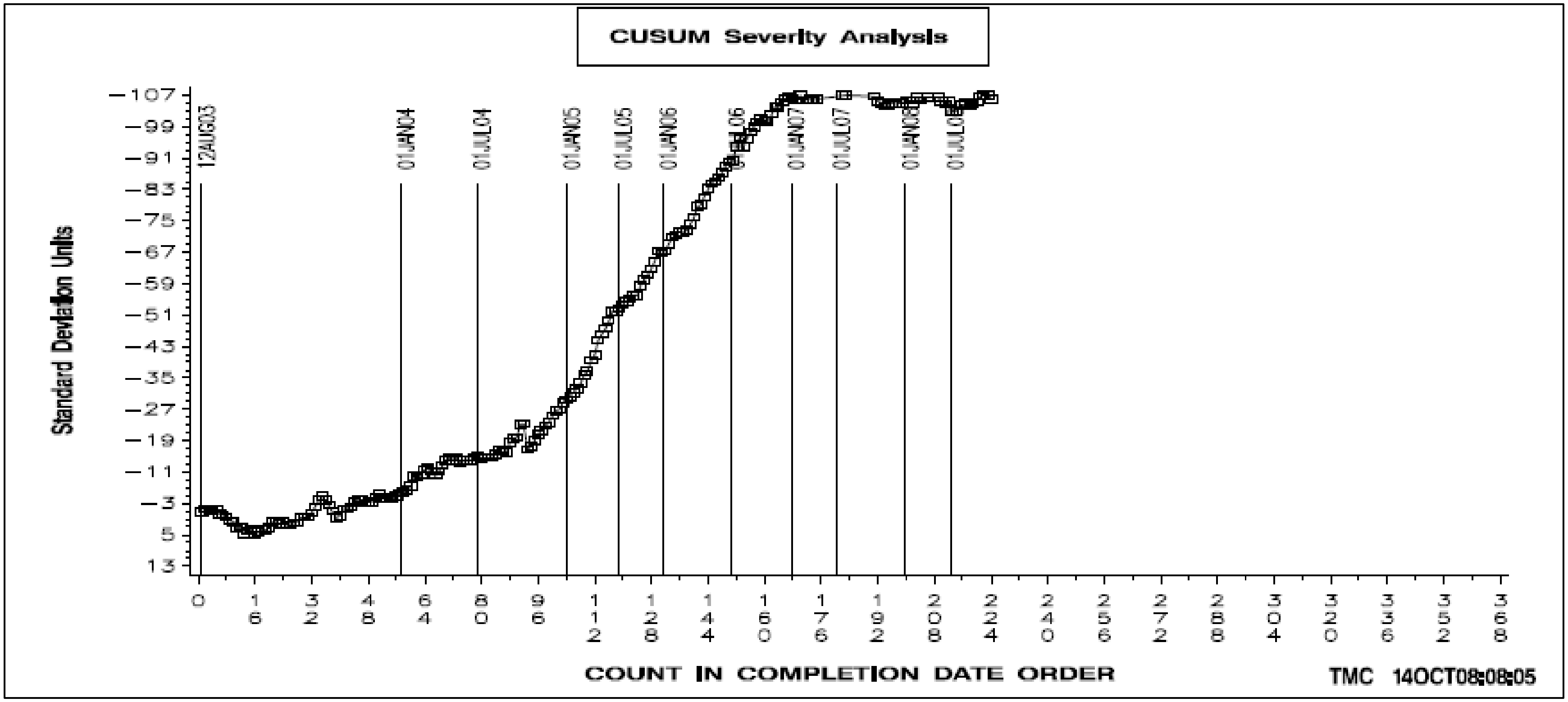
LTMS Severity Chart (Ln(PVIS) Parameter)



LTMS Precision Chart (Ln(PVIS) Parameter)

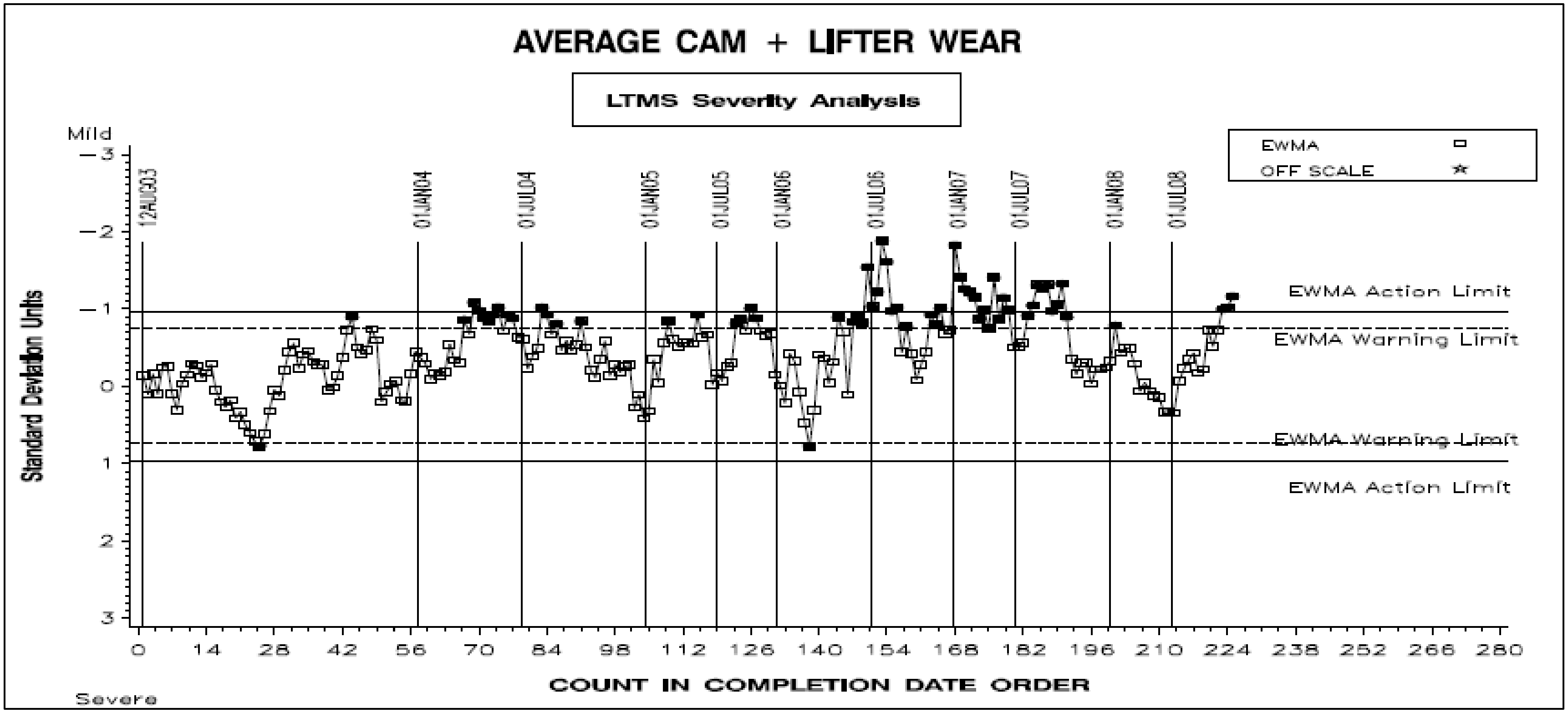


LTMS CUSUM Plot (Ln(PVIS) Parameter)



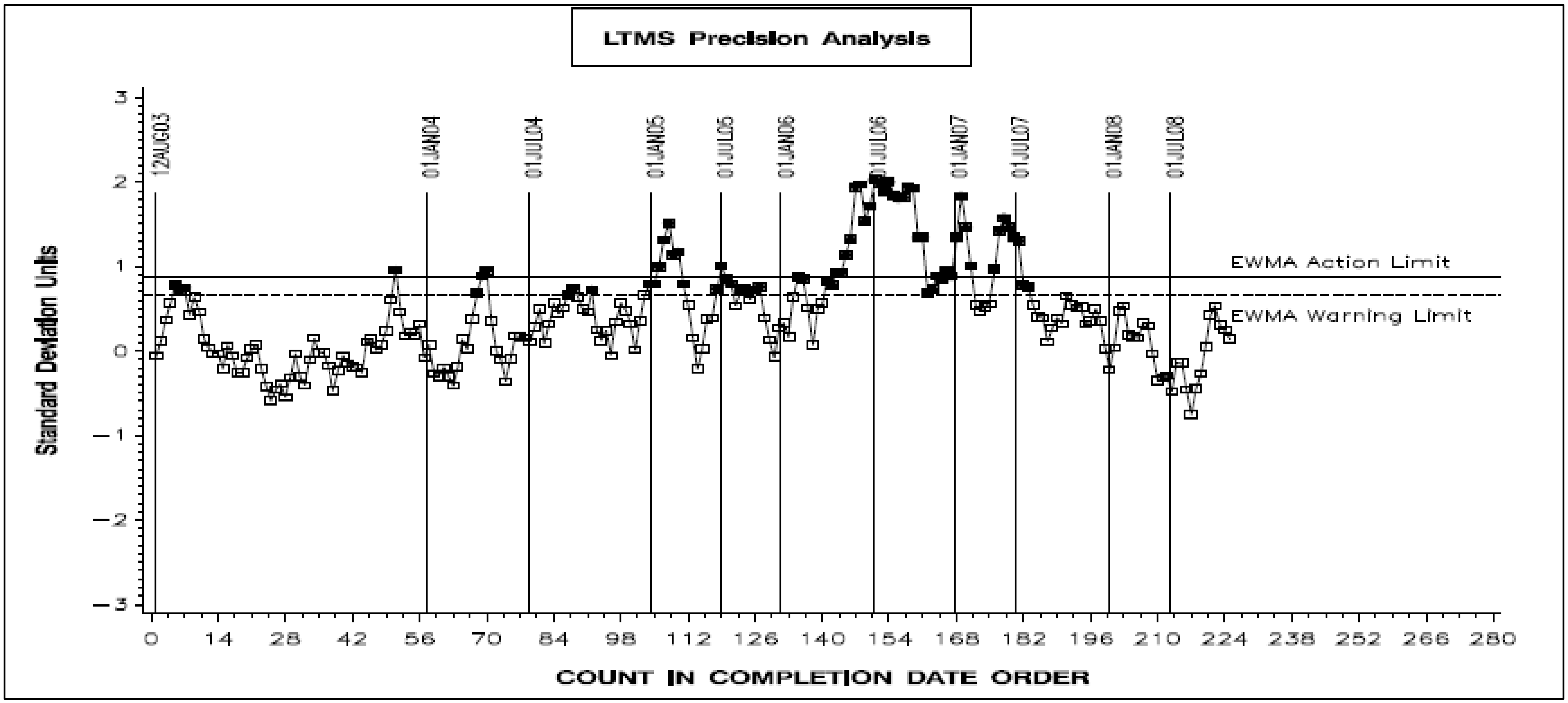
Appendix B
LTMS Charts of Ln(ACLW) Parameter

LTMS Severity Plot (Ln(ACLW) Parameter)

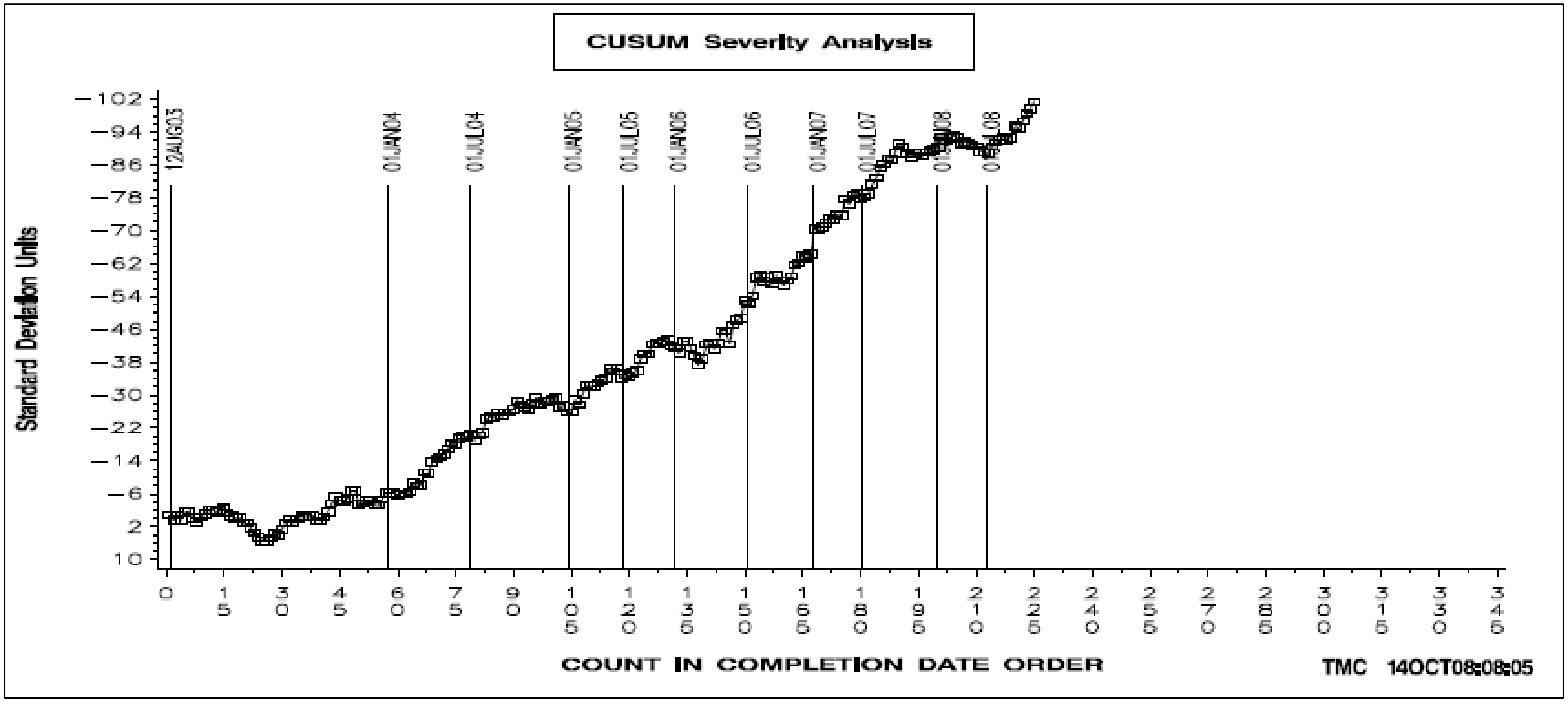


A Passion for Solutions.

LTMS Precision Plot (Ln(ACLW) Parameter)

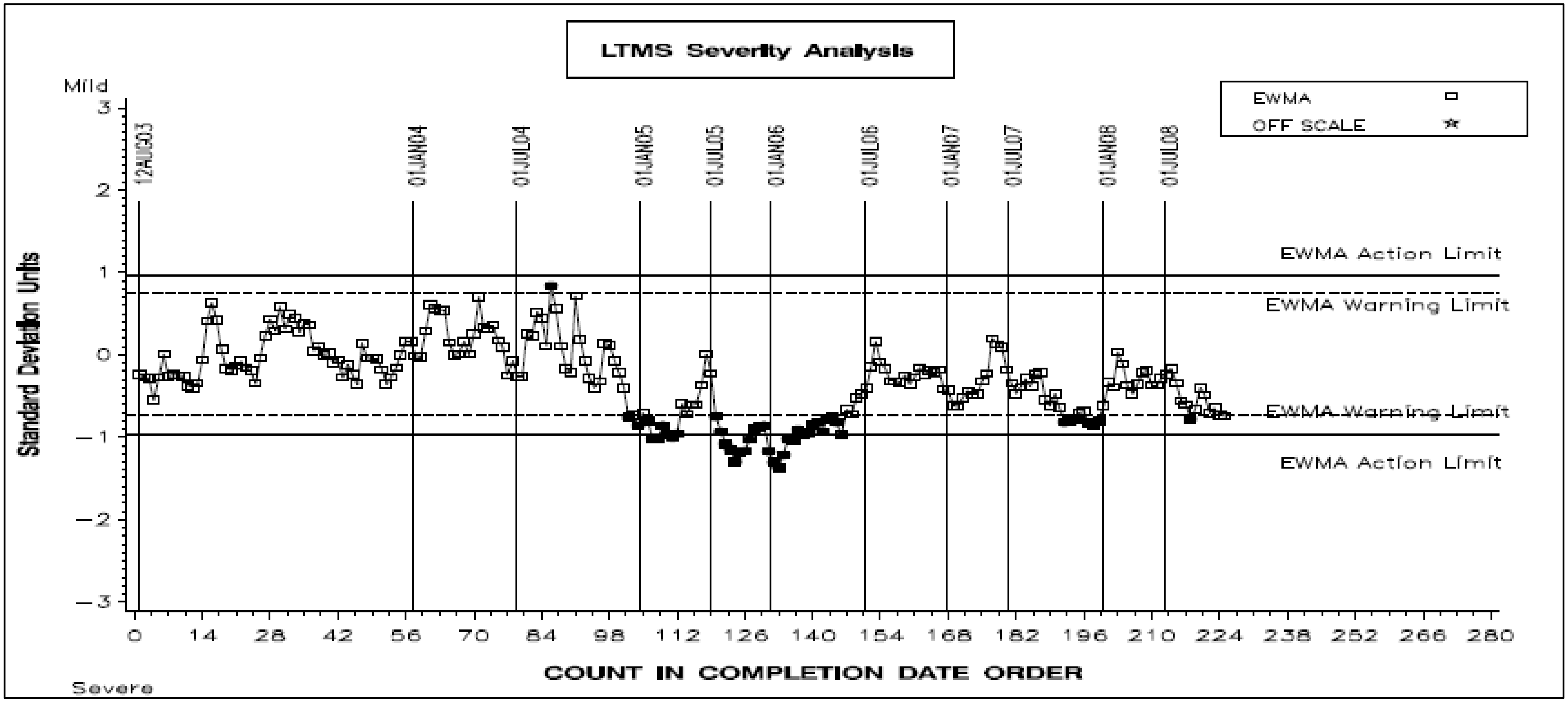


LTMS Severity CUSUM Plot (Ln(ACLW) Parameter)

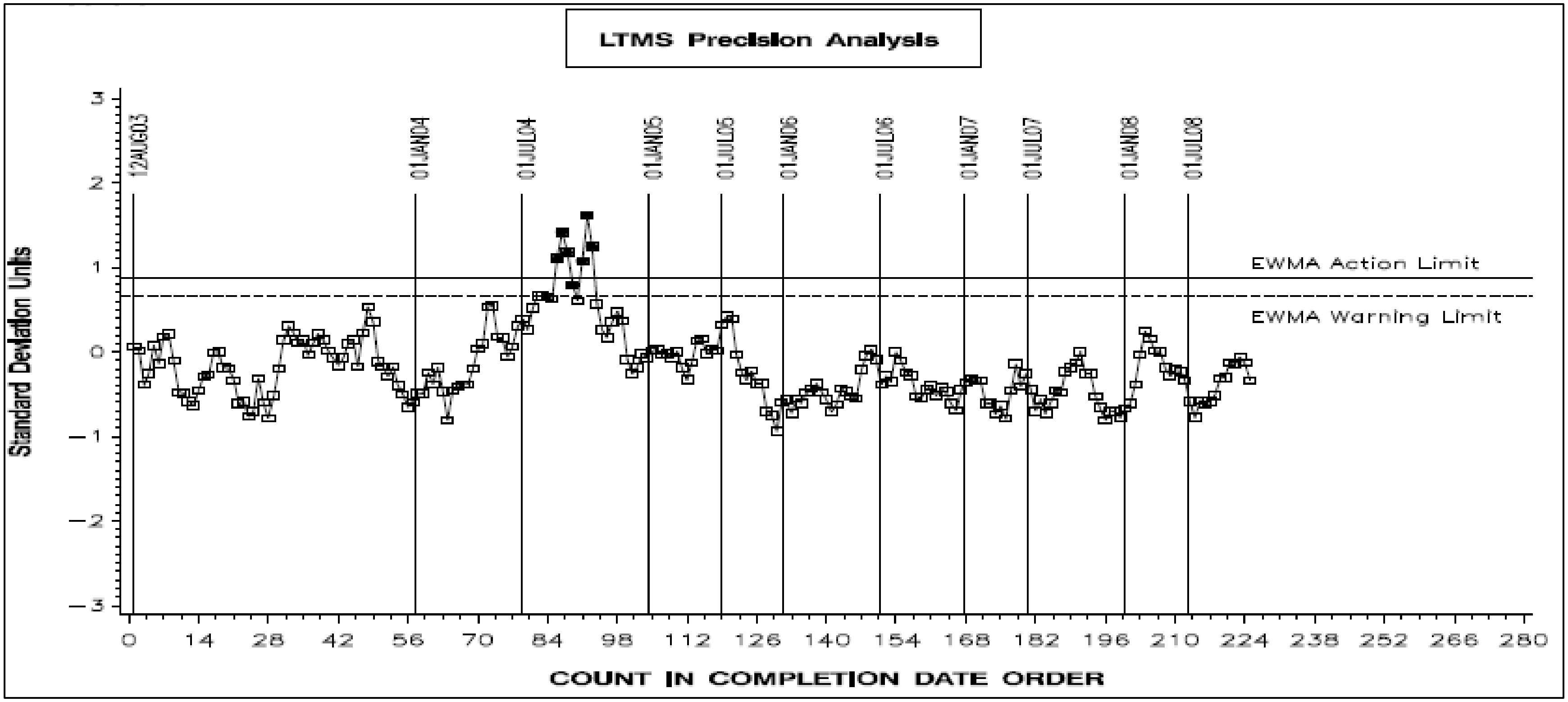


Appendix C
LTMS Charts of WPD Parameter

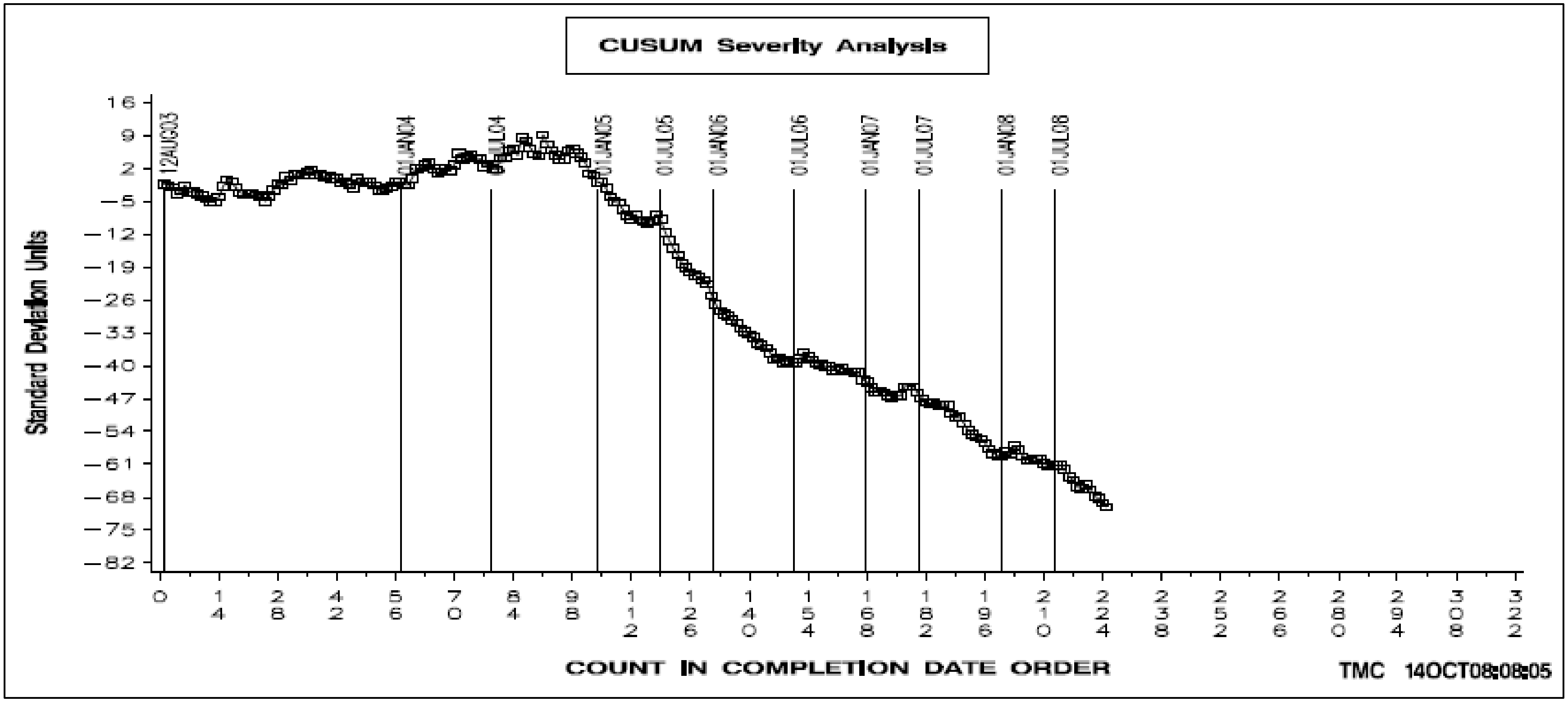
LTMS Severity Analysis Plot (WPD Parameter)



LTMS Precision Analysis Plot (WPD Parameter)



LTMS Severity CUSUM Plot (WPD Parameter)



OHT3G-093-1

OIL PAN GASKET CHANGES

DESIGN CURRENTLY IN USE WITH SEQUENCE III

- INCLUDES RAISED GASKET
- MATERIAL CANNOT BE MANUFACTERED ANYMORE

DESIGN CURRENTLY MANUFACTURED FOR GM

- DOES NOT INCLUDE RAISED GASKET
- MUST USE RTV FOR SEALANT

AFTERMARKET DESING

- INCLUDES RAISED GASKET
- MINOR WINDAGE TRAY DIFFERENCES