2.7L Nano Intake Valve Failures

U725 Warranty Claims and ERA proposal

Paul Adam

Jeff Kolodziejczyk

UPDATED: 8/4/21

PANEL

Issue Title:	Intake Valve Failures at 3rd keeper groove on 20-21MY 2.7L / 3.0L Engines.	**Champion:**	Dave Simon / Jeff Bautz
Source:	PT Current Model Quality Engine Exchange List.	**Team:**	B. Rhude, P. Adam, J. Kolodziejczyk, G. Pearson, Z. Ward T. Knott, M. Hewlett, T. Strand
Issue Description:	2020 - 21MY 2.7/3.0L Nano engine failures due to 3rd keeper groove fracture on left bank intake valves occurring at low time in service.		
Containment:	Implement micro indent core hardness checks, increase frequency of coolant flow and position checks at grinding operation, Increased visual inspection.		
Root Cause:	Side loading of the valve tip from rocker arm tipping as a result of valvetrain dynamics caused by increased lash in the system.		
Corrective Action:	Implement following ERA's: Increase frequency core micro hardness checks and control plan update. Including batch and hold Change valve material to Silchrome 1 for improved robustness to side loading and significantly higher high temperature fatigue strength properties. Increase nominal keeper groove diameter and revised tolerance.		

Workplan: (As appropriate, include corrective action selection; A-B Testing; CR authorization; DV, PV & PSW completion dates; date issue goes to major contained / comply / NIL, and other key steps. Final resolution in place and verified)

Step	Date	Lead
Supplier Inspection of returned valves (hardness and geometry)	Complete	Eaton (Wes / Tyson)
ERA1 – Increase 1 /shift hardness check to 3 per shift in reaction to returned part analysis >57 HRC - Increase 1/shift operator tip hardness check to 1/hr. Batch and hold each shift.	Complete	Tyson Strand (Eaton)
ERA2 - Silchrome 1 material implementation.		
- Confirm material availability timing	Complete	[redacted]
- Eaton NTE Cost Response	Complete	[redacted]
- Notice release (Authorization at C-Status to proceed)	Complete	[redacted]
- PPAP parts to LEP	8/26/21	[redacted]
- DR1 PV Engine builds	9/1/21	[redacted]
- PV Testing (PRDC PV Length EFT) – Verify heat treat and tempering process setting for Sil1	Est 9/21/21	[redacted]
- Production parts available at LEP	9/1/21	[redacted])

Prevent Action:					
Risk Projections: (Major/ Major Contained/ Comply)				**Date Issued:**	07/21/21
				Revised:	8/11/21

PANEL

Workplan:
(As appropriate, include corrective action selection; A-B Testing; CR authorization; DV, PV & PSW completion dates; date issue goes to major contained / comply / NIL, and other key steps. Final resolution in place and verified)

Step	Date	Lead
Increase HLA Height for CLAG Reduction (RFF Guidance) - Determine feasible change maintaining lash adjuster functional range (reviewing seat recession ETAG) - Update Layout Solver / Marked Up Drawing to LEP / CEP for feasibility and timing - Stack up review / CLAG VSA - CEP / LEP Timing for implementation	 Complete Complete Complete TBD	 Adam Heggie Adam Adam / Hewlett / Mancini
U725 return part analysis: (receive parts 8/2/21) - Valve analysis by Eaton - Schaeffler RFF and HLA inspection - Cylinder head – HLA bores roundness, depth, true position of the HLA bore and the true position of the valve guide. Cam bore alignment	 Complete Complete 8/15/21	 Wes Grundemann Larry Trpcevski F. Heggie
U725 Oil pan handling evaluation - Successfully completed. The oil pressure warning light did not illuminate when the oil level was adjusted from 1.5 US quarts below the full mark to 1.0 US quart below the full mark. 100% down High RPM (45 deg)	Complete	Pearson
Other material substitution for Sil1 (Star Wire recommending EMS248 – Japan variant of EMS1 (Sil1))	Complete	Wes Grundemann
Impact testing of Silchrome 1 vs Silchrome lite at central labs	9/1/21	B. Rhude

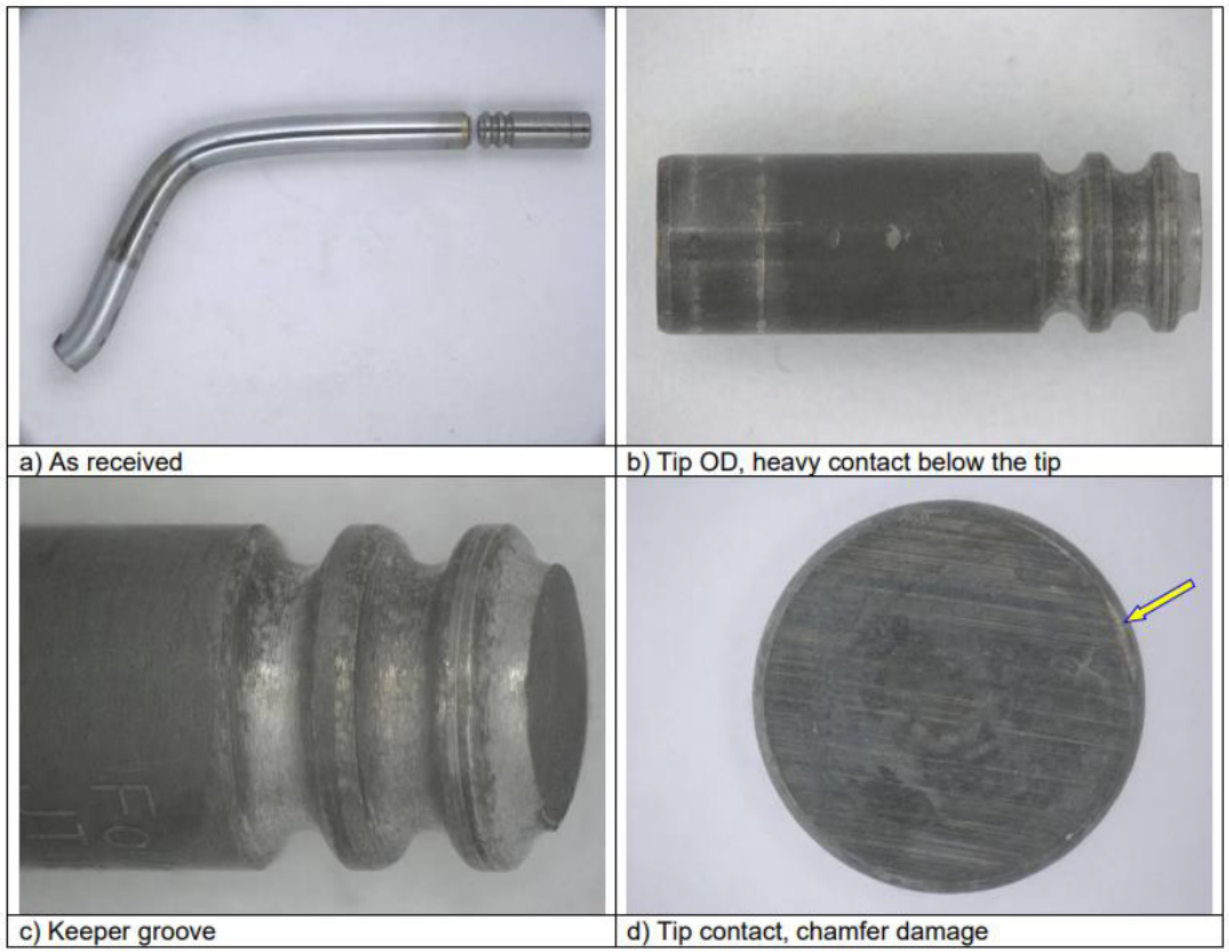
PANEL

Workplan:
(As appropriate, include corrective action selection; A-B Testing; CR authorization; DV, PV & PSW completion dates; date issue goes to major contained / comply / NIL, and other key steps. Final resolution in place and verified)

Step	Date	Lead
ERA3 - increasing 3rd keeper groove root diameter for x-sectional area		
- Stackup to identify opportunity w/ key bead clearance	Complete	Adam
- EATON feasibility/timing for grinding modification and sample timing (wheel change vs. tool path change)	Complete	EATON (Adam / Kolodziejczyk)
- Production run of increased root diameter at Eaton	Complete	EATON (Adam / Kolodziejczyk)
- Ship PTR parts to LEP	8/11/21	Wes Grundemann (Eaton)
- Production Parts (Included with Sil1 material change)	8/26/21	Tyson Strand (Eaton)
- Impact testing to quantify strength benefit	9/3/21	B. Rhude
Implement Oil Pressure Increase (Calibration)		
- Develop updated tables based on 2-Stage Oil Pressure Survey	Complete	Kolodziejczyk
- Confirm FE Impact (M Delproposto / Kristen Hauser) – (0.2% M/H Degradation – Data provided to CVSP)	Complete	Delproposto / Hauser
- Program Fuel Economy Impact from CVSP results (P702 & U725)	8/12/21	Hauser / Parrado
- Calibration / Certification Impact	8/13/2021	A. Dame / J. Murphy
- Cert Review for calibration release (Whitepaper if program FE impact <0.05 MPG M/H)	8/18/21	A. Dame / J. Murphy
- Vehicle confirmation of cal changes	Complete	J. Murphy
- Cal release timing	TBD	A. Dame / J. Murphy
Increase LH HLA Gallery Restriction in Head Gasket		
- Identify existing orifice punch sizes from gasket supplier – (Anything 3.6mm or less available – Turned down from stock)	Complete	Henne
- Verify current model prediction for LH HLA gallery	Complete	Chen
Run lubrication model simulation on baseline vs. increased orifice sizes – (increase increments delta 0.25)	Complete	Crowe / Chen
- Model impact to VCT on all application (Edge LH head w. vac pump)	8/12/21	Chen
- Head gasket cost and implementation timing – (3 weeks for PPAP parts)	Complete	Henne
- 3.0L Lube survey validation / model correlation	8/20/21	S. Yamada
- Production Parts at LEP (Pending analysis of lube system performance)	TBD	J. Henne
Eaton quality history (Hardness, Hardness Depth, Stem Diameter, Keeper Groove Root Diameter)	Complete	EATON (Adam / Kolodziejczyk)
Schaeffler capability assessment for 0.5mm (1/2 tolerance) refinement (Roller Perpendicularity, Roller Parallelism)	8/4/2021	Schaeffler (Adam / Kolodziejczyk)
- Concern for 0.05 perpendicularity pending capability data (Currently at W-Status)	TBD	Rhude
Tolerance refinement to support RFF alignment improvement		
- LEP/CEP capability study to support tolerance refinement (Guide true position, HLA bore true position)	Complete	Heggie / Reinhart
- LEP/CEP implementation timing for tolerance refinement	TBD	LEP (TBD)

Problem Statement:

37 total Nano 2.7L & 3.0L engine exchanges in 2020 - 2021MY due to 3rd keeper groove fracture on left bank intake valves occurring at low time in service. Fractured valves show evidence of side loading.



a) As received | b) Tip OD, heavy contact below the tip

c) Keeper groove | d) Tip contact, chamfer damage

- All returned valves show evidence of side loading / impact.
- Witness marks of RFF side wall contact & RFF tipping. Significant wear depth at witness marks.
- Chamfer impact damage aligning with crack initiation point on fractured surface.
- RFF side wall broken or damaged in some cases.
- Parts within specification. Hardness 50-57 HRC

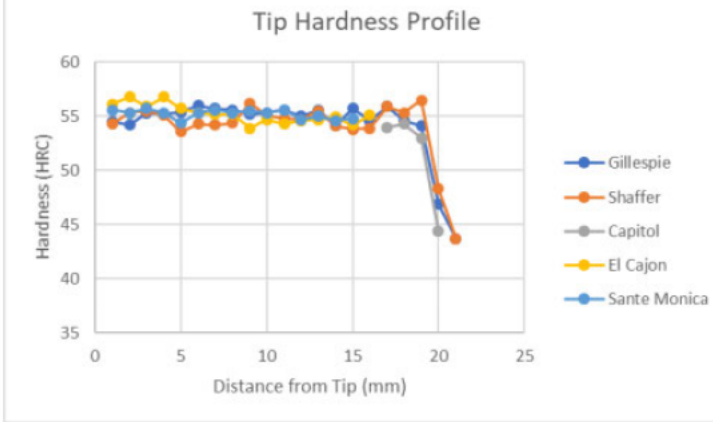
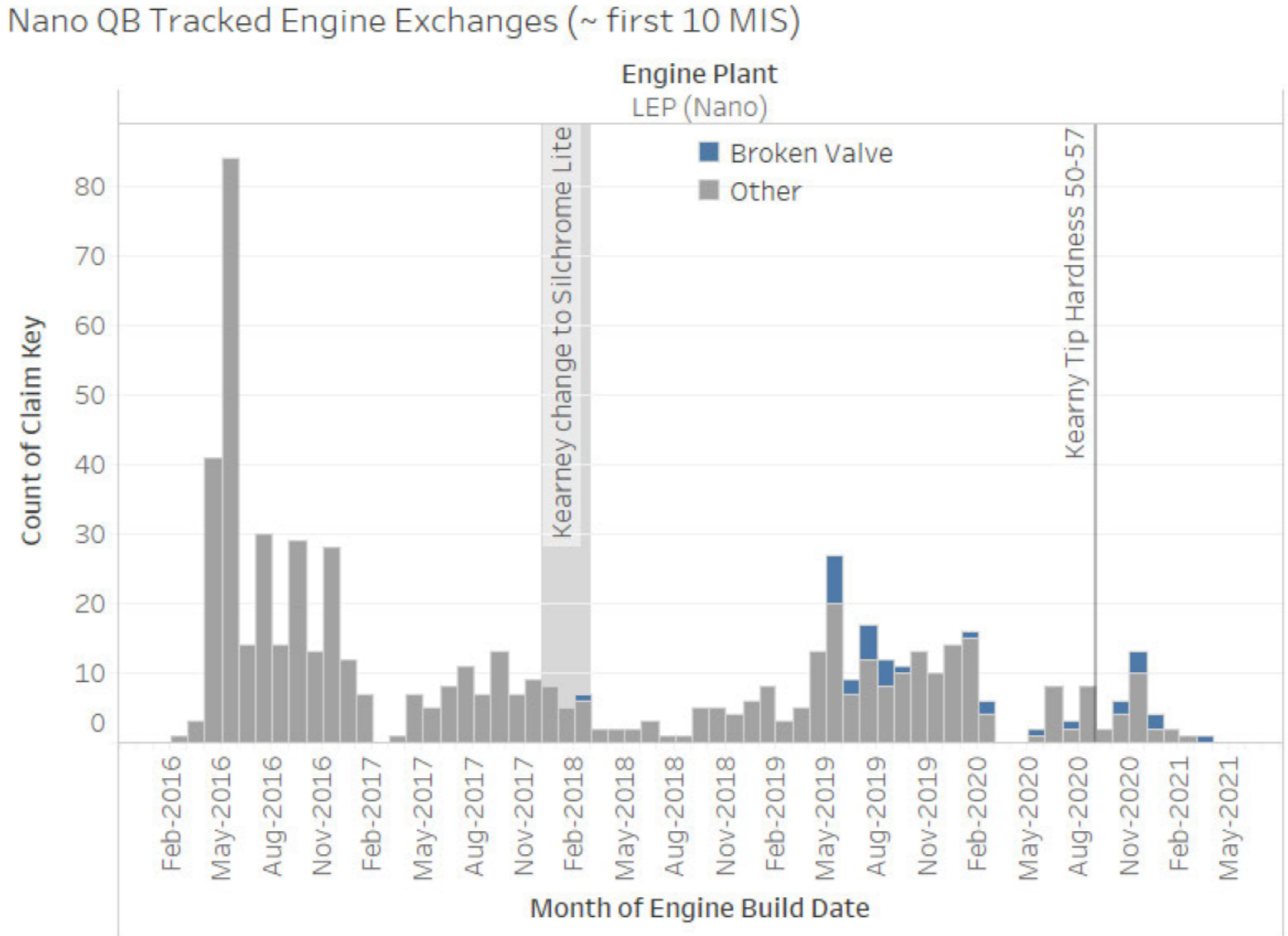


Figure 7: Tip hardness profile measured HV0.5 and converted to HRC. The valve tips exhibit a typical induction hardened profile.



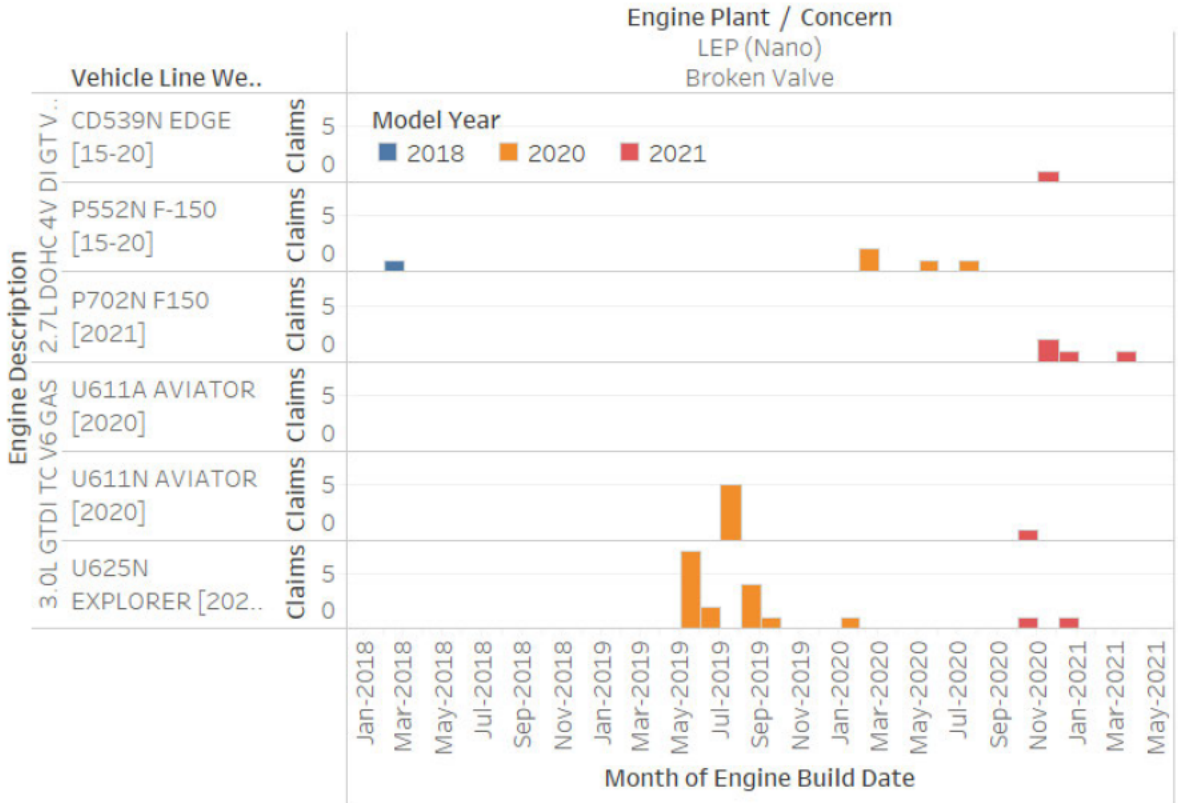
- 25 intake valve 3rd keeper groove claims in 2020MY
- 10 claims in 2021MY
- 1 claim prior in 2018MY

- FT4E-6507-CA –
  - Original MY 2015 Production Launch Intake Valve
  - Silchrome 1 Material
  - Tip Hardness 50 MIN
  - Scraper groove on stem
- JT4E-6507-AA
  - SOP September of 2016.
  - MY upgrade. Only change from FT4E design is the absence of a scraper groove
  - Silchrome 1 material
  - Tip Hardness 50 MIN
- JT4E-6507-AB
  - SOP Q1 of 2018.
  - TVM action material change to Silite
  - Launched with tip hardness spec of 50MIN
  - Tip hardness spec changed to 50-57 HRC in October 2020.

PANEL

3rd Keeper Groove Failures

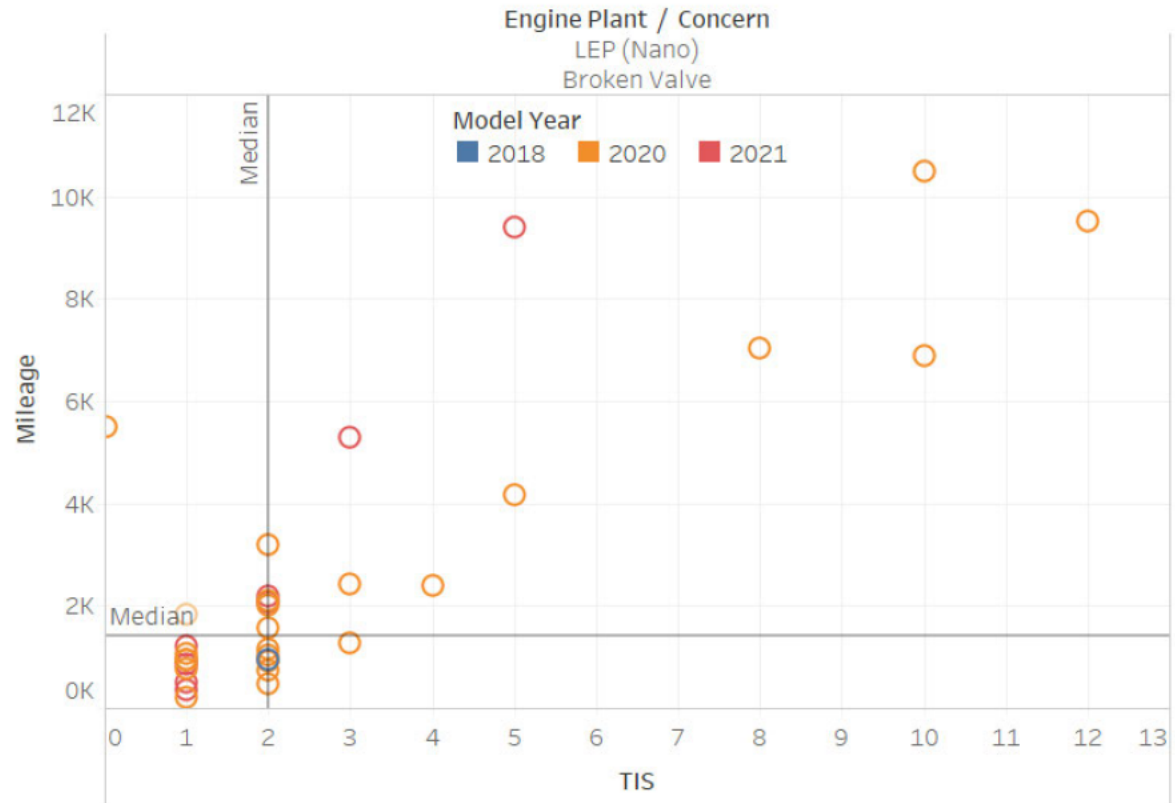
Nano 3rd Keeper Groove Failures



Claims on both 2.7L & 3.0L. Truck and car

1 claim prior to 2020 MY on 2.7L F150

Nano 3rd Keeper Groove TIS & Mileage



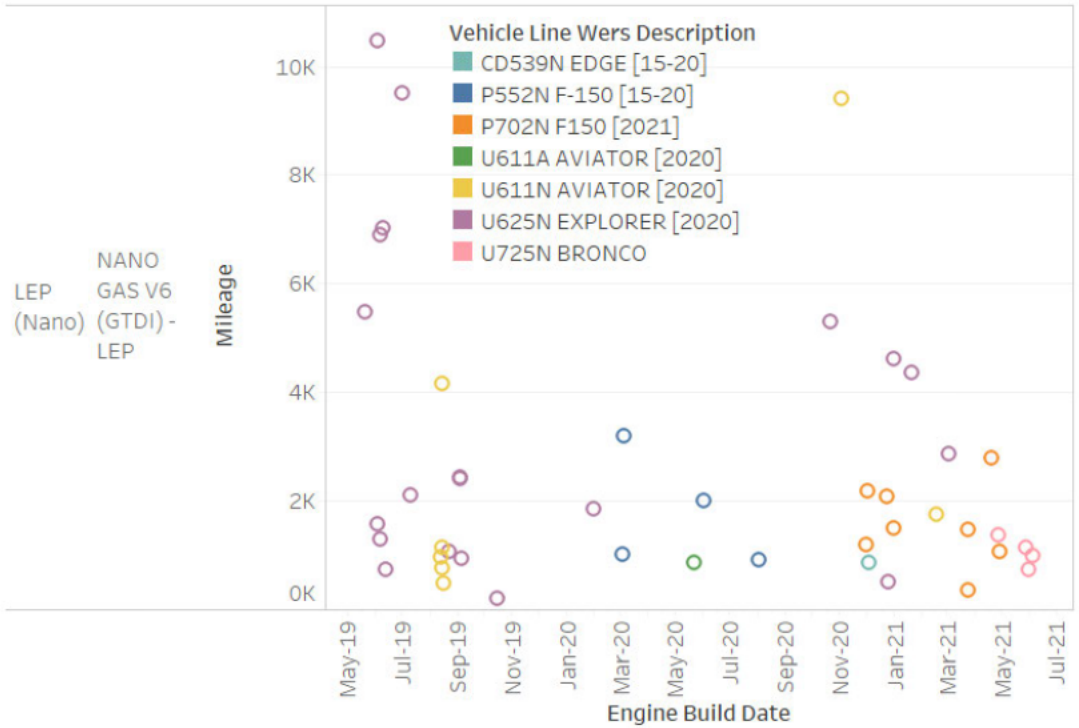
Failures occur at low time in service

PANEL

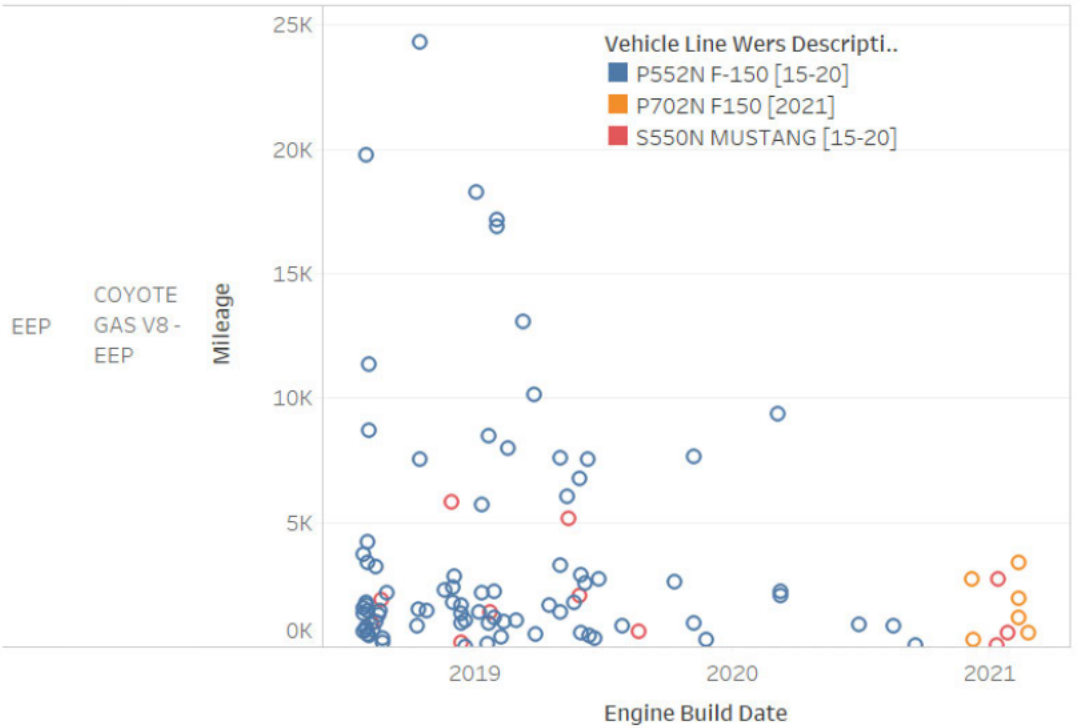
3rd Keeper Groove Failures

Updated 9/1/21:

QB tracked 3rd Keeper Groove Failures



QB tracked 3rd Keeper Groove Failures



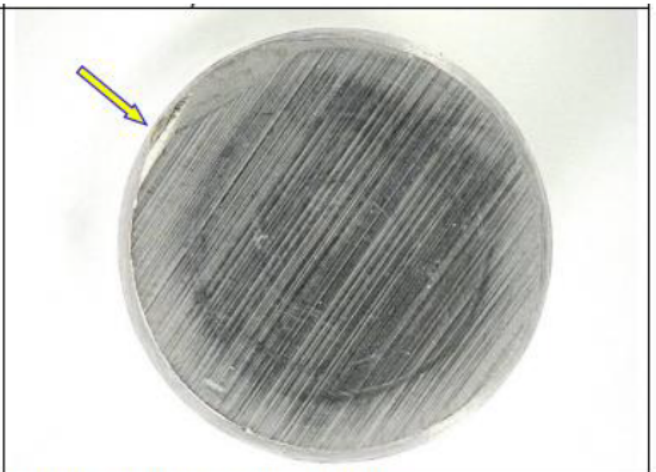
U725 Valve Failure Teardown Observations: (Grand Rapids Vehicle VIN 6408)

- #6 Secondary intake valve 3rd keeper groove failure
- Signs of RFF tipping in other locations. #4 primary Intake & 5 secondary intake.
- RFF side walls show edge break and polishing.
- #4 primary shows valve tip chamfer damage and other marks indicting side loading.
- Failure consistent with previous warranty claims.

a) As received

b) Tip OD, heavy contact below the tip (arrows indicate the orientation of the chamfer damage to crack initiation)

c) Keeper groove



d) Tip contact, chamfer damage

U725 Valve Failure Teardown Observations: (Bommarito Ford Vin: 1500)

- #5 Primary intake valve 3rd keeper groove failure
- Failure consistent with previous warranty claims.

a) As received

b) Tip OD, heavy contact below the tip (arrows indicate the orientation of the chamfer damage to crack initiation)

2% Nital 100X
c) Fracture origin at the keeper groove

2% Nital 100X
d) Final fracture at the keeper groove

Figure 4: Etched micrographs on the longitudinal section thru the fractured valve tip. The valve tip microstructure consists of tempered martensite at the surface and core consistent for hardened and tempered EMS-322. The keeper groove surface exhibits light grinder burn.

Table 1: Microhardness measurements on the left and right keeper groove cross-sections measured HV0.5 and converted to HRC. The left and right keeper grooves exhibit typical hardness values.

	Left Side	Right Side
KG 1	56.1	57.6
KG 2	56.3	58.0
KG 3	56.7	57.5

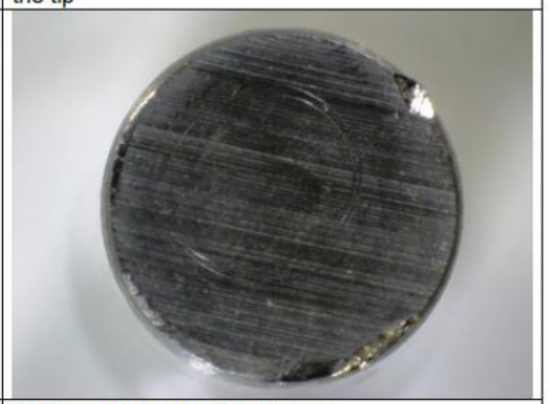
U725 Valve Failure Teardown Observations: (Autonation Ford Frisco Vin: 2960)

- #6 Primary intake valve 3rd keeper groove failure
- Failure consistent with previous warranty claims.

a) As received

b) Tip OD date code 21-E-08, heavy contact below the tip

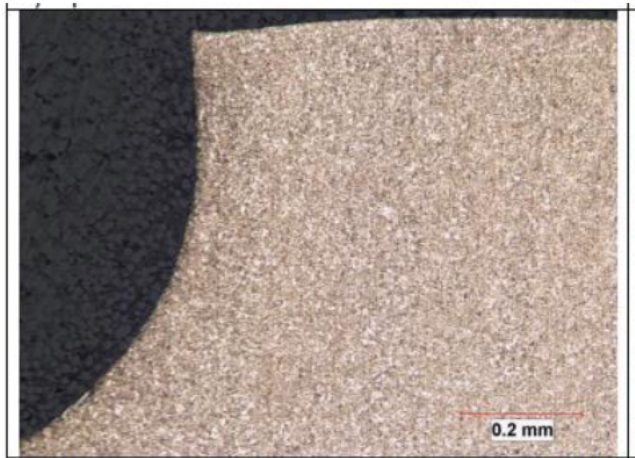
c) Keeper groove, typical contact



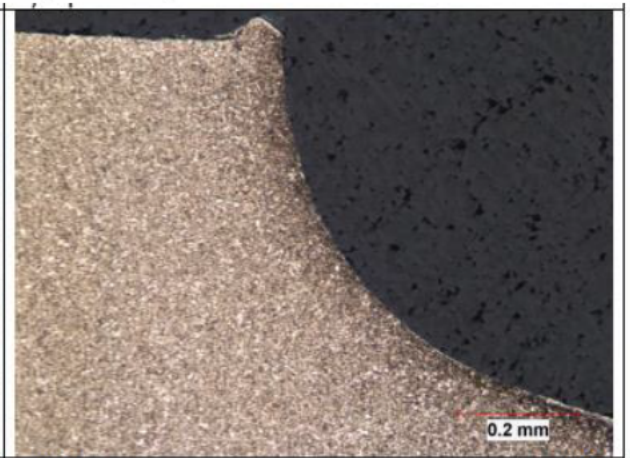
d) Tip contact, chamfer damage

Table 1: Microhardness measurements on the left and right keeper groove cross-sections measured HV0.5 and converted to HRC. The left and right keeper grooves exhibit typical hardness values.

	Left Side	Right Side
KG 1	59.2	58.9
KG 2	59.3	59.2
KG 3	59.1	58.4



2% Nital 100X
c) Fracture origin at the keeper groove



2% Nital 100X
d) Final fracture at the keeper groove

Figure 4: Etched micrographs on the longitudinal section thru the fractured valve tip. The valve tip microstructure consists of tempered martensite at the surface and core consistent for hardened and tempered EMS-322. The keeper groove surface shows no evidence of grinder burn at the fracture.

- EF06A21161120082 MB3E 6007 AA (1146 miles Grand Rapids Mi.)

Valve production date May 14, 2021

GENERAL VEHICLE INFORMATION: (Related Claims) (QLS Concerns) (Lincoln PDI)

VIN:	1FMEE5DP3M[redacted]	**Vehicle Line WERS:**	T/G1 - U725N BRONCO [2021]	**Engine:**	T/WQ - 2.7L DOHC 4V DI GT V6 GAS/FFV
Model Year:	2021	**Vehicle Line AWS:**	B1 - BRONCO	**Global Engine:**	E2277 - NANO GAS V6 (GTDI) - LEP
Vehicle Type:	T	**Vehicle Line Global:**	HL - BRONCO (NA-MAP)	**Engine Plant:**	EN22 - LIMA
Inv. Dealer:	48100	**Drive Code:**	T/F - 4 WHL L/H FULL TIME DRIVE	**Transmission:**	T/ET - 10 SPD AUTO TRANSMISSION-10R60
Vehicle Status Code:	800	**Body Cab Style:**	T/WL - 5 DOOR	**Global Trans:**	A0822 - AT - 10R60 - LTP
Market Derived:	F - FORD	**Version/Series:**	T/HJ - BADLANDS	**Trans Plant:**	AT08 - A/T LIVONIA

- EF06A21165120177 MB3E 6007 AA (743 Miles Missouri)

Valve production date March 17, 2021

GENERAL VEHICLE INFORMATION: (Related Claims) (QLS Concerns) (Lincoln PDI)

VIN:	1FMEE5BP[redacted]	**Vehicle Line WERS:**	T/G1 - U725N BRONCO [2021]	**Engine:**	T/WQ - 2.7L DOHC 4V DI GT V6 GAS/FFV
Model Year:	2021	**Vehicle Line AWS:**	B1 - BRONCO	**Global Engine:**	E2277 - NANO GAS V6 (GTDI) - LEP
Vehicle Type:	T	**Vehicle Line Global:**	HL - BRONCO (NA-MAP)	**Engine Plant:**	EN22 - LIMA
Inv. Dealer:	*	**Drive Code:**	T/E - 4 WHL L/H PART TIME DRIVE	**Transmission:**	T/ET - 10 SPD AUTO TRANSMISSION-10R60
Vehicle Status Code:	800	**Body Cab Style:**	T/WL - 5 DOOR	**Global Trans:**	A0822 - AT - 10R60 - LTP
Market Derived:	F - FORD	**Version/Series:**	T/HE - OUTER BANKS	**Trans Plant:**	AT08 - A/T LIVONIA

- Potential 3rd engine failure
- EF06A21169120323 MB3E 6007 AA (985 miles Frisco Texas)

Report# :	M8XEB004 NHL			**Received:**	08/24/2021
CCRG/EPRC:		**Reviewed Status:**		**Date:**	
Vehicle:	2021,BRONCO 4X4 ,ADVANCE,4DR ,MPV ,1FMEE5DP0[redacted]			**Build Date:**	06/30/2021
Odometer :	985 M	**Engine:**	2.7L 4V	**Calibration:**	
Transmission:	10R60	**Axle:**		**A/C:**	YES
Dealer:	USA 02441 AutoNation Ford Frisco			**Phone#:**	972-335-5000
City:	Frisco	**State:**	Texas	**Country :**	USA
Originator:	JASON SMITH	**Originator e-mail:**	SMITHJ19@AUTONATION.COM		
Symptom:	4 40 1 02 ST/RN/MV,STARTING,NO CRANK,ALWAYS				
Status:					
VFG:	V52 DRIVEABILITY				
Additional Symptom:	engine damage				
Fix:	**Causal Component :**		--		
Condition Code:					

Torn down Monday 9/20. Parts shipped to Eaton

Confirmed: Bommarito Ford – cyl head assembled 09-JUN-21 (ESN EF06A21165120177MB3E 6007 AA)
Confirmed: Keller Ford – cyl head assembled 07-JUN-21 (ESN EF06A21161120082MB3E 6007 AA)
Suspect: Autonation Frisco – cyl head assembled 12-JUN-21 (ESN EF06A21169120323MB3E 6007 AA)
Suspect: Dewey Moore Ford – cyl head assembled 07-MAY-21 (ESN EF06A21131120228MB3E 6007 AA)

4th engine failure to be confirmed
1FMEE5DP8M[redacted]

- Potential 4th engine failure

Report# :	M84EU002 NHL			**Received:**	08/30/2021
CCRG/EPRC:		**Reviewed Status:**		**Date:**	
Vehicle:	2021,BRONCO 4X4 ,ADVANCE,4DR ,MPV ,1FMEE5DP8N[redacted]			**Build Date:**	06/12/2021
Odometer :	1,372 M	**Engine:**	2.7L 4V	**Calibration:**	MTG1WQNA
Transmission:	10R60	**Axle:**		**A/C:**	YES
Dealer:	USA 02508 Dewey Moore Ford			**Phone#:**	[redacted]
City:	Hughes Springs	**State:**	Texas	**Country :**	USA

[redacted]

Symptom: 4 40 1 02 ST/RN/MV,STARTING,NO CRANK,ALWAYS

Status:

VFG: V52 DRIVEABILITY

Additional Symptom: smoke from exhaust/stalled

Fix: **Causal Component :** --

Condition Code:

Hotliner: TMASCARI **Phone:**

Engineering:

Dlr Contact: [redacted]

Engine arrived at EMDO 9/22/21
#5 primary intake valve
Valve date code 12C17

- Potential 5th engine failure

Attachments : 0

Report# :	M9HDF003 NHL			**Received:**	09/08/2021
CCRG/EPRC:		**Reviewed Status:**		**Date:**	
Vehicle:	2021,BRONCO 4X4 ,ADVANCE,4DR ,MPV ,1FMEE5DP4[redacted]			**Build Date:**	06/09/2021
Odometer :	1,444 M	**Engine:**	2.7L 4V	**Calibration:**	
Transmission:	10R60	**Axle:**		**A/C:**	YES
Dealer:	CAN B6292 North Star Ford Sales (Calgary			**Phone#:**	403-239-1115
City:	Calgary	**Province**	Alberta	**Country :**	CAN
Originator:	JOHN FLEMING	**Originator e-mail:**	JOHNLESLIEZOEY@GMAIL.COM		
Symptom:	4 40 1 02 ST/RN/MV,STARTING,NO CRANK,ALWAYS				
Status:					
VFG:	V52 DRIVEABILITY				
Additional Symptom:	engine failure				
Fix:	**Causal Component :**		--		
Condition Code:					

- Potential 6th engine failure

Report# :	M9ME5001 NHL			**Received:**	09/13/2021
CCRG/EPRC:		**Reviewed Status:**		**Date:**	
Vehicle:	2021,BRONCO 4X4 ,ADVANCE,4DR ,MPV ,1FMEE5DP8[redacted]			**Build Date:**	06/29/2021
Odometer :	2,167 M	**Engine:**	2.7L 4V	**Calibration:**	MTG1WQNA
Transmission:	10R60	**Axle:**		**A/C:**	YES
Dealer:	[redacted]n Motors, Inc.			**Phone#:**	713-869-4661
City:	[redacted]	**State:**	Texas	**Country :**	USA
Originator:		**Originator e-mail:**			
Symptom:	5 50 A 02 DRV PERF,RUNS ROUGH,ALL RUNNING,ALWAYS				
Status:					
VFG:	V52 DRIVEABILITY				
Additional Symptom:	short block damage				
Fix:	**Causal Component :**				
Condition Code:					

Hotliner: RDEWIT17 Phone: Regn Cd: C2 Houston

Engineering: Phone: TAR:

Dlr Contact: HUMBERTO RAMOS Phone: Title Cde: T

DTC:

PCM:P0300,P0303,P0306

Comments :

CONCER 09/13/2021 11:19AM RHETT DEWITT MSS - FCSD - TECH ASSIT CENTER

Web Form Data(118392097) Description of Vehicle Concern: CUSTOMER STATES VEHICLE IS MAKING KNOCKING NOISE AND WILL NOT STAY RUNNING Please list any diagnostics already performed: REMOVED AND CUT OPEN OIL FILTER, PCM SELF TEST, RELATIVE COMPRESSION TEST, BORE SCOPE TEST Parts Replaced: NONE Your Question: VEHICLE CAME IN AND WOULD NOT STAY RUNNING FINALLY GOT IT TO RUN AND HEARD LOWER END KNOCKING NOISE LIMPED VEHICLE IN TO STALL AND PROCEEDED TO CHECK FLUIDS AND FOUND ALL FULL CHECKED OIL AND FOUND TO HAVE METALLIC FLAKES IN OIL REMOVED OIL FILTER AND FOUND SOME METAL IN OIL FILTER PROCEDED TO CHECK FOR ANY TSBS AND FOUND NONE RELATED TO CONCERN SELF TESTED PCM AND FOUND P0300, P0303, P0306, PROCEEDED TO RUN RELATIVE COMPRESSION TEST AND FOUND CYL NO. 6 5% DOWN PROCEEDED TO REMOVE SPARK PLUGS AND INSPECTED WITH BORE SCOPE AND FOUND TOP OF THE PISTONS TO HAVE DAMAGE LOOKED LIKE SOMETHING WAS HITTING TOP OF PISTON FOUND HEAVY SCORING ON CYLINDER WALLS. INSPECTED VALVES AND FOUND ONE OF THE VALVES TO HAVE A 2 CM PIECE MISSING FROM THE VALVE SEAT AREA , ALSO FOUND DAMAGE TO THE FACE OF THE CYLINDER HEAD INBETWEEN THE VALVES. WITH THE EXTENT OF THE DAMAGE TO PISTON, CYLINDER WALL AND CYLINDER HEAD AND METAL IN OIL WHAT WOULD BE THE NEXT STEP? WILL THE TURBOS NEED TO BE REPLACED DUE TO OIL IN METAL? PHOTOS ATTACHED BELLOW

- VINs for 3rd keeper groove failures.

- 1FMEE5BP1MLA71500
- 1FMEE5DP3MLA66408
- 1FMEE5DP0MLA72960
- 1FMEE5DP8MLA63603
- 1FMEE5DP4MLA64764
- 1FMEE5EP3MLA40194
- 1FMEE5DP8MLA69224

Attachments : 0

Report# :	M9QD7011 CREDSR--or-- Q 202193802653			**Received:**	09/17/2021
CCRG/EPRC:		**Reviewed Status:**		**Date:**	
Vehicle:	2021,BRONCO 4X4 ,4X4 ,4DR ,MPV ,1FMEE5E[redacted]			**Build Date:**	06/03/2021
Odometer :	1,880 M	**Engine:**	2.7L 4V	**Calibration:**	MTG1WQNA
Transmission:	10R60	**Axle:**		**A/C:**	YES
Dealer:	CAN B7002 Lake City Ford Sales Inc			**Phone#:**	[redacted]
City:	[redacted]			**Country :**	
Originator:					
Symptom:					
Status:					
VFG:	V44 POWERTRAIN MALFUNCTION				
Additional Symptom:					
Fix:	**Causal Component :**		ENGINE ASSY/BARE -- RPL		
Condition Code:					

Region Code: 07 Region Name: 07 Pacific District

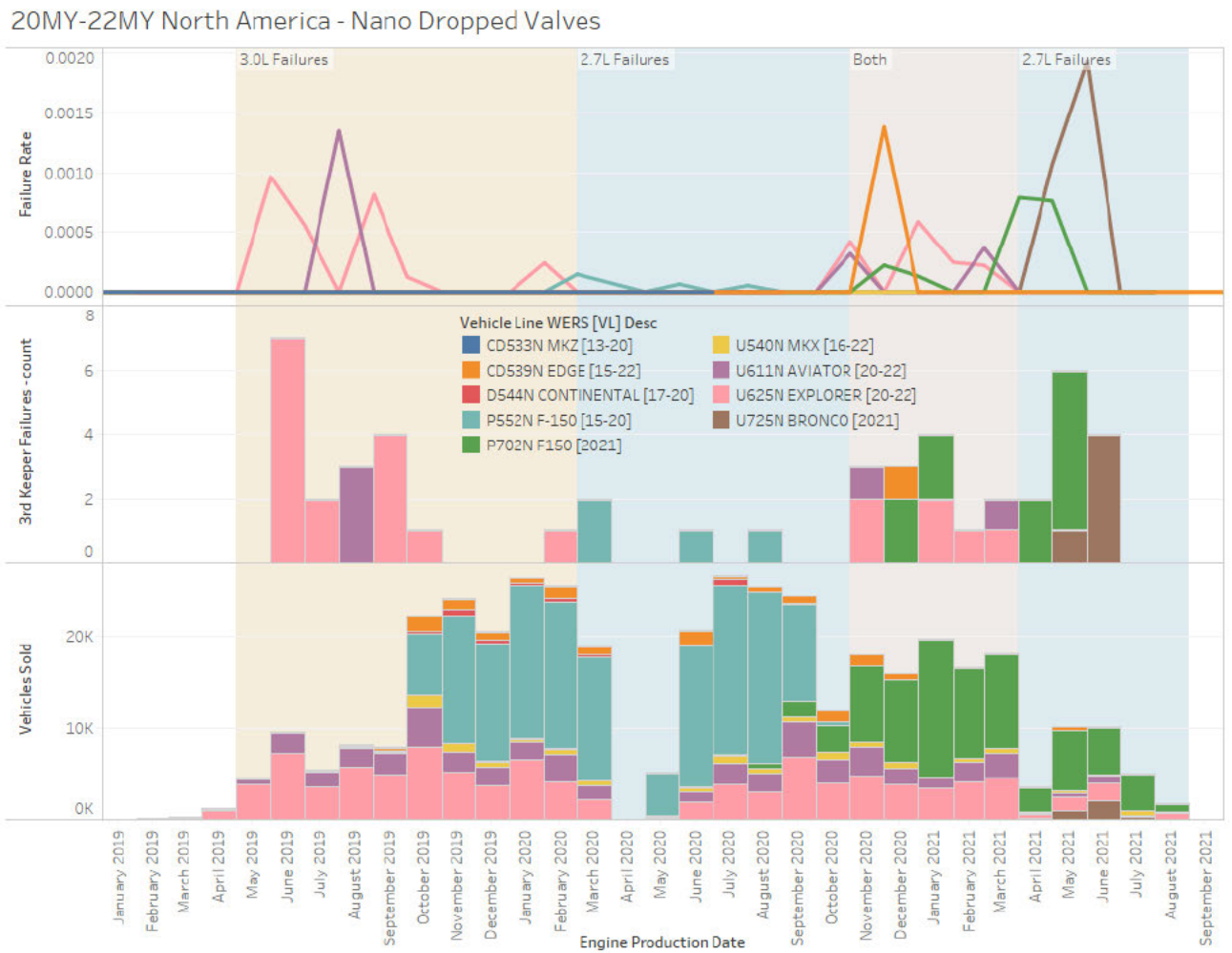
Comments :

CONCER 09/17/2021 01:58PM

DIAG FOR DASH SAID PULL OVER SAFELY TURN VEHICLE OFF - NOW IT WONT START

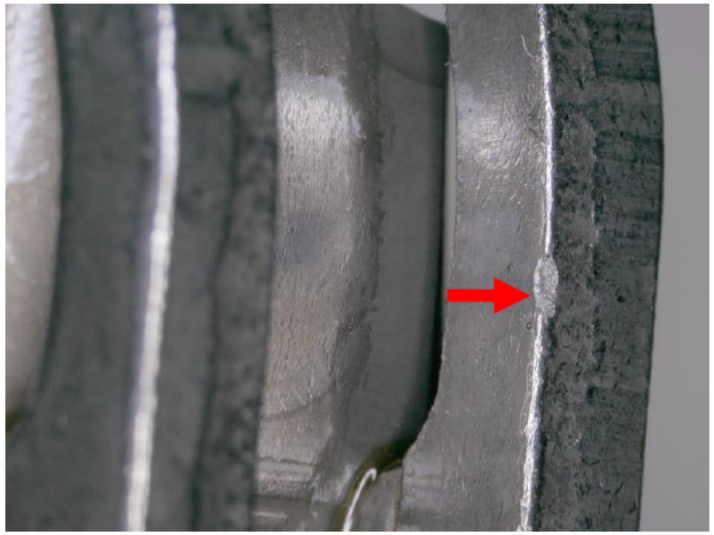
TECH/C 09/17/2021 01:58PM

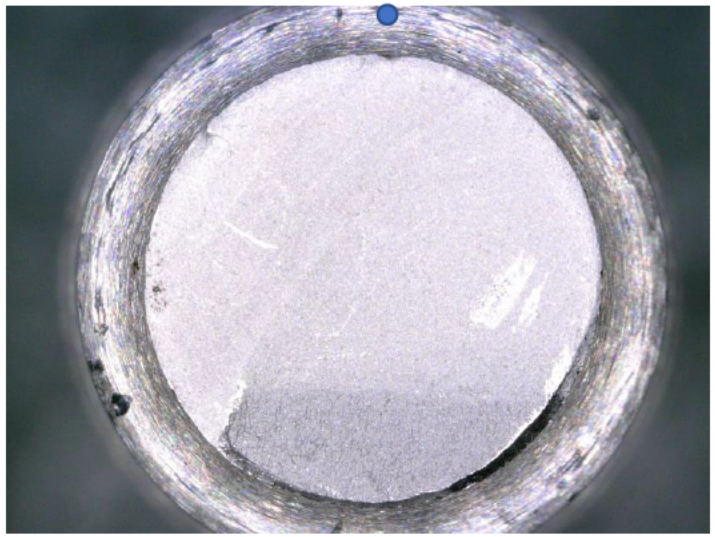
CHECK CODES FIND ONLY LONG CRANK TIME CODE. ATTEMPT TO START AND ENGINE RUNS BARELY AND KNOCKS. SHUT OFF, CHECK OIL LEVEL OK, REMOVE FILTER AND INSPECT OK. CHECK RELATIVE COMPRESSION #6 3% LOW BUT ALL ELSE OK. START ENGINE AGAIN BUT ENGINE SIEZES AND WILL NOT CRANK ANYMORE. REQUIRES TEARDOWN. VEHICLE IS VERY NEW, CONTACT ENGINEERING TO SEE IF THEY WANT TO INSPECT THE COMPLETE ENGINE WITHOUT TEARDOWN FIRST. REMOVED OIL PAN TO INSPECT AS PER BULLENTIN WTY-2020-31N. FOUND LARGE CHUNKS OFF DEBRIS IN OIL PAN. REQUEST REPLACEMENT ENGINE AS PER BULLETIN "LOW TIME IN SERVICE (LTIS) ASSEMBLY REPLACEMENT"

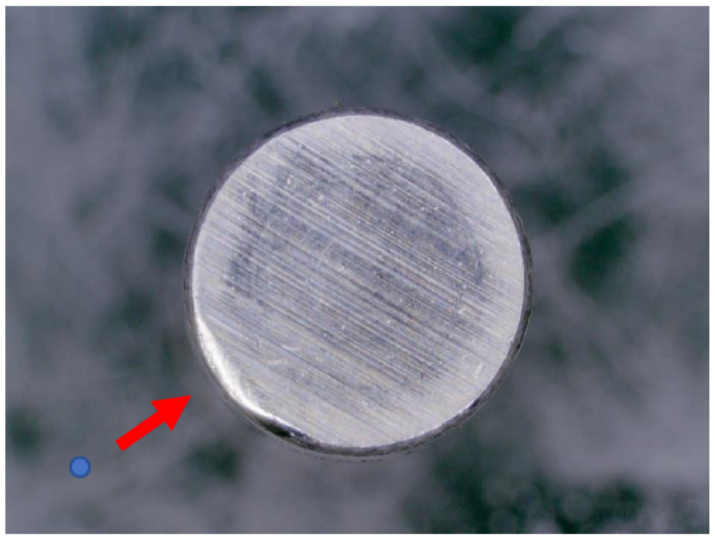


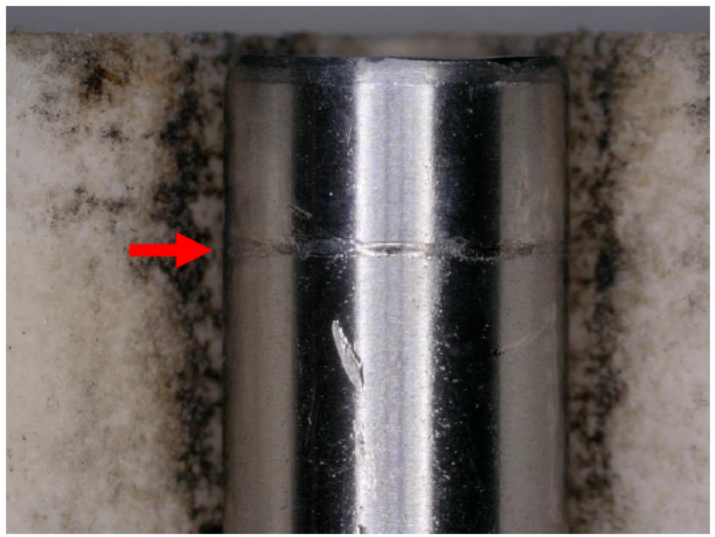
	F	G	H	I	J	
	Valve mfg date	LH Cylinder Head Assy Da	Engine Production D	Vehicle Production Date	Warranty Start Da	Dealer
60		5/31/2019	6/4/2019	6/14/2019	1/2/2020	ZEIGLE
84		6/13/2019	6/18/2019	7/11/2019	3/14/2020	TITUS-\
80		6/14/2019	6/18/2019	6/24/2019	9/14/2019	CAPITA
48		6/20/2019	6/21/2019	7/10/2019	12/5/2019	JONES
11		6/20/2019	6/21/2019	7/9/2019	3/11/2020	LUCAS
22		6/20/2019	6/24/2019	7/9/2019	9/17/2019	KALISF
55		6/26/2019	6/27/2019	7/15/2019	12/31/2019	FRIEND
80		6/28/2019	7/15/2019	8/1/2019	9/30/2019	ZEIGLE
68		7/19/2019	7/25/2019	8/14/2019	11/25/2019	FIVE S
56		8/27/2019	8/27/2019	9/13/2019	1/28/2020	MONTI
74		8/27/2019	8/28/2019	9/14/2019	10/19/2019	TOM R
34		8/27/2019	8/28/2019	9/8/2019	12/6/2019	HEISEI
24		8/27/2019	8/29/2019	9/9/2019	1/16/2020	LC Zhu
04		8/29/2019	8/30/2019	9/11/2019	8/21/2020	
91		8/30/2019	9/5/2019	9/24/2019	2/23/2021	FOX FC
04		9/16/2019	9/18/2019	9/23/2019	2/27/2020	UNIQUI
32		9/17/2019	9/18/2019	9/26/2019	11/22/2019	PHIL LC
35		9/17/2019	9/19/2019	9/28/2019	8/13/2020	HEMPS
85		10/24/2019	10/29/2019	11/4/2019	6/16/2020	CHILLI
09		2/10/2020	2/14/2020	2/24/2020	4/11/2020	MAC H
20		3/17/2020	3/17/2020	5/26/2020	7/31/2020	AUTON
81		3/18/2020	3/19/2020	5/28/2020	8/3/2020	WAYNI
		6/4/2020				LC Zhe
58		6/9/2020	6/16/2020	6/22/2020	9/2/2020	RYE FC
67		8/14/2020	8/17/2020	8/23/2020	9/2/2020	BENNA
77		11/2/2020	11/4/2020	11/13/2020	12/4/2020	CAPITA
18		11/13/2020	11/16/2020	12/6/2020	4/7/2021	MEADO
88		11/13/2020	11/17/2020	12/9/2020	12/24/2020	SANTA
76		12/15/2020	12/14/2020	1/4/2021	1/27/2021	EL CA
86		12/15/2020	12/16/2020	1/8/2021	2/6/2021	KEN G
00		12/16/2020	12/17/2020	2/11/2021	3/5/2021	SHAFF
84		12/18/2020	1/8/2021	1/24/2021	2/26/2021	HOFFM
04		12/18/2020	1/8/2021	1/22/2021	5/14/2021	MCCO'
28		1/1/2021	1/14/2021	1/30/2021	3/12/2021	LARRY
04		1/5/2021	1/7/2021	1/14/2021	2/1/2021	GILLES
97		1/13/2021	1/14/2021	1/22/2021	2/23/2021	BOWE
16		2/2/2021	2/3/2021	2/11/2021	4/5/2021	CREST
44		2/24/2021	3/3/2021	3/15/2021	5/1/2021	AUTON
86		2/26/2021	2/26/2021	3/15/2021	8/23/2021	MULLIN
22		3/12/2021	3/16/2021	3/20/2021	4/20/2021	ACTON
55		4/6/2021	4/7/2021	5/6/2021	5/28/2021	PAT MI
79		4/6/2021	4/7/2021	5/10/2021	6/24/2021	KELOV
91		4/6/2021	5/3/2021	5/18/2021	5/21/2021	RANDA
84		4/6/2021	5/3/2021	5/18/2021	5/29/2021	SCOTT
28		5/7/2021	5/11/2021	6/12/2021	7/31/2021	DEWE'
06		5/10/2021	5/14/2021	5/25/2021	7/20/2021	MID-TC
29		5/12/2021	5/13/2021	6/9/2021		NORTH
69		5/12/2021	5/13/2021	6/21/2021	7/12/2021	METRC
64		5/12/2021	5/13/2021	6/24/2021	8/2/2021	GARY
82		6/7/2021	6/10/2021	6/25/2021	6/30/2021	KELLE
78		6/7/2021	6/10/2021	6/24/2021	7/28/2021	JIM BU
77		6/9/2021	6/14/2021	6/19/2021	7/13/2021	BOMM
23		6/12/2021	6/18/2021	6/30/2021	7/27/2021	AUTON

#6 Secondary intake valve observations

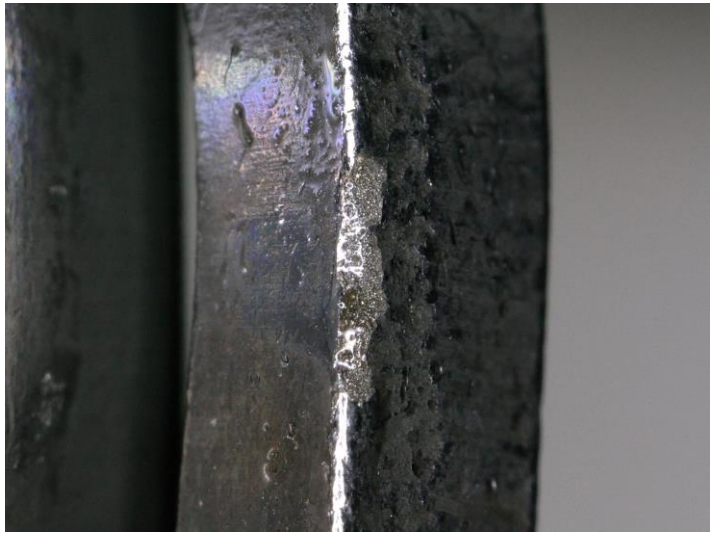








#4 Primary intake valve observations



U725 Valve Failure Teardown Observations: (Missouri Vehicle VIN 71500)

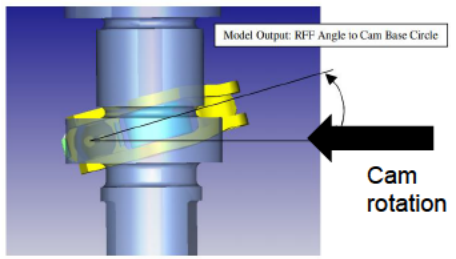
- #5 Primary intake valve 3rd keeper groove failure. Tip remained in retainer.
- #5 Secondary broken RFF side wall. May be secondary.
- Parts being shipped to supplier 8/6/21

5P Intake

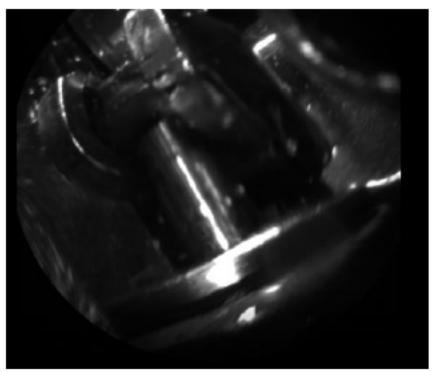
5S Intake

Root Cause Hypothesis:

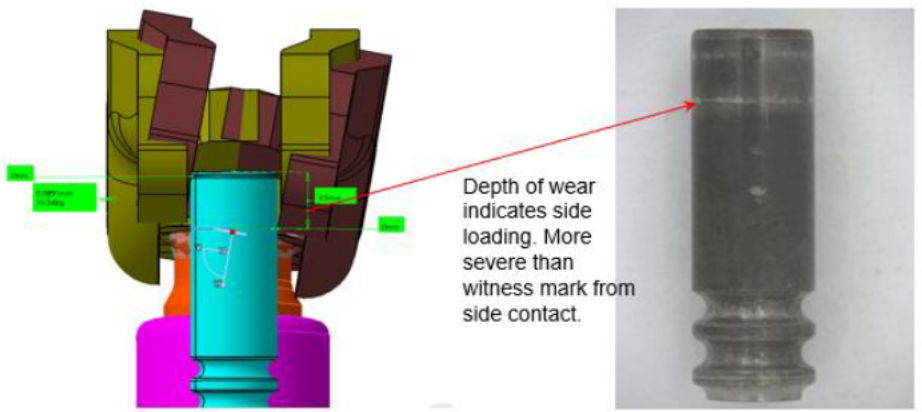
- RFF's more susceptible to misalignment on LH bank due to cam shaft rotation pushing RFF toward lash adjuster. Misalignment of RFF increases tipping and side loading of valve tip.
- Valve tip is being side loaded as a result of increased lash in the system.
- Increased lash in the system can be caused by spongy / collapsed HLA's caused by oil pressure or higher aeration levels.
- Valve tip strength, Push side RFF, increased lash, are all factors that align for failure.
- Focus on emergency response robustness actions in the following areas:



1. Hardware characteristics
   - Valve tip hardness depth / Micro hardness profile 50-57 HRC
   - tip is near max hardness for wear resistance resulting in lower toughness
   - Material selection
   - Valve key groove geometry
   - RFF alignment
2. Oil Pressure
   - Main factor for lash control



Slow motion video with lash in the system show tipping and side loading of valve tip.



Root Cause	Evidence	ERA	PCA's under evaluation	PCA Validation Plan
Valve Tip Side Load from RFF tipping / push side misalignment	Impact mark on valve tip RFF dynamics from PFSL HS video	1) Keeper Groove Diameter	Key groove geometry: 1) Additional Increase in Diameter 2) Couple diameter with higher key (less cantilever). 1) Compound radius to reduce stress riser RFF Geometry: 1) Longer fingers & narrower fingers 2) Cylindrical roller 3) Valve stem diameter (reduced side wall clearance)	1) FEA (9/10/21) 2) Side load impact test (10/25/21) 3) HS PFSL screener (10/19/21) 4) EFT (Lead 5.0L / Nano) (11/16/21) 1) PFSL Dynamics Rig (Nov 2021) 2) EFT (Lead 5.0L / Nano) (Dec 2021)
Increased Lash	PFSL spinner rig showing RFF Instability / tipping & 3rd keeper groove failure	1) Oil Pressure Calibration 2) LH Head Gasket HLA restrictor.	Increase height of HLA pocket for reduced lash with collapsed HLA	1) CAD VSA Stack Up (9/8/21)
Material Toughness Resistance to grinder burn HRC>57	HRC > 57	1) Tip hardness and micro hardness check frequency. 2) Sil1 Material Change.	1) Coolant control 2) Oven temper 3) Hardness uniformity	1) Impact Testing (9/20/21) 2) Microstructure Analysis (9/24/21)

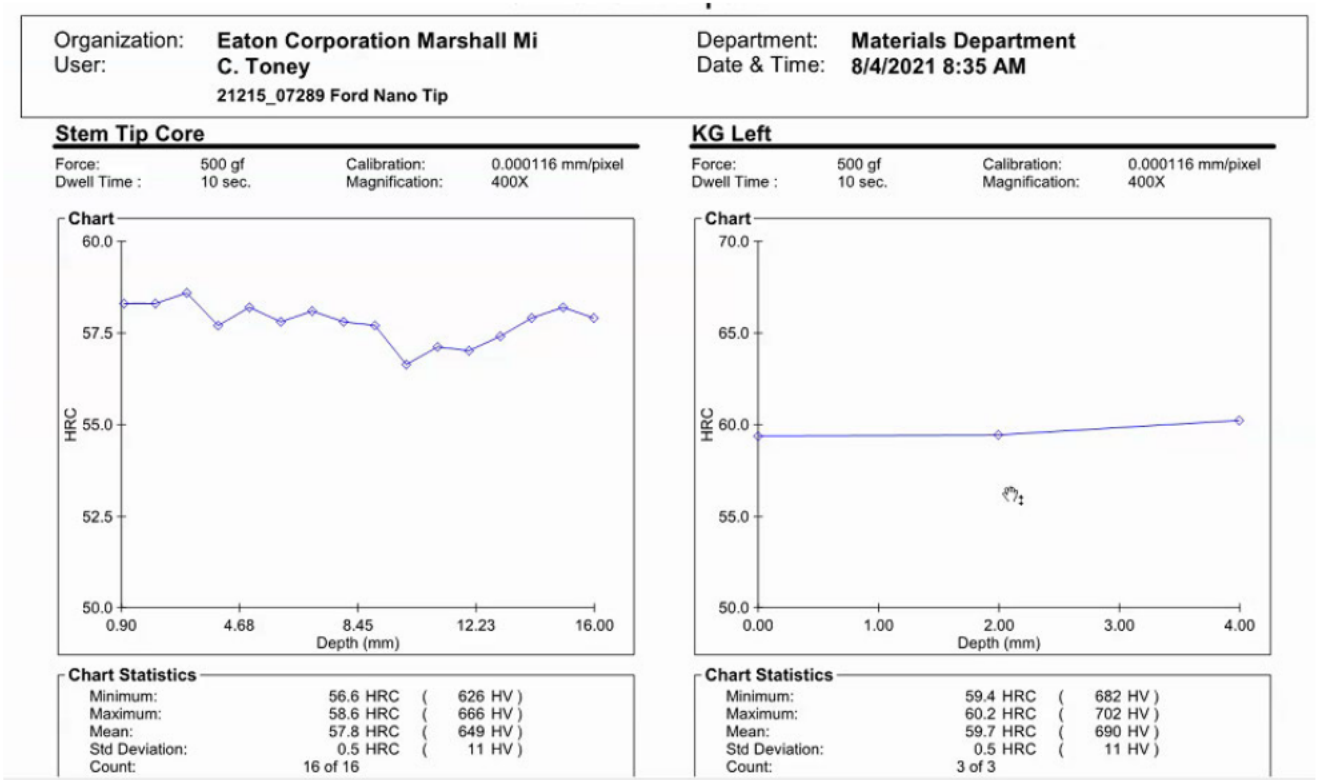
- Emergency Response Actions:
  1. Control plan updates (Complete)
  2. Sil 1 Material Change (Production parts 9/1/21)
  3. Keeper Groove Diameter (Production parts 8/26/21)

- Other robustness actions under investigation
  - Oil Pressure Calibration (Pending CVSP FE assessment 8/12)
  - LH Head Gasket HLA Gallery Restrictor

Returned valve inspection from U725 Veh 6408 (1143 mi)

- Failed valve tip core hardness above 50 – 57 HRC spec.

- ERA 1 – Increase core microhardness check from 1 to 3 times per shift. (beginning, middle, end of shift)
- Add operator tip hardness check 1 / hour (was 3/shift).



Organization: **Eaton Corporation Marshall Mi**
User: **C. Toney**
21215_07289 Ford Nano Tip
Department: **Materials Department**
Date & Time: **8/4/2021 8:35 AM**

Stem Tip Core

Force: 500 gf
Dwell Time : 10 sec.
Calibration: 0.000116 mm/pixel
Magnification: 400X

Chart
HRC: 60.0, 57.5, 55.0, 52.5, 50.0
Depth (mm): 0.90, 4.68, 8.45, 12.23, 16.00

Chart Statistics

Minimum:	56.6 HRC	(626 HV)
Maximum:	58.6 HRC	(666 HV)
Mean:	57.8 HRC	(649 HV)
Std Deviation:	0.5 HRC	(11 HV)
Count:	16 of 16	

KG Left

Force: 500 gf
Dwell Time : 10 sec.
Calibration: 0.000116 mm/pixel
Magnification: 400X

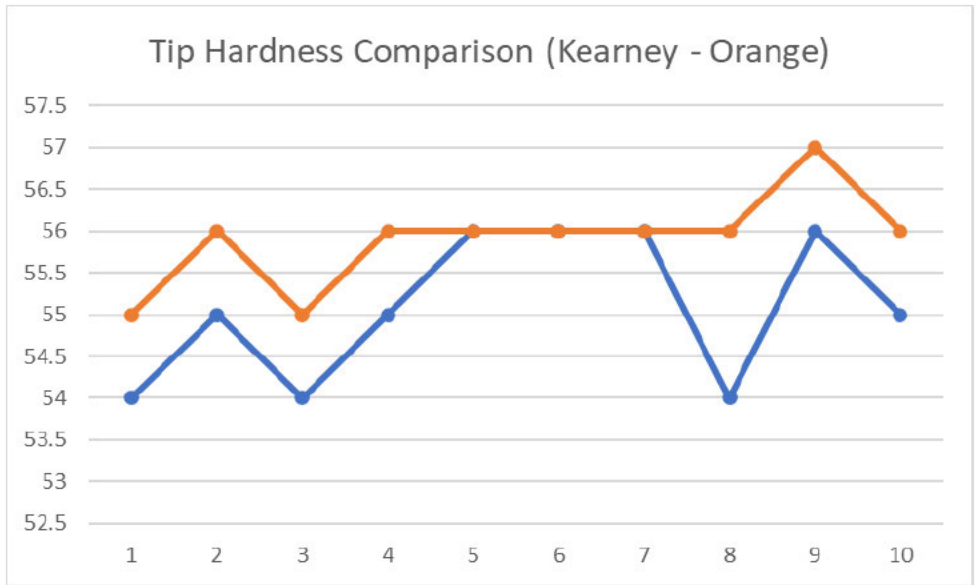
Chart
HRC: 70.0, 65.0, 60.0, 55.0, 50.0
Depth (mm): 0.00, 1.00, 2.00, 3.00, 4.00

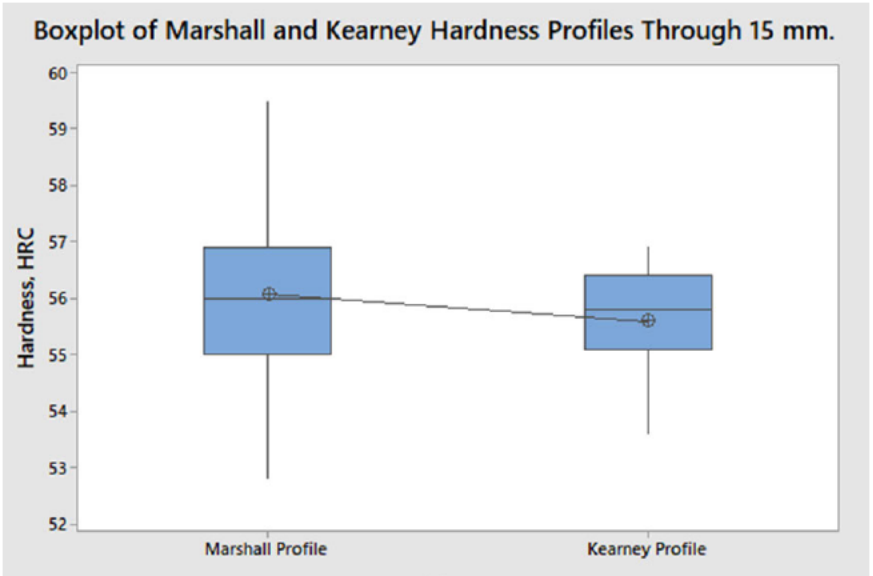
Chart Statistics

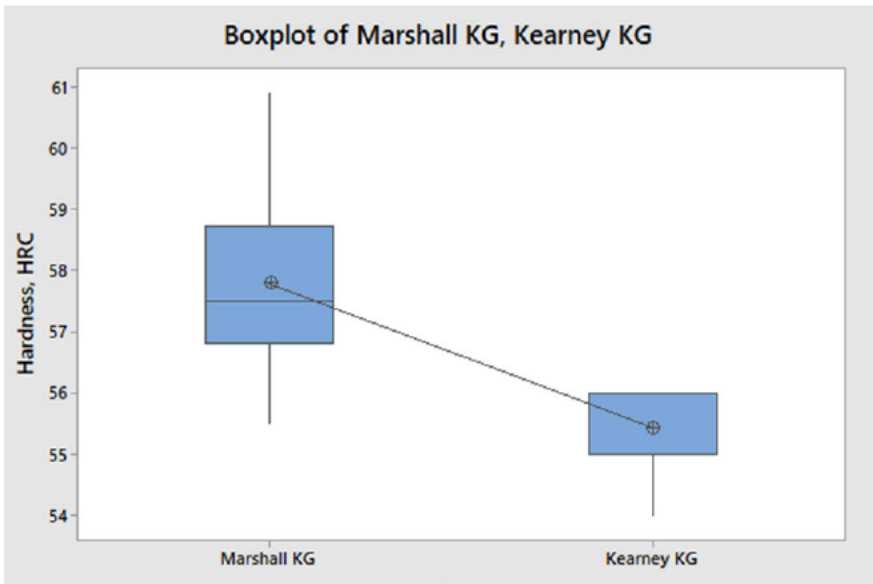
Minimum:	59.4 HRC	(682 HV)
Maximum:	60.2 HRC	(702 HV)
Mean:	59.7 HRC	(690 HV)
Std Deviation:	0.5 HRC	(11 HV)
Count:	3 of 3	

Kearney vs Marshal HRC correlation

- **Equipment:**
- Kearney
- Standard Hardness Tester: Instron Series 2000
- Microhardness Tester: Tukon 2500 (Instron) Semi-automated
-
- Marshall
- Standard Hardness Tester: Wilson Rockwell
- Microhardness Tester: Automated Clemex
-
- Results
- Standard Hardness Tester: Hardness were mostly within one point of each other.
- Microhardness Tester (profile): The bulk microhardness tests were similar through 15 mm (fully hardened area) which was selected for comparison purposes.
- Microhardness Tester (Keeper Groove hardness): The microhardness measurements were found to be +2.4 HRC (on average) in Marshall vs. Kearney. This difference is not fully understood at this time.


Tip Hardness Comparison (Kearney - Orange)
57.5
57
56.5
56
55.5
55
54.5
54
53.5
53
52.5
1
2
3
4
5
6
7
8
9
10


Boxplot of Marshall and Kearney Hardness Profiles Through 15 mm.
Hardness, HRC
60
59
58
57
56
55
54
53
52
Marshall Profile
Kearney Profile

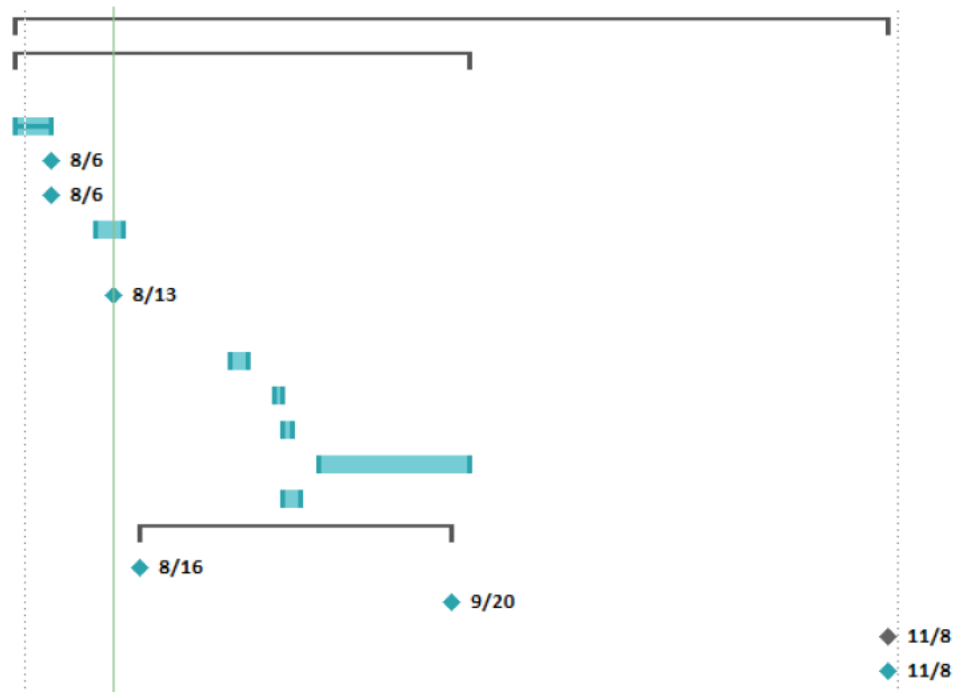

Boxplot of Marshall KG, Kearney KG
Hardness, HRC
61
60
59
58
57
56
55
54
Marshall KG
Kearney KG

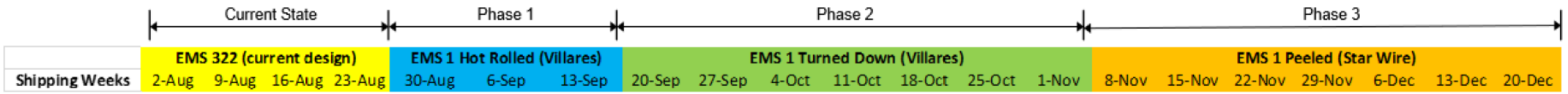
Emergency Response Action 2

Additional checks for 3 phases

- Design change to Silchrome 1 material for added robustness to side loading and grinder variation.
- 3 Phase approach proposed by Eaton to eliminate costly air freight from Villares India and expedite timing

	SIL1 material Change	**70 days?**	**Mon 8/2/21**	**Mon 11/8/21**
	Phase 1 (EMS hot rolled Villares EMS1)	**37 days**	**Mon 8/2/21**	**Tue 9/21/21**
✓	Present NTE cost to Ford for CR	4 days	Mon 8/2/21	Thu 8/5/21
✓	Ford approval to proceed	0 days	Fri 8/6/21	Fri 8/6/21
✓	Star Wire Authorization	0 days	Fri 8/6/21	Fri 8/6/21
	Revised notice for part number change	3 days	Wed 8/11/21	Fri 8/13/21
	Meeting with STA to align on PPAP requirements)	0 days	Fri 8/13/21	Fri 8/13/21
	Ship PV parts to LEP	2 days	Thu 8/26/21	Fri 8/27/21
	Build DR1 heads	1 day	Tue 8/31/21	Tue 8/31/21
	Build DR1 engines	1 day	Wed 9/1/21	Wed 9/1/21
	100 hr PV EFT PRDC	13 days	Sun 9/5/21	Tue 9/21/21
	Production parts to LEP	2 days	Wed 9/1/21	Thu 9/2/21
	Phase 2	**25 days**	**Mon 8/16/21**	**Mon 9/20/21**
	Funded alert approval	0 days	Mon 8/16/21	Mon 8/16/21
	EMS 1 Turned down stock (Villares)	0 days	Mon 9/20/21	Mon 9/20/21
	Phase 3	**0 days?**	**Mon 11/8/21**	**Mon 11/8/21**
	EMS 1 peeled (Star Wire)	0 days	Mon 11/8/21	Mon 11/8/21





- PPAP requirements aligned with STA
  - PTR to be concurrent with PV DR1 build – Need LEP approval
  - Need back up plan for IP engine due to cam cover
  - SCAAF, Control Plan documents to be updated (PFMEA to reflect changes)
    - Safe launch frequency of hardness checks (phase 1,2,3)

      3/shift for microhardness – in process

      1/hr for operator tip hardness – in process
    - Grinder burn - Add grain structure rating

      Boundary sample (visual sample for grain structure / Grinder burn)

      Need discussion on in process grinder burn process check
    - 5 part full layout (phase 1,2,3)
    - 30 piece Xbar & R (phase 1,2,3)
      - Groove diameter
      - Surface finish
  - Ben Rhude to update SCAFF and send out
  - LEP – IMDF need to align

Inspection	Phase 1	Phase 2	Phase 3	Comments
3/shift Microhardness checks	X	X	X	
1/hr operator tip hardness check	X	X	X	
Grinder burn microstructure check	X	X	X	Visual sample for acceptance criteria (Need alignment
5 part full layout	X	X	X	
30 pc X-bar & R chart				
Groove Diameter	X	X	X	
Surface Finish	X	X	X	
125 pc SC Checks	X		X	

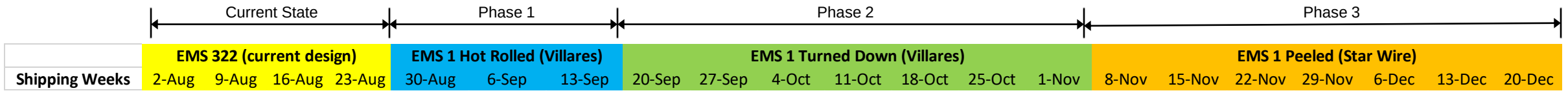
Part number released in Ford System:
JT4E-6507-BA

- Need confirmation that part number is release in Eaton system to trigger drawing update in TC and scheduling o Sil1 production part runs.

[redacted]

Timing Plan with Interim Supply – 8/6/21

ID	Task Name	Duration	Start	Finish
1	Develop cost model & business case	2 days	Tue 8/3/21	Wed 8/4/21
2	Review with Eaton senior mgmt	1 day	Thu 8/5/21	Thu 8/5/21
3	Present NTE price to Ford	1 day	Thu 8/5/21	Thu 8/5/21
4	Ford approval to proceed (pricing agreement letter)	1 day	Thu 8/5/21	Thu 8/5/21
5	Production Start with Villares EMS 1 Hot Rolled	1 day	Wed 8/18/21	Wed 8/18/21
6	Shear	2 days	Wed 8/18/21	Thu 8/19/21
7	Forge	2 days	Fri 8/20/21	Mon 8/23/21
8	Machine	3 days	Tue 8/24/21	Thu 8/26/21
9	Chrome Plate	1 day	Fri 8/27/21	Fri 8/27/21
10	Inspect	2 days	Mon 8/30/21	Tue 8/31/21
11	Ship to Lima Engine Plant	1 day	Wed 9/1/21	Thu 9/2/21



Powering Business Worldwide

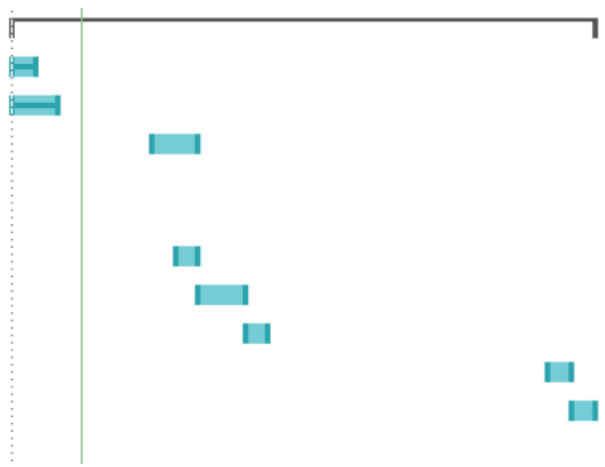
Next Steps

Item	Lead	Target Date
Ford approval to proceed with Star Wire order including air freight	J. Kolodziejczyk	8/6/21
Issue Star Wire order	Eaton	8/6/21
Ford approval to proceed with Interim supply plan – Phase 1	J. Kolodziejczyk	8/9/21
Ford approval to proceed with Interim supply plan – Phase 2	J. Kolodziejczyk	8/9/21

Emergency Response Action 3 –

- Increase keeper groove root diameter
  - Eaton process demonstrating capability.
  - Current mean 4.15mm (spec 4.08 – 4.28 mm)
  - Max target to meet design guide 4.26 mm.
  - Proposed process change 4.10 – 4.30 target.
    - Alert Authorized
    - No change to process other than inspection camera adjustment and verification of heat treat and tempering process settings.

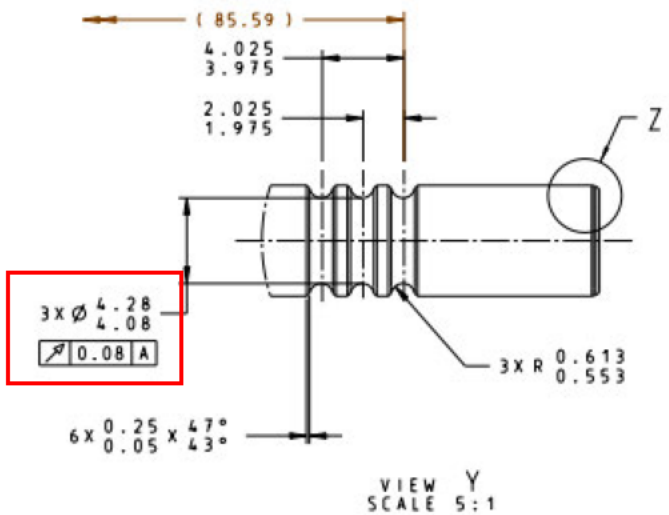
	Keeper Groove Diameter Increase	19 days	Tue 8/3/21	Fri 8/27/21
✓	Stack up and finalize target Dia.	1 day	Tue 8/3/21	Tue 8/3/21
✓	Issue Alert for LEP trail parts	2 days	Tue 8/3/21	Wed 8/4/21
	Run Trial parts at 4.2 Nom. (Spec 4.1-4.3)	2 days	Mon 8/9/21	Tue 8/10/21
	Chrome plate			
	Part inspection	1 day	Tue 8/10/21	Tue 8/10/21
	Ship to LEP	2 days	Wed 8/11/21	Thu 8/12/21
	LEP Trial (800 engines under alert)	1 day	Fri 8/13/21	Fri 8/13/21
	Start production at Eaton	1 day	Thu 8/26/21	Thu 8/26/21
	Ship to LEP	1 day	Fri 8/27/21	Fri 8/27/21

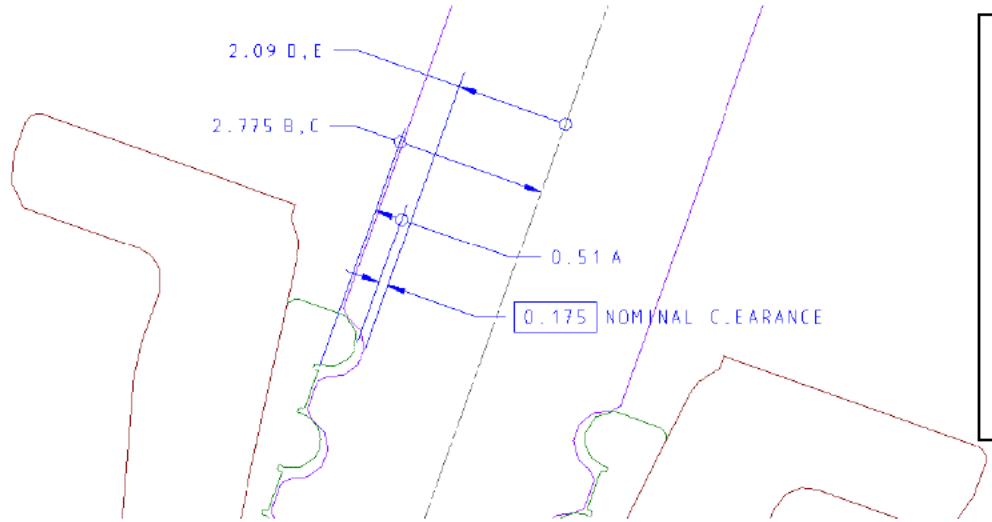


Requested Pull ahead of production schedule

Eaton working to receive material earlier to support

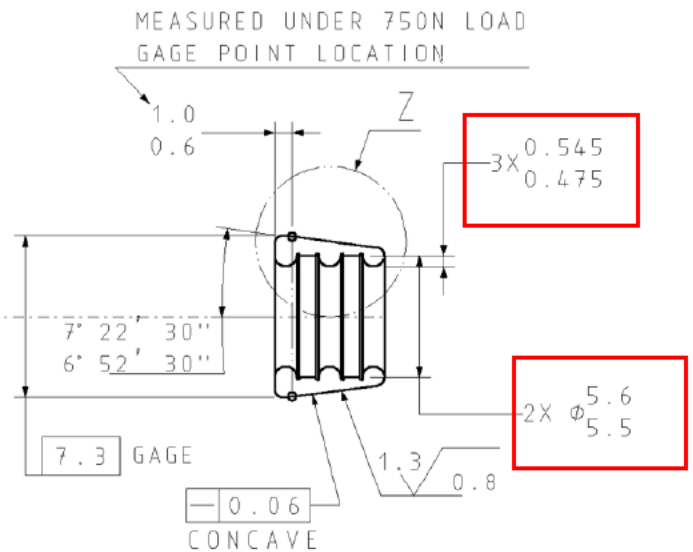
Keeper Groove Root Diameter Increase





Arithmetic

Key Flat to Key ID:	0.545
Key flat to Axis Key:	-2.750
Key-Valve Aligned	0.000
Valve Axis to KG ID:	2.140
Valve Runout:	0.040
Clearance	0.025



Benefit (X-Sectional Area)

Nominal Dia. Today: 4.18mm

Nominal Area Today: 13.72mm^2

Nominal Dia. Prop: 4.2mm

Nominal Area Prop: 13.99mm^2

Area increase +1%

Statistical Results

Random Number Seed: -9223372036854775808

Sample Mean [redacted]

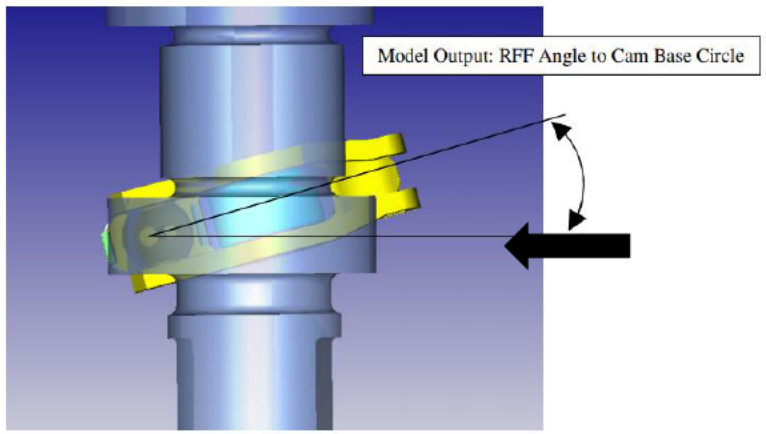
Sample Minimum [redacted]

E2KS Value = 0.025

(Min Clearance or Max Interference conditions) 3.0 Sigma Minimum Condition	0.0969395
(Min Clearance or Max Interference conditions) 4.0 Sigma Minimum Condition	0.0708976
(Min Clearance or Max Interference conditions) 4.5 Sigma Minimum Condition	0.0578767
(Min Clearance or Max Interference conditions) 5.0 Sigma Minimum Condition	0.0448558
(Min Clearance or Max Interference conditions) 6.0 Sigma Minimum Condition	0.0188140

Oil Pressure Robustness Action

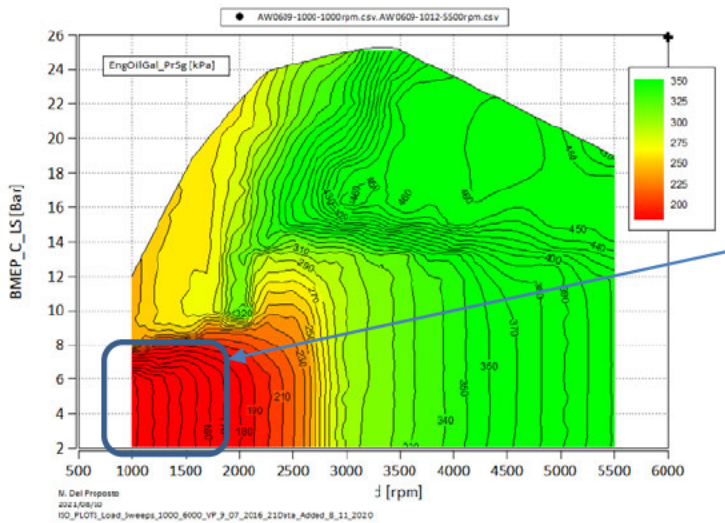
- VDOP Oil Pressure Increase.
  - High valve tip loading can result from RFF tipping / misalignment.
  - Worse on LH head due to cam rotation pushing RFF towards HLA. RH bank pulls away from HLA and naturally acts to align RFF.
  - Lash in the system increases misalignment and RFF side loading.
  - Oil pressure is main factor in loss of lash control.
  - Oil pressure also acts to improve compressibility of aerated oil and keep air in solution.
  - Proposing to increase oil pressure 40 kPa at idle -1000 RPM region as robustness to hardware / lube system variation.
  - Data at 95 C oil temp and above the LH HLA gallery could drop below min HLA requirement.



Revised VDOP Schedule

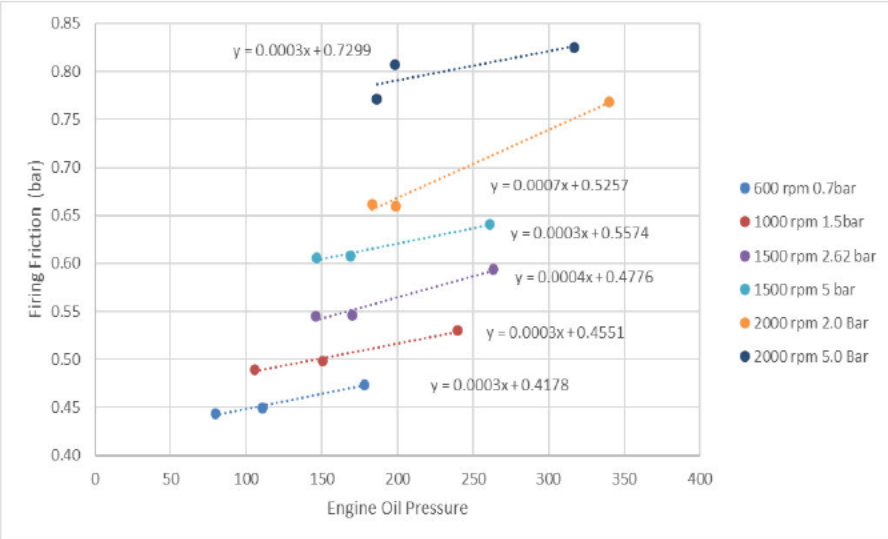
P702 & U725 2.7L - cVOP; 2021MY - 2022MY						
	Current cVOP status					
	elvop_eop_hot_prot_m					
	Y \ X	500	1000	2800	3000	6500
	0.25	70	105	240	300	450
	0.5	70	105	240	300	450
	0.7	70	240	240	300	450
	1	70	300	300	300	450
	1.2	70	300	450	450	450

Proposed changes to improve HLA pressure					
elvop_eop_hot_prot_m					
Y \ X	500	1000	2800	3000	6500
0.25	110	150	240	300	450
0.5	110	150	240	300	450
0.7	110	240	240	300	450
1	110	300	300	300	450
1.2	110	300	450	450	450



Proposal is to increase pressure 500 rpm – 2000 rpm 40-45kpa (5-7psi)

2021 2.7L U725 Oil Pressure Sweeps



Part Throttle Fuel Economy and Emissions Mini-Map					
Program Mini-Map Points		BSFC g/kW-hr			
Speed (rpm)	Load (bar)	phasing	Status	Revised EOP	% status
600	0.70	mbt	676	681	(0.7)
		spk reserve			
1000	1.50	mbt	408	410	(0.5)
1500	2.62	mbt	312	313	(0.3)
1500	5.00	mbt	255	255	(0.1)
2000	2.00	mbt	357	358	(0.4)
2000	5.00	mbt	255	255	(0.1)
3000	7.50	mbt	246	246	0.0
1500	9.0	bl	243	243	0.0
2000	9.0	bl	239	239	0.0
2500	14.0	bl	242	242	0.0
1500	7.0	mbt	241	241	0.0
2000	7.0	mbt	240	240	0.0
1500	8.0	bl	240	240	0.0
2000	8.0	bl	238	238	0.0
1750	12.00	bl	246	246	0.0
Test Conditions				10 cr	
38 ACT/93 ECT 91 E10 Certification Fuel (M4CX373-B)					
Report Link					

Oil Pressure sweeps from dyno at 90c Oil Temp.
Used to develop Friction sensitivity vs. oil pressure

Program Mini-Map Points		Friction penalty Delta Kpa
Speed (rpm)	Load (bar)	
600	0.70	1.20
1000	1.50	1.35
1500	2.62	1.08
1500	5.00	0.81
2000	2.00	1.26
2000	5.00	0.54

Mini-map BSFC points /time weights to estimate fuel economy impact

Regular Fuel	City	Hwy	US06	M/H
Thermal Efficiency – Status	30.1%	30.9%	39.0%	30.5%
MPG – Status	24.8	30.1	18.3	27.0
Thermal Efficiency – Target	29.1%	30.9%	39.0%	29.9%
MPG – Target	24.9	30.1	18.3	27.0
Difference	-0.2%	-0.1%	0.0%	-0.2%

Key Take-away : With the revised oil pressure , increases friction ~ 1 kpa impact on fuel -0.2% degradation on M/H

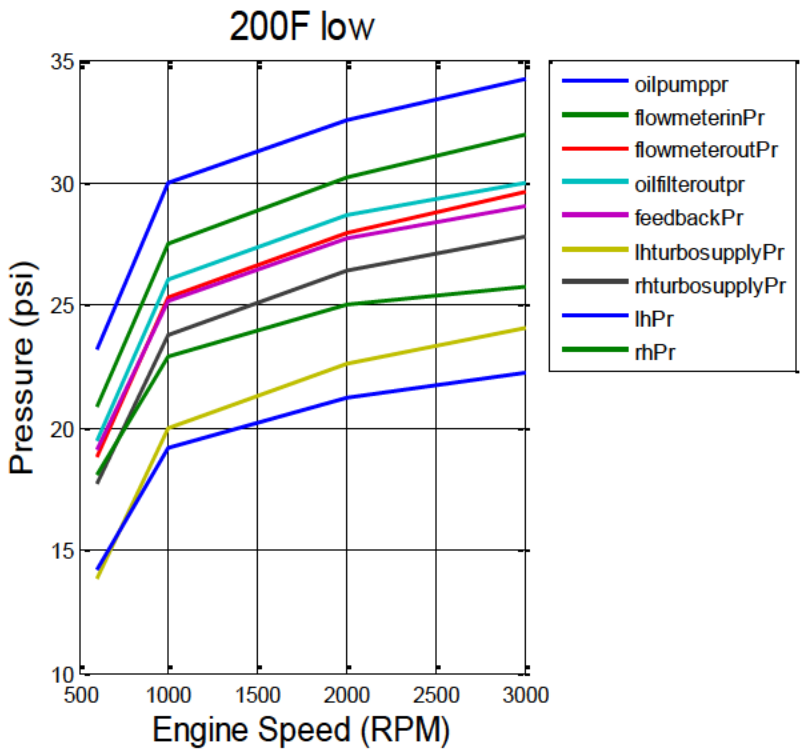
CVSP runs for U725 and P702.
Revised fuel file provided. Est completion 8/12/21.

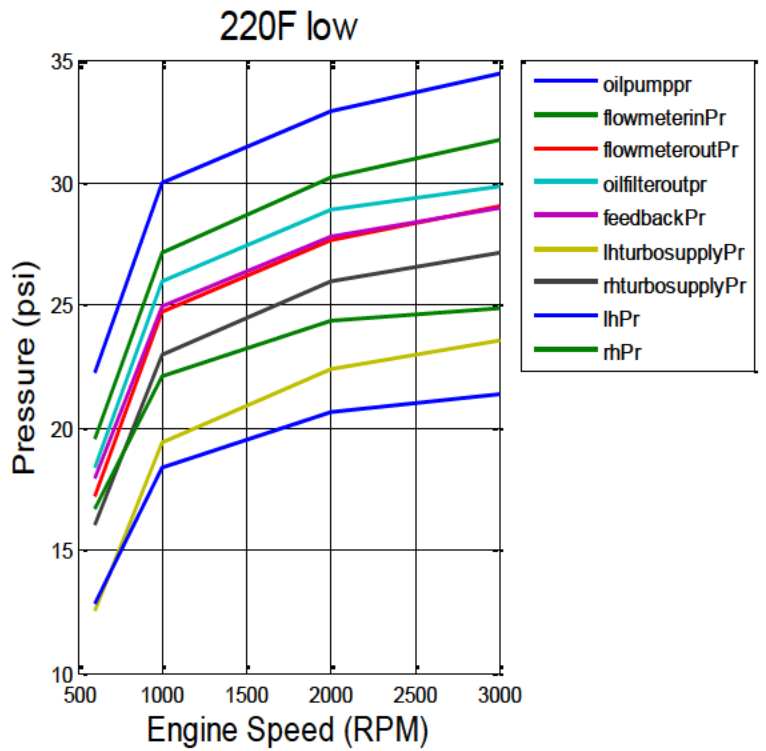
Run	Drive Mode	Fuel	S/S	VDOP Schedule	Road Loads
1	Normal	98R E0	On	Production	FE Ctrl High Vol
2	Normal	98R E0	Off	Production	FE Ctrl High Vol
3	Normal	98R E0	On	Proposed	FE Ctrl High Vol
4	Normal	98R E0	Off	Proposed	FE Ctrl High Vol
5	Sport	91R E10	Off	Production	Emissions
6	Sport	91R E10	Off	Proposed	Emissions

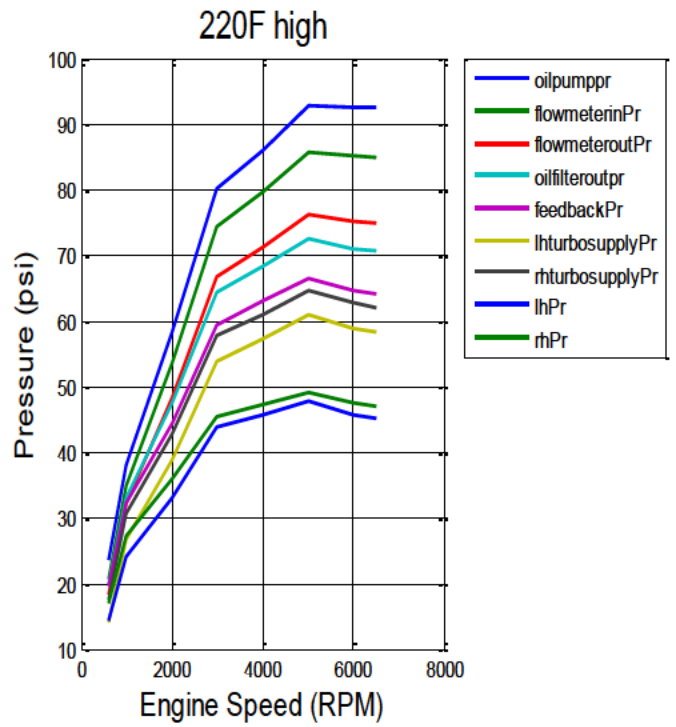
Emissions Config	P702	U725
ETW	5250	5500
F0	46.03	51.28
F1	0.2994	0.5031
F2	0.0374	0.0501
Tire	LT265/70R18	LT265/70R17
FDR	3.73	4.46

Empirical Analysis – 18MY 2.7L RWD

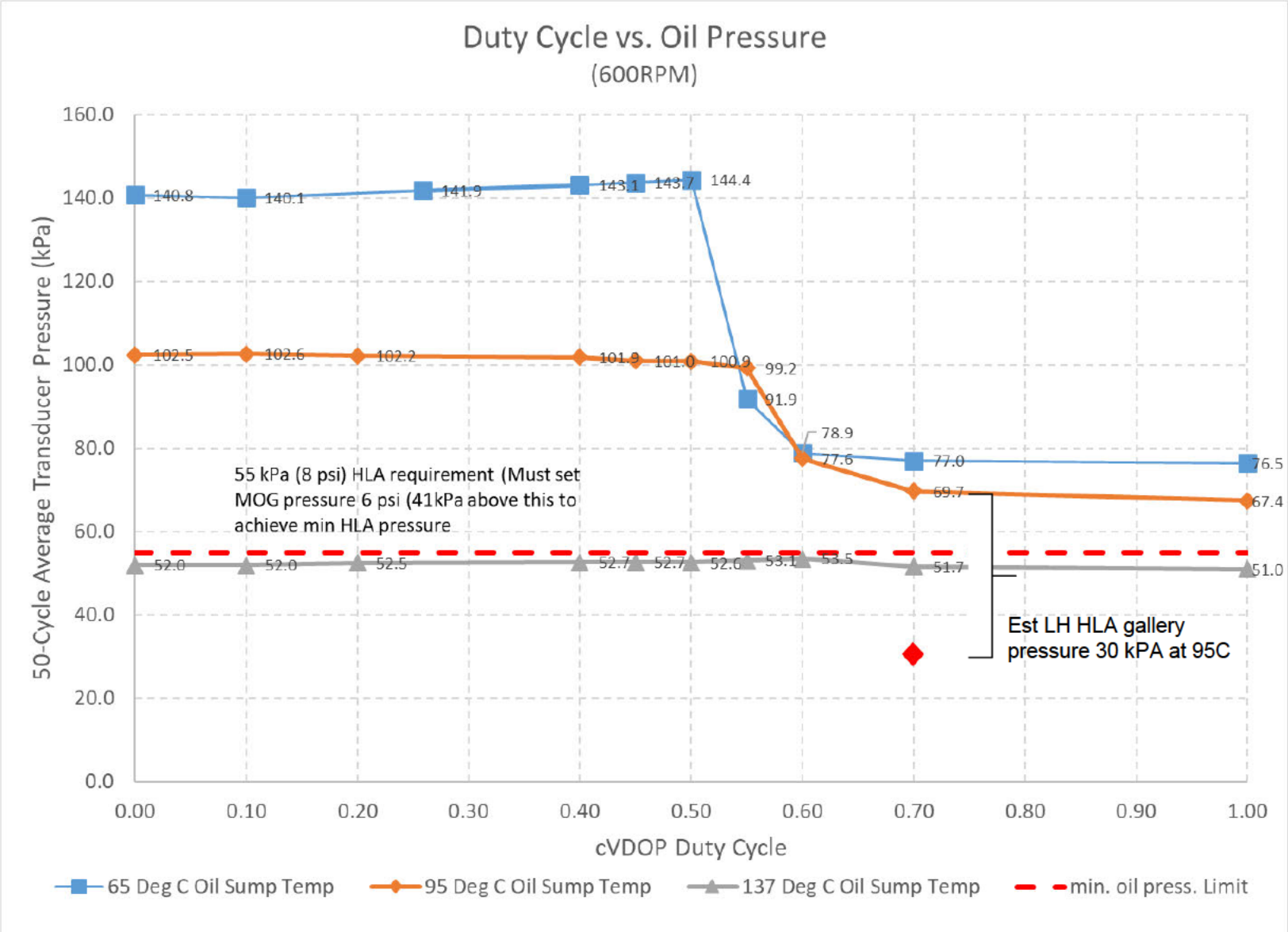
- Empirical data on 18MY 2.7L RWD shows lower oil pressure on LH vs RH cylinder heads (~4psi)





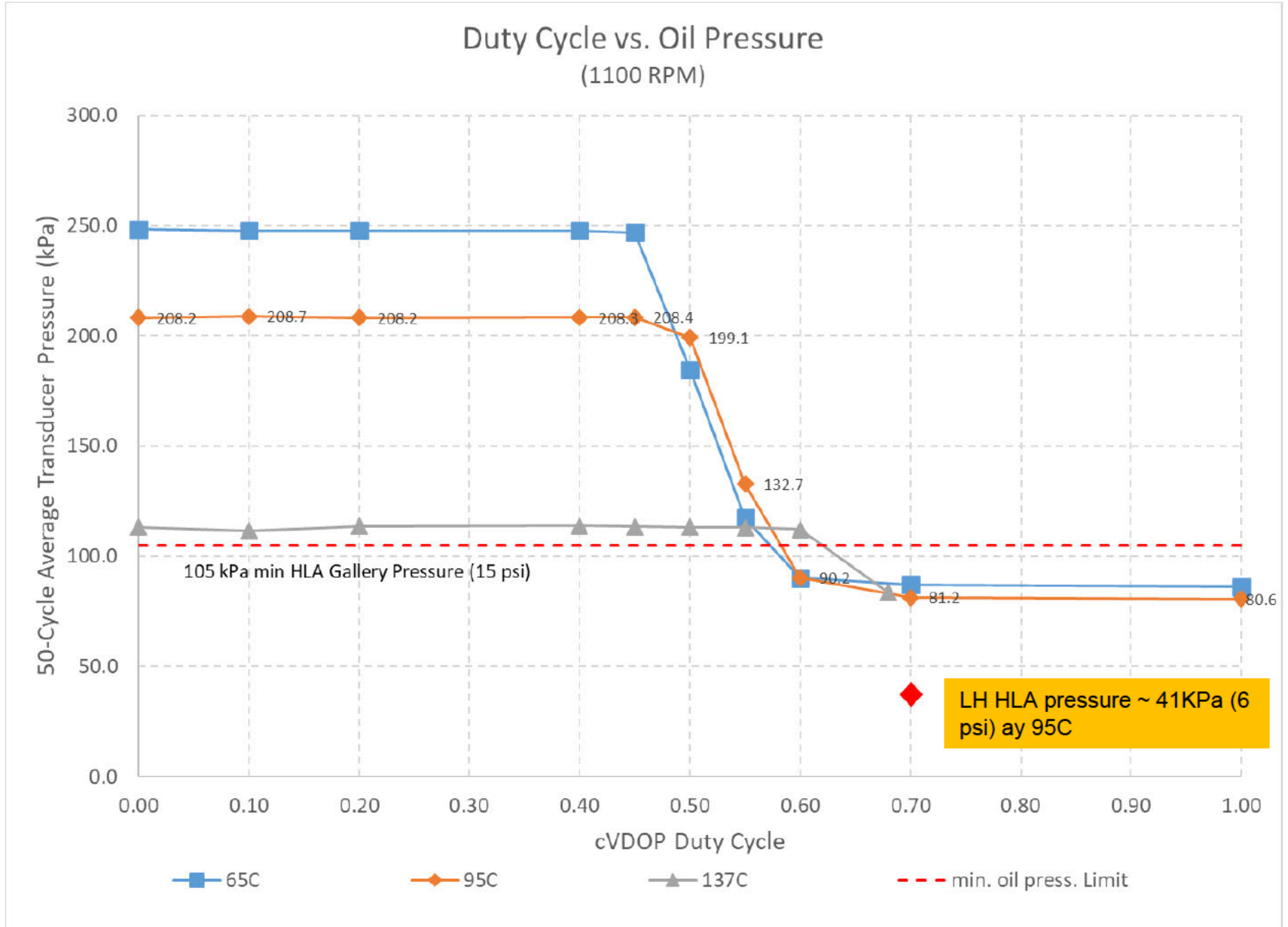


cVDOP Characterization Data 18MY P552



Based on 18 MY lube survey data LH HLA gallery has potential to drop below min pressure. ~ 30 kPa (4.5 psi)

cVDOP Characterization Data



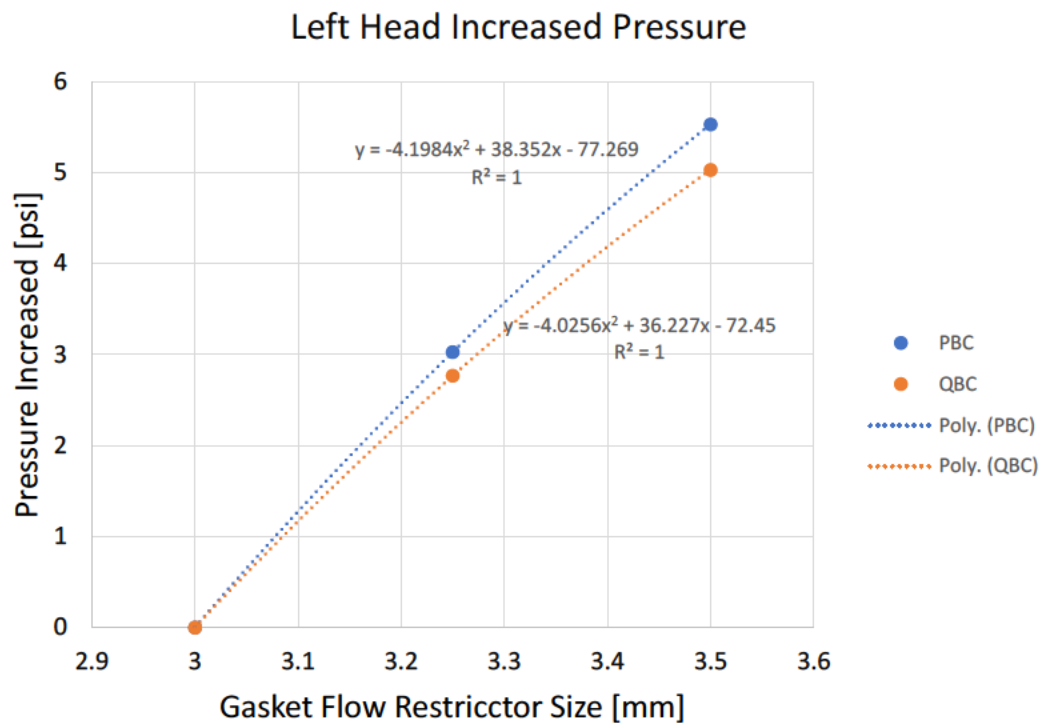
Proposed calibration changes

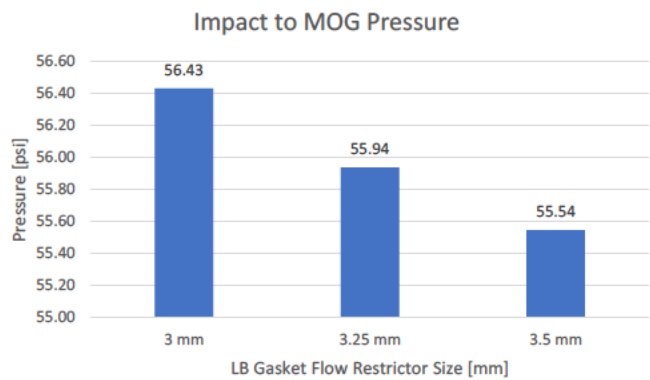
Current cVOP status						
elvop_eop_hot_prot_m						
Y \ X	500	1000	2800	3000	6500	
0.25	70	105	240	300	450	
0.5	70	105	240	300	450	
0.7	70	240	240	300	450	
1	70	300	300	300	450	
1.2	70	300	450	450	450	
elvop_eop_min_p_m						
Y \ X	500	1000	2800	3000	4500	6500
-10	500	500	500	500	500	500
20	240	240	300	400	400	450
50	150	150	150	300	350	450
90	105	105	105	300	350	450
110	70	105	105	300	350	450
150	70	105	105	300	350	450

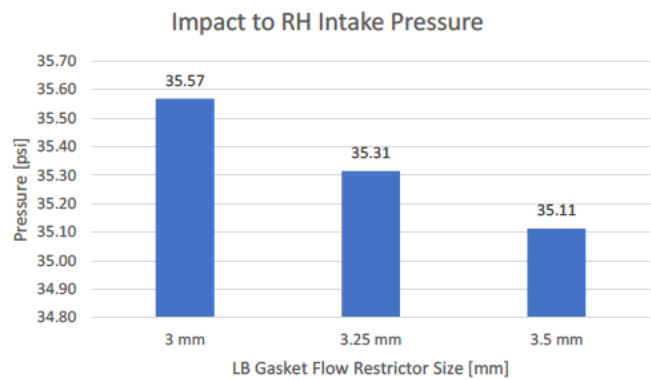
Proposed changes to improve HLA pressure						
elvop_eop_hot_prot_m						
Y \ X	500	1000	2800	3000	6500	
0.25	110	150	240	300	450	
0.5	110	150	240	300	450	
0.7	110	240	240	300	450	
1	110	300	300	300	450	
1.2	110	300	450	450	450	
Proposed changes to improve LH HLA pressure						
elvop_eop_min_p_m						
Y \ X	500	1000	2800	3000	4500	6500
-10	500	500	500	500	500	500
20	240	240	300	400	400	450
50	150	150	150	300	350	450
90	110	150	105	300	350	450
110	110	150	105	300	350	450
150	110	150	105	300	350	450

Oil pressure robustness action

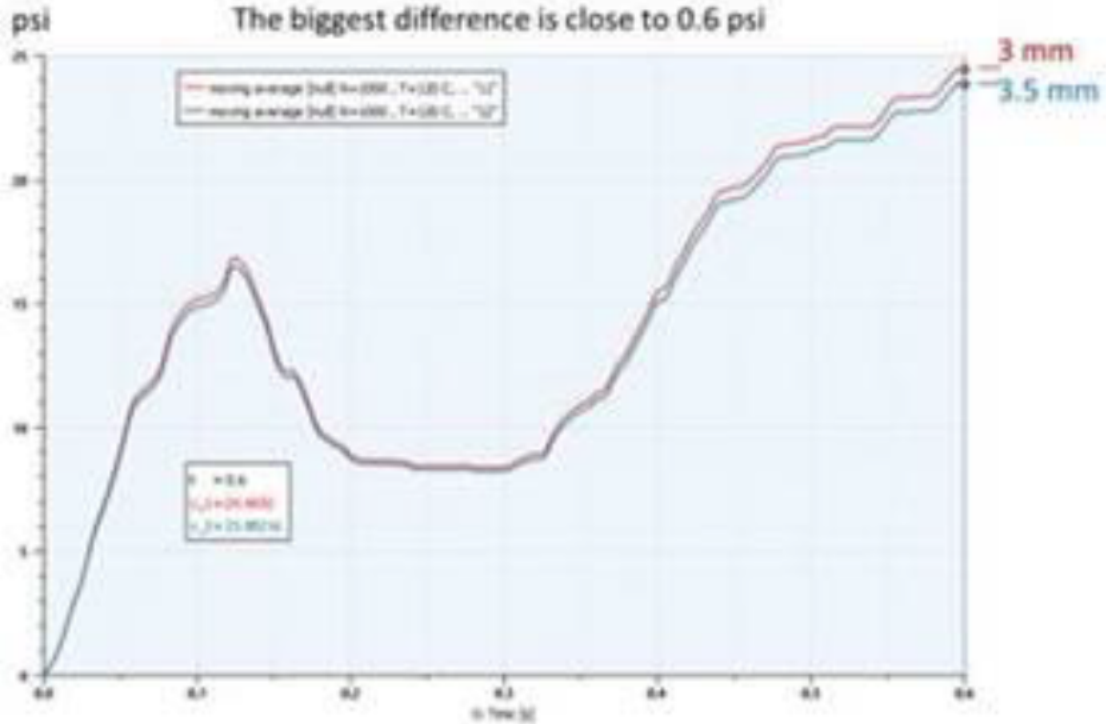
- LH Head gasket restrictor change
  - Run Model simulation of different orifice sizing on LH head HLA restrictor
  - 5 psi increase capable with 0.5mm increase (3.5mm orifice)
  - Negligible impact to MOG and RH head.
  - Further sensitivity analysis to VCT required







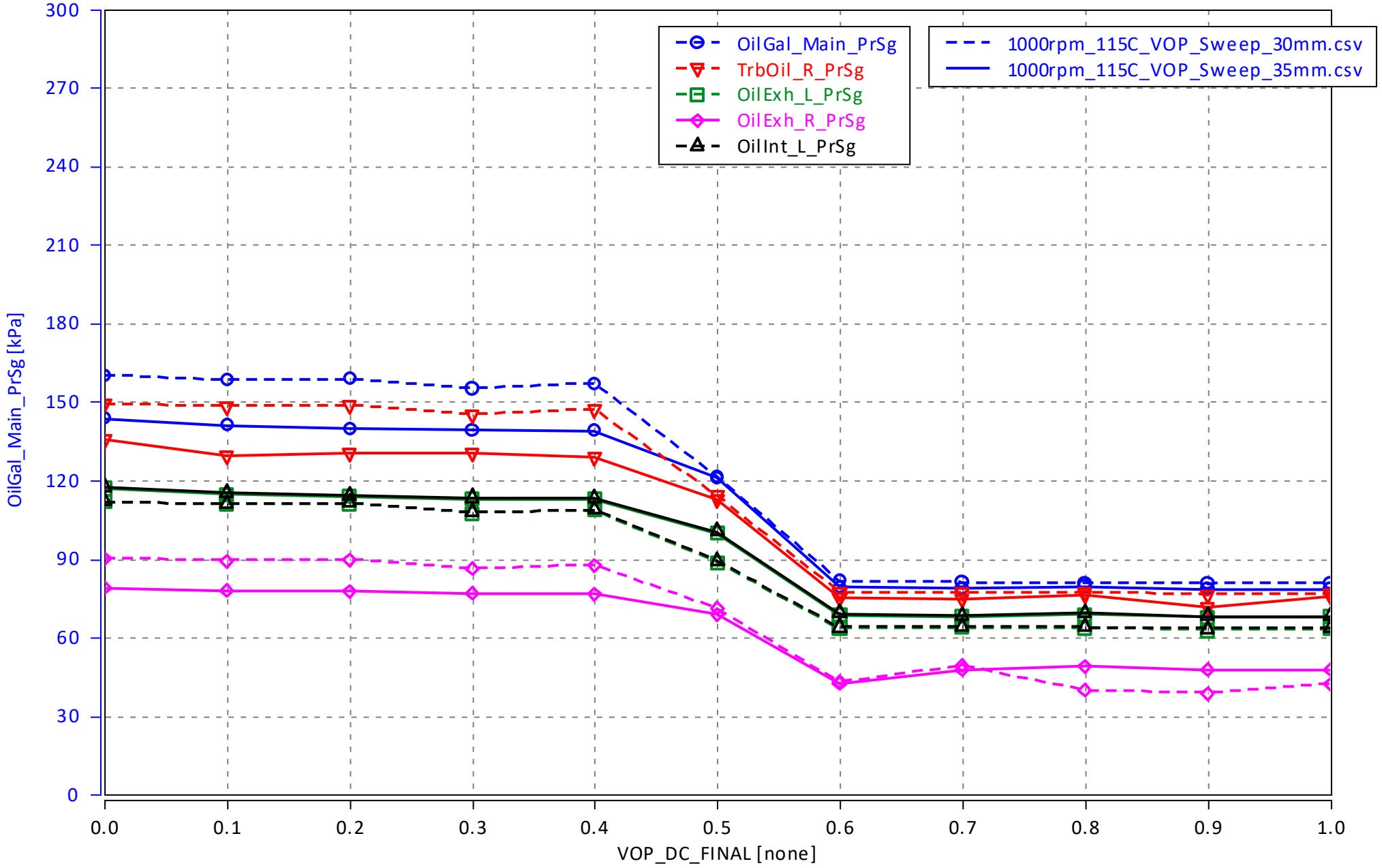
Cycle Averaged LB Intake VCT Supply Pressure



3.0L dyno lube survey test plan for restrictor change:

- Baseline RPM sweep at 95C and 140C
  - Results indicate variability to due oil temperature control.
- VDOP duty cycle sweep at 95C and 140C at 600 & 1000, and 1500 RPM. (8/13/21)
  - Improved temperature control eliminated variability
  - Data supports CAE with slight improvement in LH head HLA pressure and slight reduction at other locations.
- Time to prime after hot restart (Only 3.0mm gasket)
- Low load speed 1000 – 4500 RPM sweep running baseline VDOP cal. (3.0mm gasket)
- VCT stability and shift velocity:

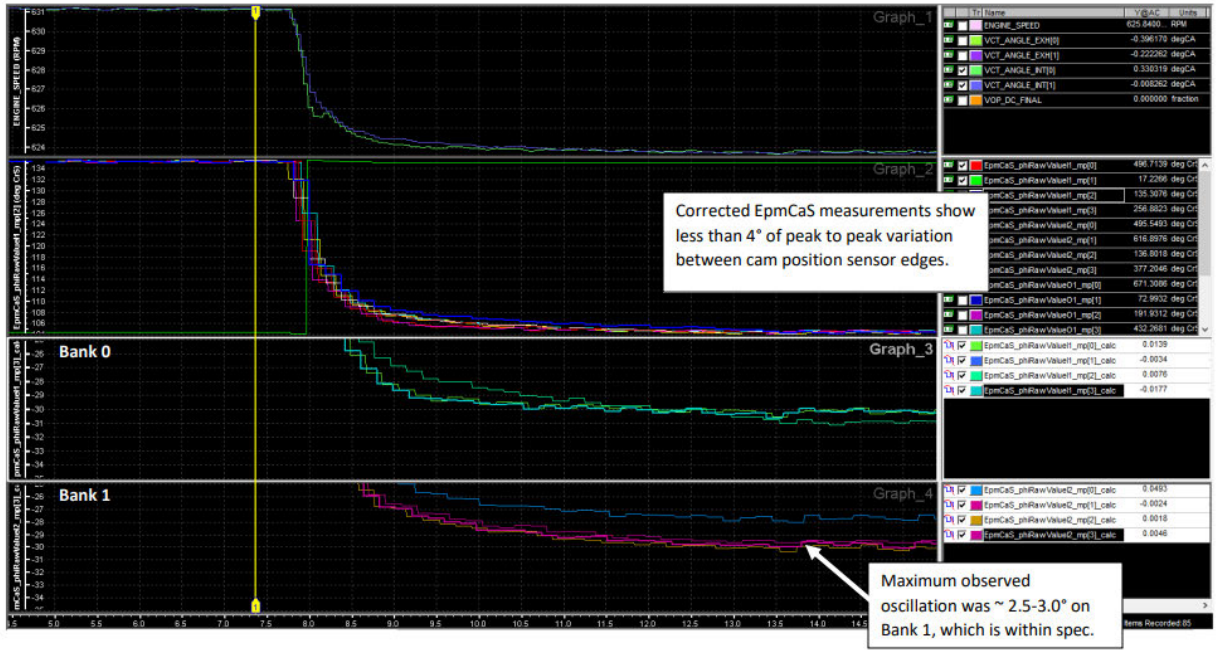
Engine Speed	Oil Temperature	Head Gasket	Phasing	Oil Pump Mode
600 RPM	100 C	3.0 mm orifice 3.5 mm orifice	IN: Measure shift time to 30°. Measure stability at 10° advance. EX: Home Position	High Mode
600 RPM	110 C	3.0 mm orifice 3.5 mm orifice	IN: Measure shift time to 30°. Measure stability at 10° advance. EX: Home Position	High Mode
1000 RPM	100 C	3.0 mm orifice 3.5 mm orifice	IN: Measure shift time to 30° and 60° positions. Measure stability at mid position (30°) EX: Measure shift time to 25° and 50° positions. Measure stability at mid position (25°)	Scheduled Pressure
1000 RPM	110 C	3.0 mm orifice 3.5 mm orifice	IN: Measure shift time to 30° and 60° positions. Measure stability at mid position (30°) EX: Measure shift time to 25° and 50° positions. Measure stability at mid position (25°)	Scheduled Pressure


OilGal_Main_PrSg
TrbOil_R_PrSg
OilExh_L_PrSg
OilExh_R_PrSg
OilInt_L_PrSg
1000rpm_115C_VOP_Sweep_30mm.csv
1000rpm_115C_VOP_Sweep_35mm.csv
OilGal_Main_PrSg [kPa]
VOP_DC_FINAL [none]
300
270
240
210
180
150
120
90
60
30
0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0

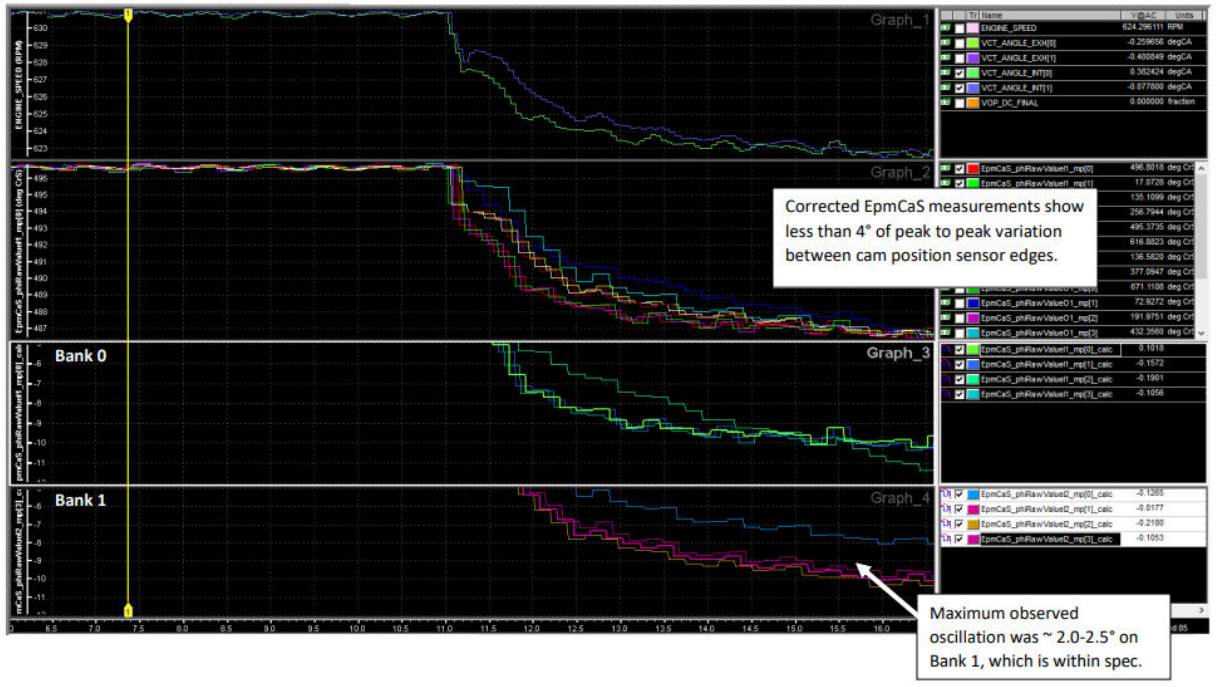
VCT Stability and shift velocity

- Both results showed oscillation within specification (max VCT spec is 4° peak to peak).
- Shift speed time differences are negligible
- Do not see any significant impacts to VCT performance between the 3.0 mm and 3.5 mm head gasket orifice.

Condition:
1000 RPM, 110 °C Oil Temperature, Scheduled VDOP, 0° to -30° intake VCT Shift
3.5 mm orifice head gasket



Condition:
625 RPM, 110 °C Oil Temperature, VDOP MAX, 0° to -10° intake VCT Shift
3.5 mm orifice head gasket



Other Test Requests: Open Items

- Install gasket on 2.7L Edge and evaluate VCT performance (Timing TBD)
  - Andy Dame checking if he has a calibration vehicle that can be updated.
- This is confirmation of any calibration impacts of having more draw from vacuum pump on LH VCT supply
- PCV performance due to 0.5L/min flow.
  - Confirmation that additional splash will not have impact on oil separator performance.
  - Engine programs working through test plan options.
  - Proposing to evaluate separator performance on back to back A-B EFT cycle confirmation.

No impact to 2.7L due to separator entrance
Concern is on 3.0L due to entrance location.
A-B testing to be performed as confirmation only. (Assume required until we hear further)

Vehicle Comparison (2.7L Edge)

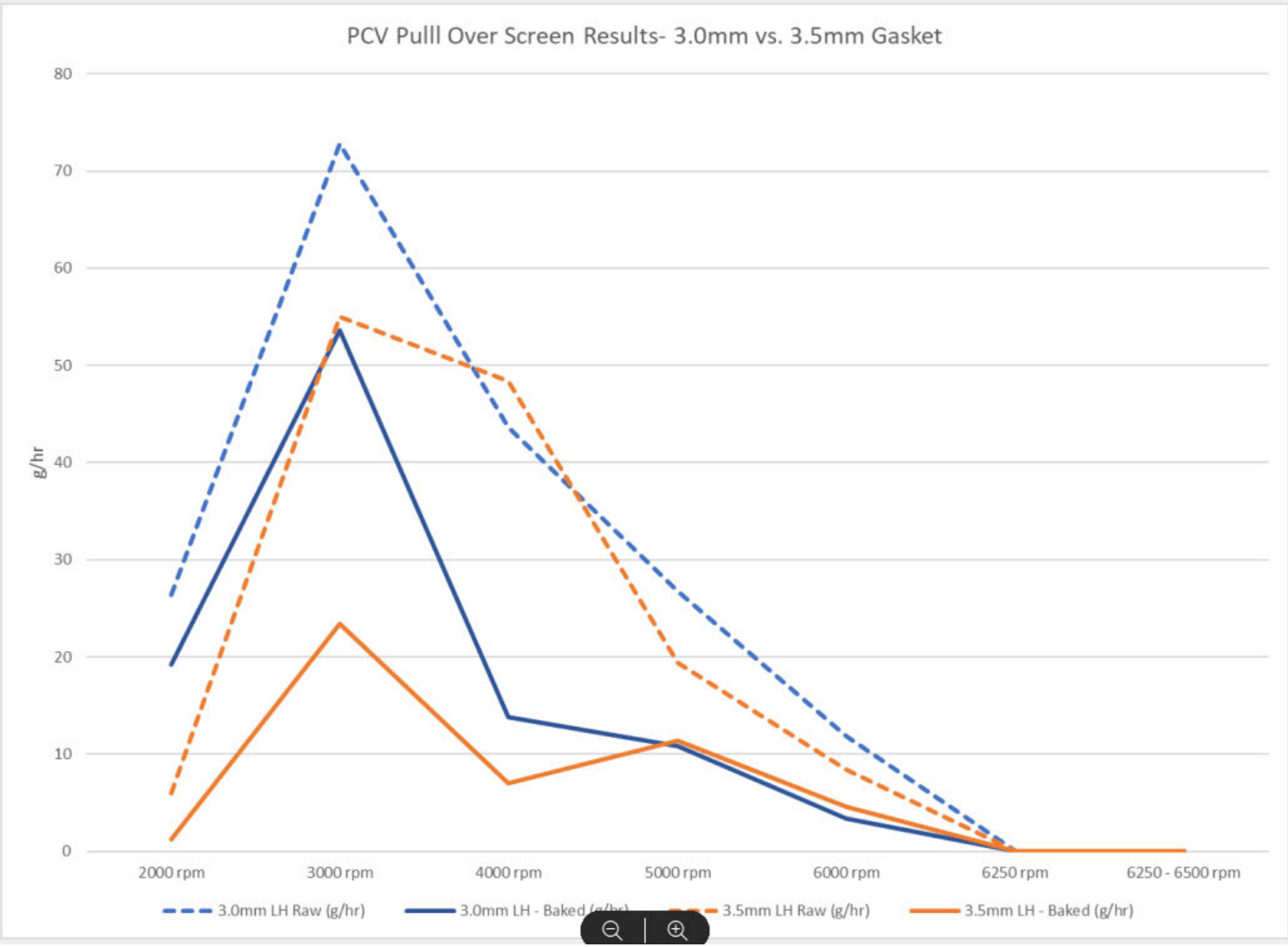
- VCT step script to command various step changes in VCT commanded position.
- Compare the VCT response for the current production gasket to the new gasket to see if there is any impact to VCT control.
- Edge vehicle selected due to vacuum pump draw on LH cyl head

run #	engine speed		oil temp		LH head gasket	
	600	1000	90	110	current	new
1	x		x		x	
2		x	x		x	
3	x			x	x	
4		x		x	x	
5	x		x			x
6		x	x			x
7	x			x		x
8		x		x		x

Exhaust index	start	end
1	0	5
2	0	10
3	0	20
4	0	30
5	0	40
6	0	50
7	0	10
8	45	40
9	45	30
10	45	20
11	45	10
12	45	0

Intake index	start	end
1	0	-5
2	0	-10
3	0	-20
4	0	-30
5	0	-40
6	0	-50
7	0	-60
8	0	-10
9	-55	-50
10	-55	-40
11	-55	-30
12	-55	-20
13	-55	-10
14	-55	0

PCV Screener Test Results



Negligible difference in oil separator performance between 3.0mm and 3.5mm restrictors.

C14252615 / A14252615

Scope of change:

- Modify oil hole from 3 to 3.5mm
  - Part number change
  - Tooling change
  - Bank Build required
  - Alert required to ship parts before PPAP (to be defined if it will be under the new or old Part number)

Costs:

- **Tooling:**

  2.7L LH Tool = 5,000 USD → Off tool Parts: 5 weeks lead time (EXW out of EK Bufford)
  3.0L LH Tool = 5,000 USD → Off tool Parts: 5 weeks lead time (EXW out of EK Bufford)
  2.7L LH Tool Reman = 1,000 USD → Off tool Parts: 5 weeks lead time (EXW out of EK Bufford)

  Total Tool Cost: 11,000 USD

- **Delta Piece price:** Zero

- **Bank Build costs:** 15,000 USD
  - Required Bank Build Budget Approval from Ford Purchasing

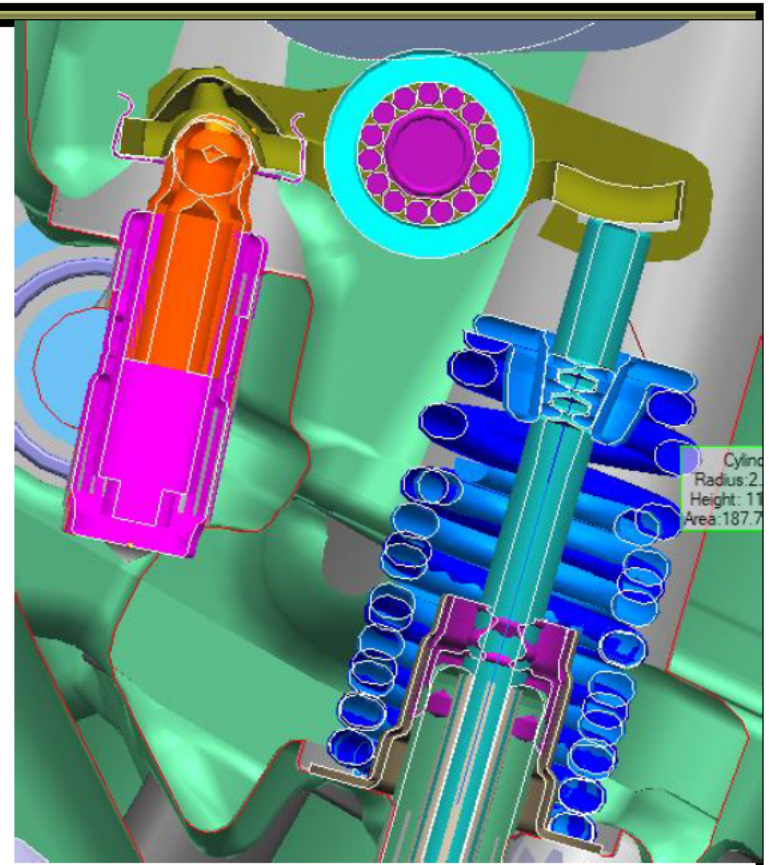
EK will start shipping parts right after tool change is completed. We cannot produce parts with the 3mm hole before the change is made.
Dimensional from hole change will be provided as PPAP documentation from EK, only!

PANEL

RFF Tipping Reduction: CLAG Reduction (HLA Move)

Hypothesis

- Excessive lash resulting in Excessive RFF Tilting + Side Load
- Excessive lash should be compensated by hydraulic lash adjuster (HLA) function



Potential Action

- Reduce Mechanical lash in event of HLA malfunction (CLAG)
- Reduced lash will better control RFF tipping in the event of malfunction

Next Steps:

- Compare seal land on Nano (4.05nom; 3.5min) to 5L (Rhude)
- Investigate SF to HLA bore cracking on Nano (Reinhart)
- Locate CMM and calculate seat recession numbers for Nano Glosys and EFT (Rhude)
- Determine CLAG required for tolerance take-up utilizing key contributors and Arithmetic / RSS methodology (Adam/Nelson)
- Determine amount of CLAG required to raise RFF finger above valve tip in valve closed position (Nelson / Adam)
- Create WORQ orders (2) for head inspection (HLA, Guide, cam bore, Gauge Line, etc. as discussed) for 2 returned heads (Reinhart)
- Update LOS for 0.2mm CLAG reduction to “test” the change (Heggie)
- Implementation timing w/ LEP / ChEP

PANEL

RFF Tipping Reduction: RFF Alignment via Tolerance Refinement

Hypothesis

- Excessive lash resulting in Excessive RFF Tilting + Side Load
- RFF tilting / side load can be minimized with component alignment

Potential Action

- Refinement of critical tolerances to improve RFF alignment
- Utilize VSA to guide “heavy hitters” for RFF Alignment

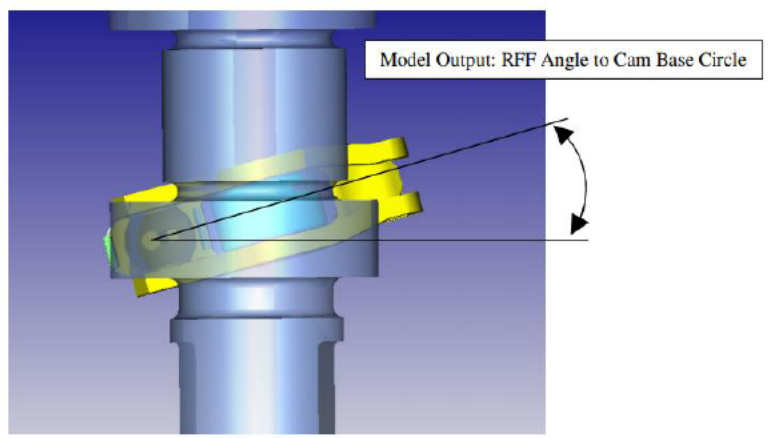
Next Steps:

- Capability study for RFF parallelism / Perp (Schaeffler) – Constraints on Refinement
- Capability study for Guide / HLA True Position (Reinhart) – LEP / CEP Timin
- Inspection of returned hardware to understand where we are in the population (Schaeffler / Reinhart)
- Timing from LEP / CEP for Refinement / Changes

Exhaust RFF Roller Axis to CamBase Circle Top View With RFF Tip to Valve Bias

Nominal : 0.3288
Process Variance : 0.0779
HLM Variance : 0.0901

Contributors	Effective Tole...	Sensitivity	Effect
1. Left Exhaust RFF Arm - Roller -> Size: Min: -0.025 Max: 0.025; |POS |Dia 0.300 |A|B|C| ; |P...	1.3889	N/A	59.43%
2. Left Cylinder Head - Exhaust LA Bore -> Size: Min: -0.005 Max: 0.005; |POS |Dia 0.250 (M) |A|B(M) |...	0.7782	N/A	18.66%
3. Left Cylinder Head - Exhaust Valve Guide Hole -> Size: Min: -0.005 Max: 0.005; |POS |Dia 0.250 |A|B(M) |C(M) |	0.6453	N/A	12.83%
4. LASH ADJ LH Exh - Spherical Tip - -> Bottomed Position -> |TRO |0.200 |A|	0.3322	1.6608	3.40%
5. Left Exhaust RFF Arm - Slot -> Size: Min: -0.150 Max: 0.150; |PER |0.150 |AC|	0.2569	N/A	2.03%
6. FT4E-6A269-AA3-PIA-01_6-C_SHFT EXH LH XM - Exhaust Base Circle -> Size: Min: -0.076 Max: 0.076; |TRO |0.025 |A-B|C|	0.2430	N/A	1.82%
7. Left Cylinder Head - Exhaust Valve Seat Pocket -> Size: Min: -0.005 Max: 0.005; |POS |Dia 0.250 |A|B(M) |C(M) |	0.1879	N/A	1.09%
8. Left Cylinder Head - Exhaust Cam Bore -> 0.8155 -> Size: Min: -0.0125 Max: 0.0125; |POS |Dia 0.200 (M) |A|B(M) ...	0.0806	N/A	0.20%



U725 Hardware differences

- Oil pan
- Oil Pump

	2021 MY				
	2.7L FWD	2.7L RWD	2.7L RWD	3.0L RWD	ASSUMES + 23MY/24MY UPG3 Option #4 + U725 Raptor DR1 based upon NU3 3.0L Content
	CD391 CD539/U540	P702	U725	U6XX gas + PHEV	
MP1	PROD	Jun-20	Dec-20	Apr-19	
JL	Dec-22	Jul-23	Jul-24	Oct-22	
Oil Pick Up Tube - 6622			A		A: Pick up tube for P702, P703, and U725 (maintain existing complexity-no change) Blank means PIA to Oil Pan, Pump, etc
Oil pressure sensor - 9D290	A	B	B	A	A: OPS (Analog) B: OPS (SENT) C: OPTS (SENT); Being Investigated for DR1
Oil Pump - 6621	A	B	C	D	A: FWD 2.7L B: P702 2.7L C: P703/U725 D: U6XX
Oil pump drive belt - 6B651	A	A	A	B	(maintain existing complexity-no change) A: P702, P703, U725 B: U6XX
Oil pump sprocket cover - 6616				A	A: U6XX only (maintain existing complexity-no change)
Piston Cooling Jet - 6K868	A	B	B	B	A: FWD 2.7L B: RWD 2.7L and 3.0L (maintain existing complexity-no change)
RH / LH Head Gasket - 6051/6083	A	A	A	B	A: c/o head gaskets for 2.7L B: 20MY/23MY 3.0L C: New gasket for 3.0L Block D: New resourced gasket for 2.7L.
RH Camshaft - Exhaust - 6A268	A	A	A	B	A: 2.7L and U725 B: U6XX 3.0L
RH Camshaft - Intake- 6A267	A	A	A	B	A: P702, P703, U725 B: 20MY U6XX due to MVP
RH Head - Assy - 6049	A	B	B	C	A: FWD 2.7L B: 21MY P702 2.7L Head with PFI C: 20MY/23MY RDE 3.0L pedestal mount DI pump (no PFI), high tension springs, GPF seals D: 22MY U725 Raptor (3.0L 20MY CD6 head with upgraded material, EGR delete, 2.7L combustion/IEM location) E: 3.0L Machining difference for lubrication sealing, grommet in place of 2 o ring design F: 3.0L 23MY Low tension springs, Non-GPF seals H: (B) updated with revised machining for lubrication sealing, grommet
RH Head - Cstg	A	B	B	C	A: FWD 2.7L B: 21MY P702 2.7L Head with PFI C: 20MY 3.0L pedestal mount DI pump (no PFI) D: 22MY U725 Raptor (3.0L 20MY CD6 head with upgraded material, EGR delete, 2.7L combustion/IEM location)
Vacuum Pump - 2A451	A			B	A: FWD 2.7L B: 20MY 3.0L - to be removed for 3.0L U6xx for friction red, add EAWG to turbos
Valley Stuffer				A	A: 3.0L Valley Stuffer; (To be deleted from all 3.0L)
Valve - Exhaust/Intake Spring - 6513	A/A	B/B	B/B	A/A	Exhaust/Intake Springs A: FWD, 2.7L and 3.0L U6XX; GPF Springs (China applications) B: P702, U725; (maintain existing complexity); Non- GPF Springs
Valve Assy-fuel vapor purge - 9B325	A	B	B	A	A: FWD 2.7L and 20MY 3.0L U6XX B. P702 2.7L upg2; (23MY to use this - common across all at that point)
Valve- Stem Seal - 6A517	A	B	B	A	A: GPF seal B: Non-GPF seal (to be studied via Concern to pull ahead to 21MY
Valves - Exhaust - 6505	A	B	B	C	A: FWD 2.7L B: P702, P703, U725 C: U6XX 3.0L; U725 Raptor (maintain existing complexity-no change)
Valves - Intake - 6507	A	A	A	A	A: Common across all; maintain existing complexity-no change
VCT - Exhaust - 6C525	A	A	A	A	A: 2.7L/3.0L VCT
VCT - Intake - 6C524	A	A	A	A	A: 2.7L/3.0L VCTs

Continued Root Cause Identification Workplan

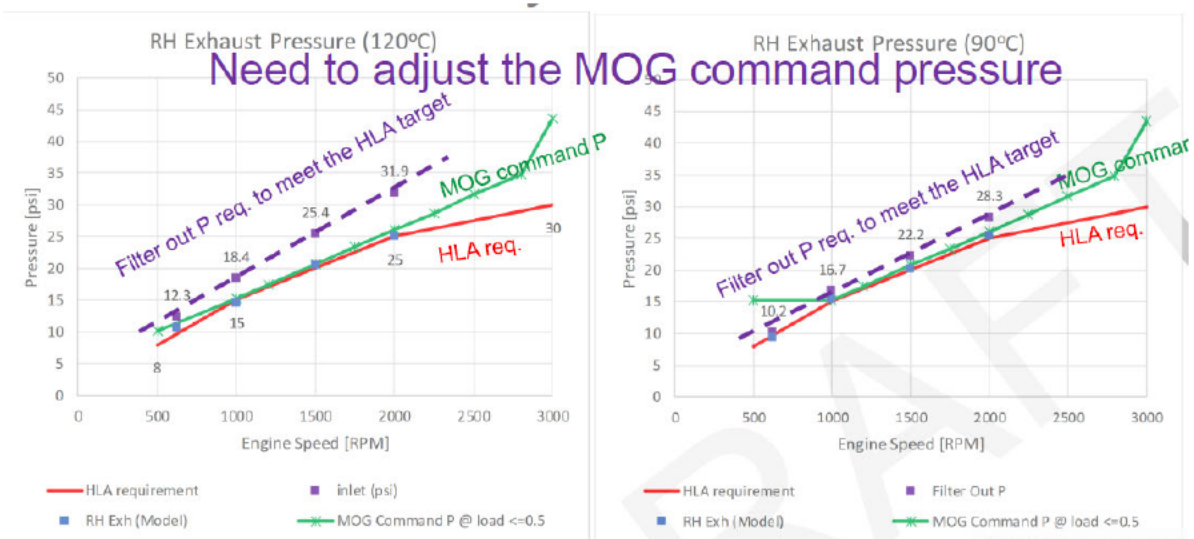
- Replicate 3rd keeper groove failure on PFSL Rig (Complete)
  - Requires non functioning HLA to produce lash in the system.
  - HS video evidence of RFF dynamics with increased lash introduce tipping and side load of valve tip.
  - Cam rotation on LH bank increases potential for RFF misalignment.
- Analytical dynamics analysis with increased levels of aeration
- Correlation to PFSL bench test
- Comparison of green engine vs higher mileage
  - Component interfaces that exacerbate misalignment/side loading on new parts
  - Deep dive of wear in characteristics
  - Lubrication system performance on green engine
- Vehicle level aeration testing – AirX equipment
  - Aeration vs grade and transient performance
  - Relationship of pressure and aeration vs conditions
- Strain gage study on valve guide at fatigue test conditions with induced side load
- Revisit how lube system is set up and how minimums are established.

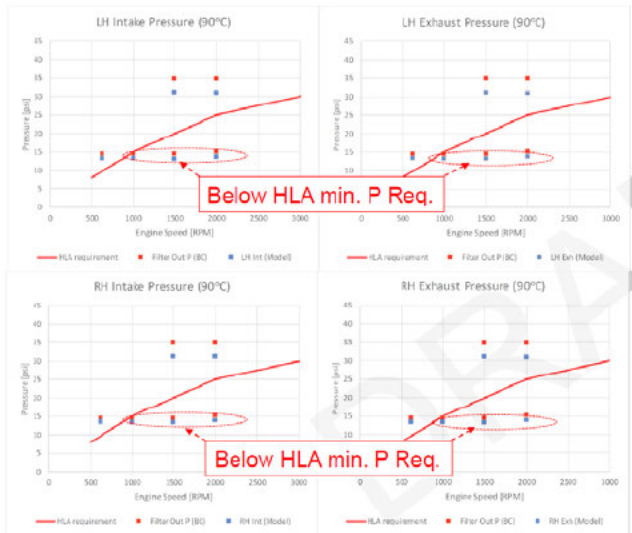
Add prox probe data for aeration testing at dyno

Back Up

Analytical Lube Model - 2020-HMS-DEARBORN-45323

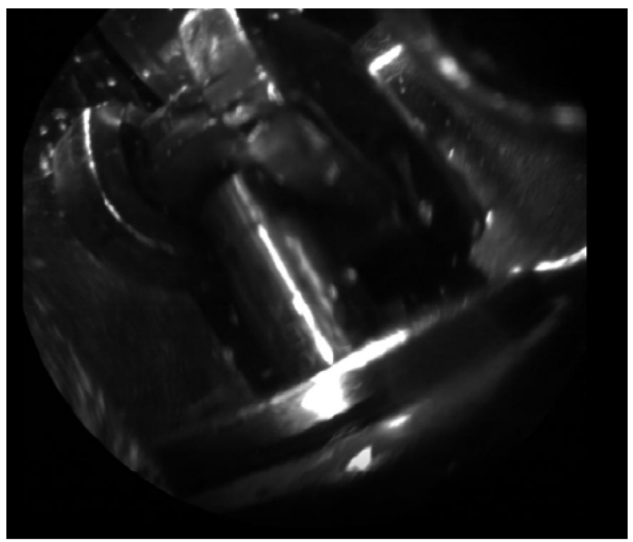
- 2022.5 MY 3.0L V6 Nano GTDI G U725 back correlated to 18MY M1 FWD AC4146
  - 18MY aeration and oil pressure data used
  - Model not run with 20MY 3.0L CD6 conditions
- Results show pressure below requirements



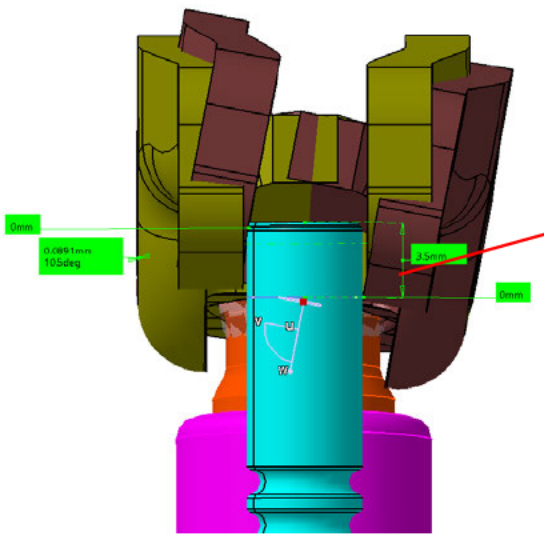


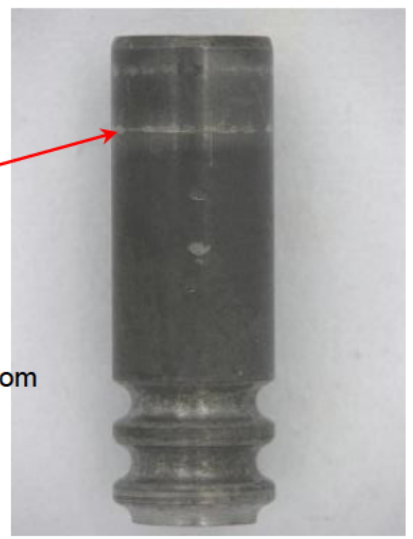
Root Cause Hypothesis:

- Valve tip is being side loaded as a result of increased lash in the system.
- Increased lash in the system is a result of spongy / collapsed HLA's potentially caused by lube system performance (oil pressure / aeration) or defective / contaminated HLA.
- 3rd keeper groove failures have been reproduced in PFSL lab by running spinner rig testing with bled down lash adjusters.
- RFF's more susceptible to misalignment on LH bank due to cam shaft rotation pushing RFF toward lash adjuster. Misalignment of RFF increases tipping and side loading of valve tip.



Slow motion video with lash in the system shows RFF tipping and side loading of valve tip.





Depth of wear indicates side loading. More severe than witness mark from side contact.

Fuel Benefits for Reduced Oil Pressure:

15 psi Idle / 20 psi Others Baseline:

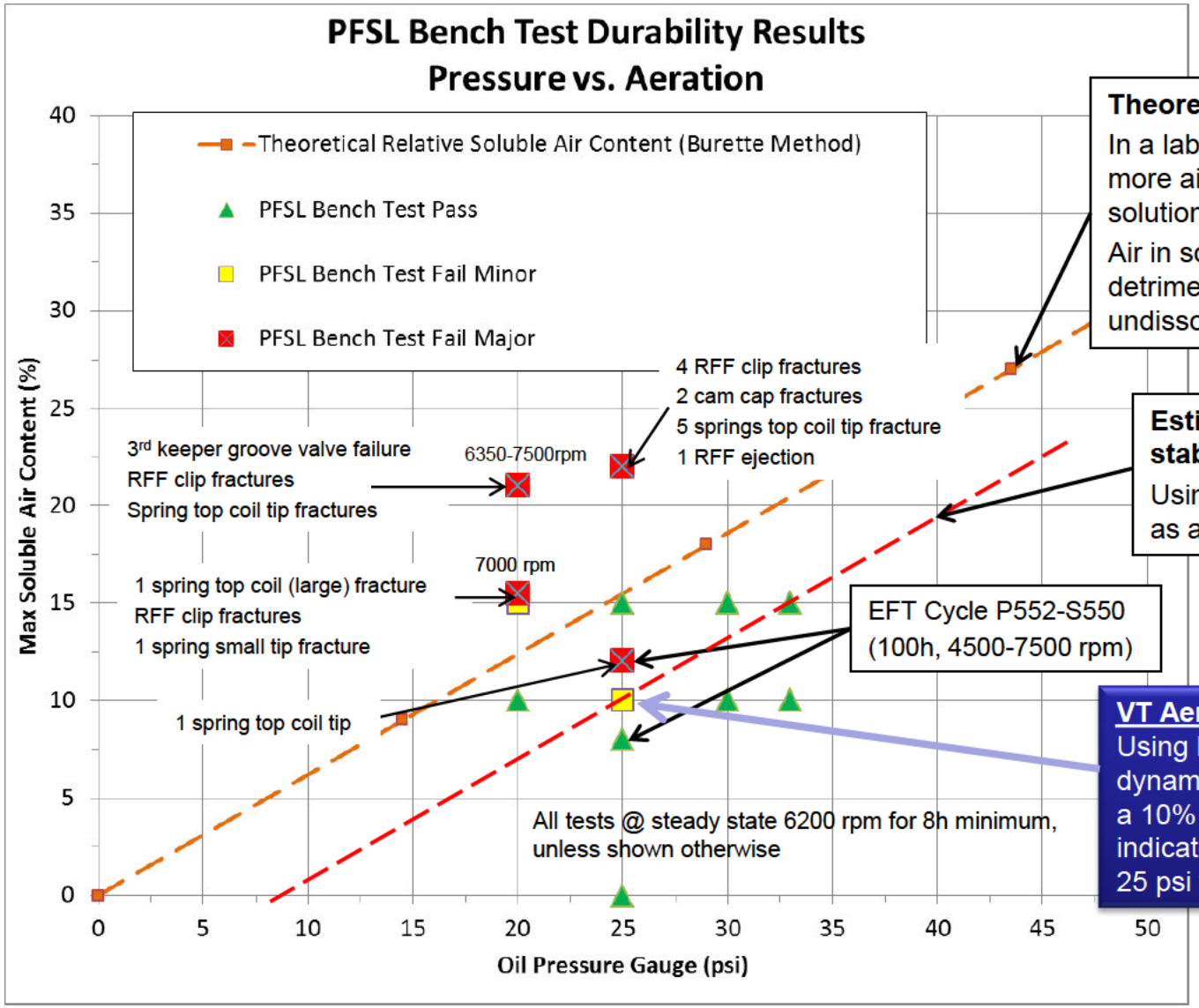
Premium Fuel	City	Hwy	US06	M/H
Thermal Efficiency - Status	27.1%	29.9%	33.5%	
MPG - Status	**32.42**	**41.47**	**27.32**	**35.95**
Thermal Efficiency - Target	27.0%	29.8%	33.4%	
MPG - Target	**32.32**	**41.38**	**27.28**	**35.85**
Difference	**0.32%**	**0.23%**	**0.17%**	**0.29%**

10 psi Idle / 15 psi Others

Premium Fuel	City	Hwy	US06	
Thermal Efficiency - Status	27.2%	29.9%	33.5%	
MPG - Status	**32.52**	**41.58**	**27.36**	**36.06**
Thermal Efficiency - Target	27.0%	29.8%	33.4%	
MPG - Target	**32.32**	**41.38**	**27.28**	**35.85**
Difference	**0.63%**	**0.48%**	**0.32%**	**0.57%**

Data Analysis on 3.0L 2020MY demonstrated ~0.2 M/H
At low speed 500-1000 RPM region.

2018MY 5.0L S550 Valve Train Aeration Sensitivity
PFSL Motored Cylinder Head Durability Status



Theoretical air to oil solubility line.

In a lab setting, as pressure increases, more air by volume is able to go into solution in oil.

Air in solution is believed to be less detrimental to HLA function compared to undissolved air (bubbles).

Estimated VT dynamic stability threshold.

Using bench test durability as an indicator.

EFT Cycle P552-S550 (100h, 4500-7500 rpm)

VT Aeration Robustness:

Using PFSL bench durability survey as a dynamics indicator, In order to withstand a 10% oil aeration level, test results indicate that a minimum oil pressure of 25 psi would be required.

5.0L P702 cVDOP Cal

Elvop_eop_min_p_m

Y \ X	500.00	900.00	2800.00	3000.00	4500.00	7000.00
-40.00	180.000000	255.000000	255.000000	255.000000	500.000000	500.000000
10.00	180.000000	255.000000	255.000000	255.000000	400.000000	400.000000
40.00	70.000000	230.000000	230.000000	250.000000	350.000000	400.000000
90.00	70.000000	200.000000	220.000000	250.000000	350.000000	400.000000
120.00	70.000000	200.000000	220.000000	250.000000	350.000000	400.000000
150.00	70.000000	200.000000	220.000000	250.000000	350.000000	400.000000

Elvop_eop_hot_prot_m

Y \ X	500.00	900.00	2800.00	3000.00	7000.00
0.00	70.000000	180.000000	220.000000	310.000000	350.000000
0.25	70.000000	180.000000	220.000000	310.000000	350.000000
0.75	70.000000	180.000000	220.000000	310.000000	350.000000
0.80	70.000000	180.000000	310.000000	310.000000	350.000000
1.00	70.000000	180.000000	310.000000	310.000000	350.000000

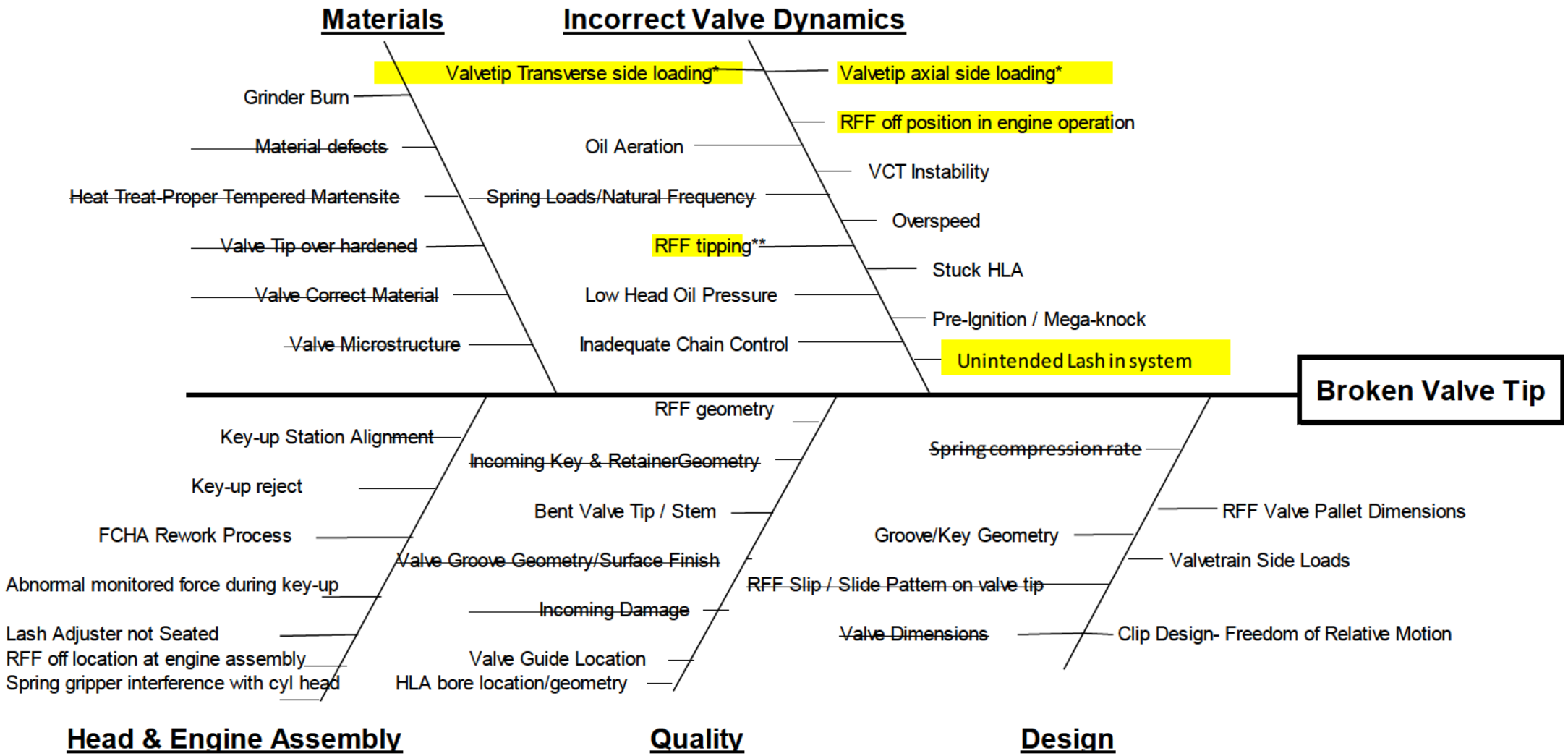
PANEL

20-21MY Engine Exchange List

Year	Dealer	Engine Disp	Vehicle	Miles	AWS Previous Repairs (Y/N)
2020	TOM ROUSH LINCOLN	3.0L	Aviator	1,140	No
2020	HEISER FORD	3.0L	Aviator	766	No
2020	PHIL LONG FORD OF DENVER LLC	3.0L	Explorer	2,426	No
2020	FRIENDLY FORD	3.0L	Explorer	743	No
2020	MONTMORENCY FORD LINCOLN	3.0L	Aviator	956	No
2020	MAC HAIK FORD	3.0L	Explorer	1,842	No
2020	TITUS-WILL FORD SALES INC.	3.0L	Explorer	1,577	No
2020	LUCAS MOTOR COMPANY INC.	3.0L	Explorer	1,282	No
2020	LC Zhuhai Litian	3.0L	Aviator	4,153	No
2020	KALISPELL FORD	3.0L	Explorer	7,026	No
2020	CAPITAL FORD OF WILMINGTON	3.0L	Explorer	10479	No
2020		3.0L	Aviator	471	Yes
2020	CHILLIWACK FORD	3.0L	Explorer	203	No
2020	FIVE STAR FORD	3.0L	Explorer	2100	No
2020	ZEIGLER FORD OF ELKHART	3.0L	Explorer	5488	No
2020	UNIQUE FORD INC.	3.0L	Explorer	2407	No
2020	FOX FORD GRAND TRAVERSE	3.0L	Explorer	1056	No
2020	HEMPSTEAD FORD	3.0L	Explorer	933	No
2020	LC Zhengzhou Aojitong Aolin	3.0L	Aviator	869	No
2020	ZEIGLER FORD OF ELKHART	3.0L	Explorer	9517	No
2020	AUTONATION FORD WESTLAKE	2.7L	F150	1021	No
2020	WAYNE AKERS FORD INC.	2.7L	F150	3200	No
2020	RYE FORD INC.	2.7L	F150	2008	No
2020	BENNA FORD SUPERIOR	2.7L	F150	903	No
2020	JONES FORD BUCKEYE	3.0L	Explorer	6898	No
2021	HOFFMAN FORD	3.0L	Explorer	513	No
2021	GILLESPIE FORD	2.7L	F150	2080	No
2021	CAPITAL FORD INC.	3.0L	Explorer	5302	No
2021	EL CAJON FORD	2.7L	F150	1203	No
2021	SHAFFER FORD	2.7L	Edge	857	Yes
2021	SANTA MONICA FORD	3.0L	Aviator	9400	No
2021	KEN GRODY FORD - REDLANDS	2.7L	F150	2178	No
2021	MULLINAX FORD	2.7L	F150	56	No
2021	FORD OF KENDALL	3.0L	Aviator	147	No
2021	PAT MILLIKEN FORD, INC.	2.7L	F150	359	Yes

PANEL

Fishbone

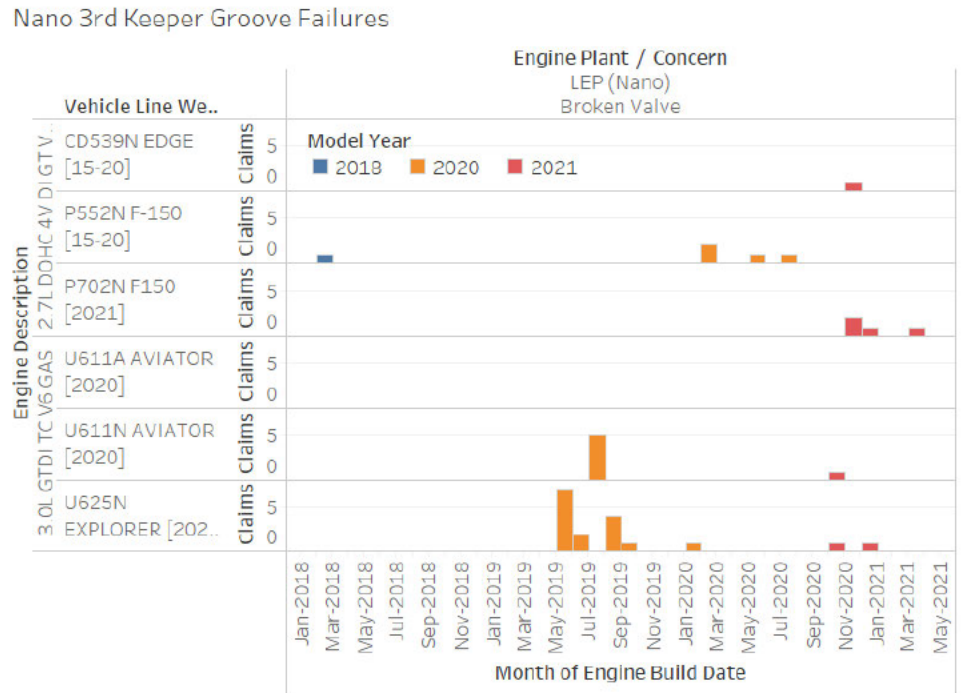


PANEL

Is / Is not info

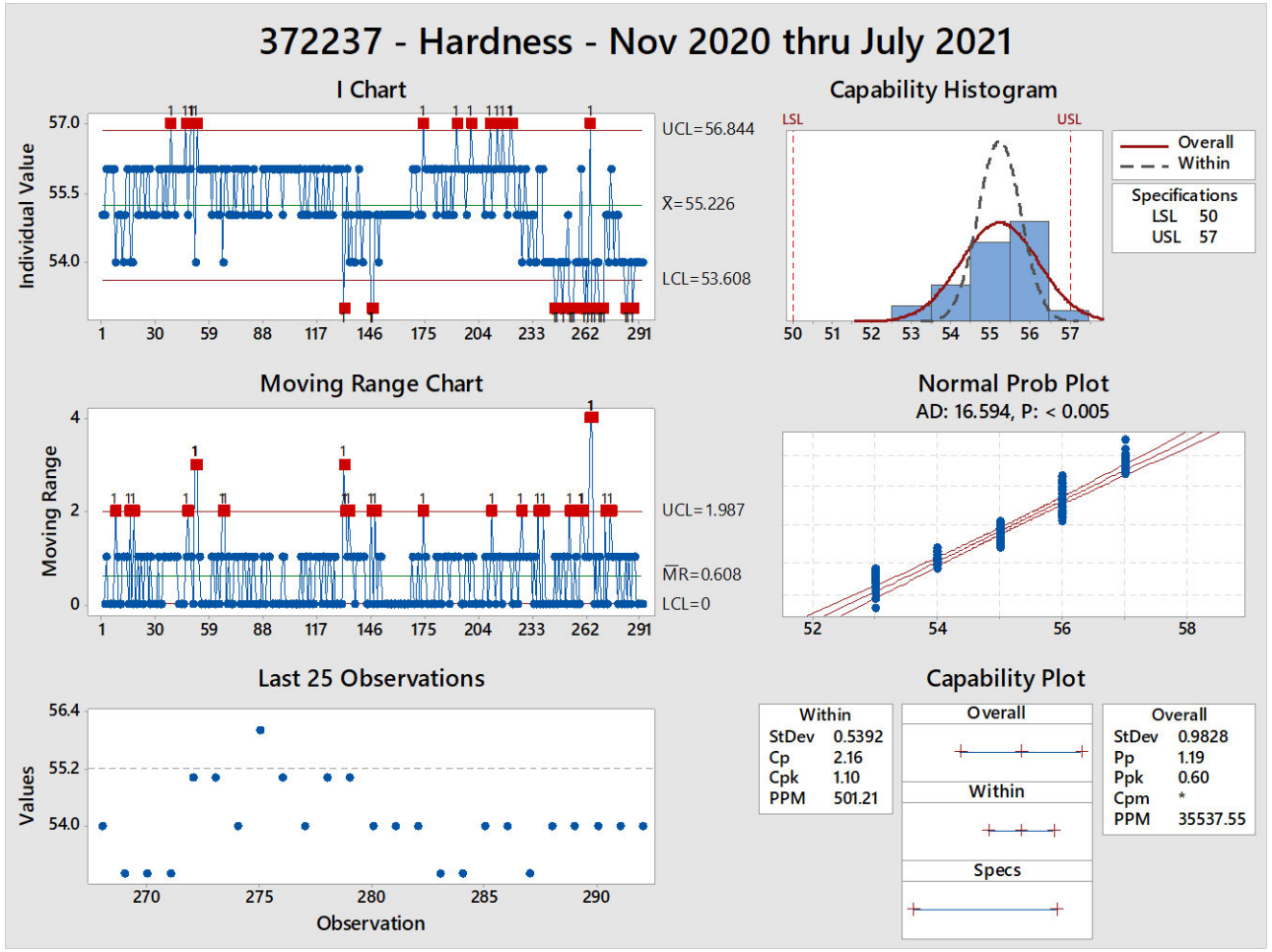
failures on Pre and Post MY21 F150, as well as CD6. Failures with and without MVP on the LHI cam

Vehicle	MVP Location
CD539N Edge (15-20)	LHI
P552N (15-20)	LHI
P702 (21)	N/A (MVP Delete)
U611A (20)	RHI
U611N (20)	RHI
U625N (20)	RHI



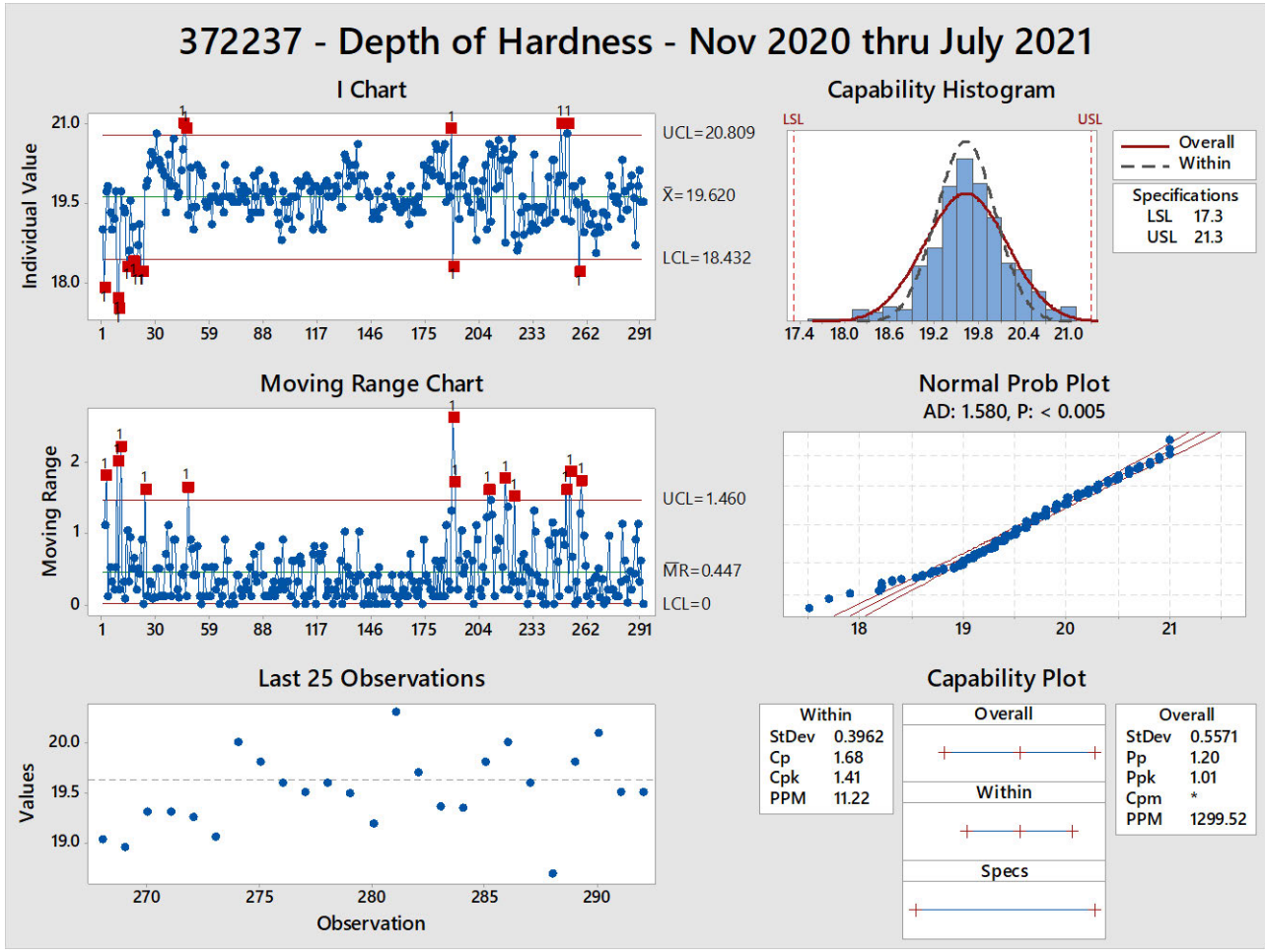
Ford Nano JT4E-6507-BB (Eaton 372237) Data Request/Analysis

- Hardness data from Tip Harden Operation
- Minitab auto-calculates control limits which represents the red points being outside of what Minitab sets as a control limit
- All data points are within specifications
- Key point is the Cp value of 2.16



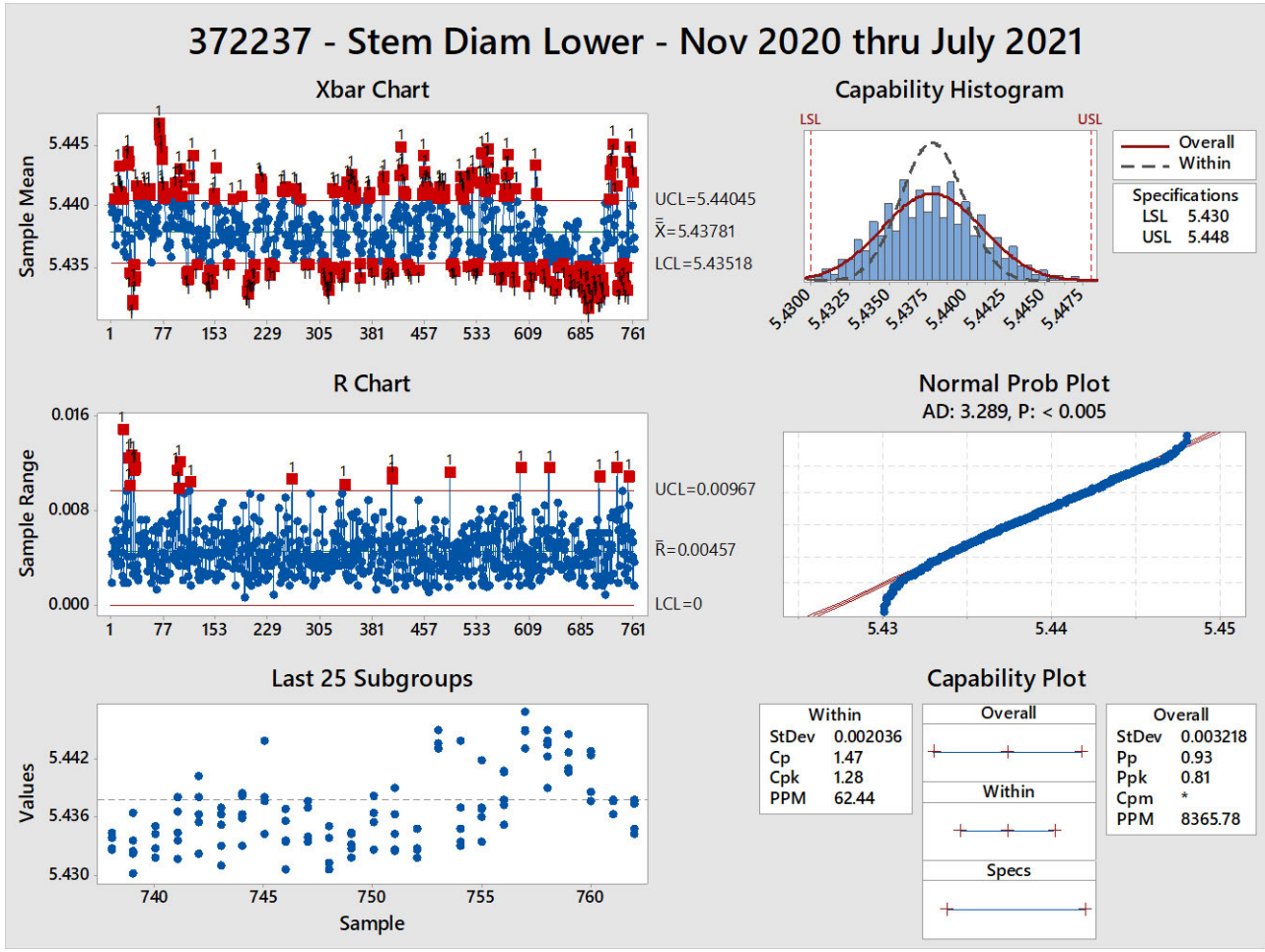
Ford Nano JT4E-6507-BB (Eaton 372237) Data Request/Analysis

- Depth of Hardness data from Tip Harden Operation
- Minitab auto-calculates control limits which represents the red points being outside of what Minitab sets as a control limit
- All data points are within specifications
- Key point is the Cp value of 1.68



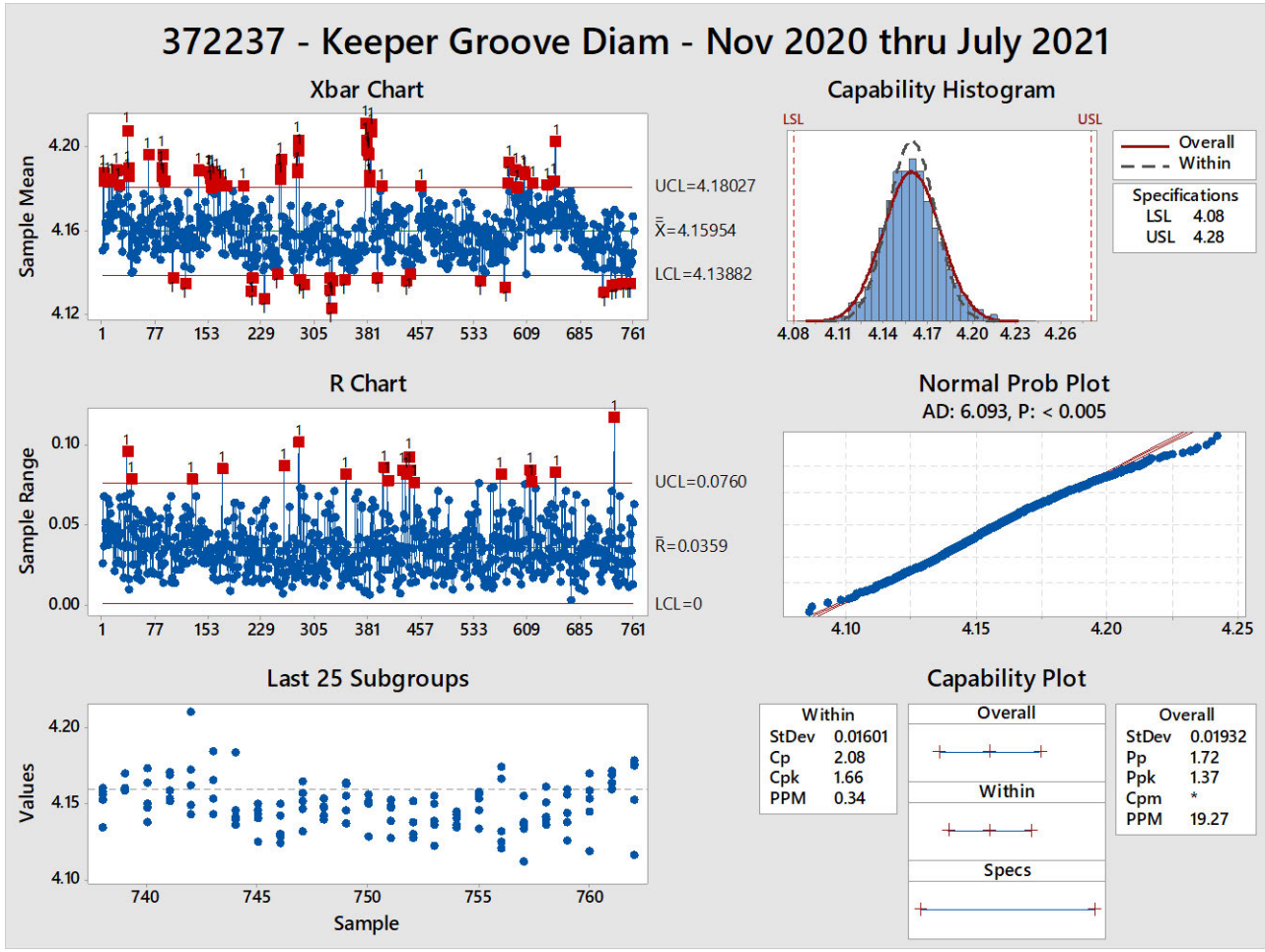
Ford Nano JT4E-6507-BB (Eaton 372237) Data Request/Analysis

- Stem Diameter data from final audit, this data point from location closest to Keeper Groove
- Minitab auto-calculates control limits which represents the red points being outside of what Minitab sets as a control limit
- All data points are within specifications
- Key point is the Cp value of 1.47



Ford Nano JT4E-6507-BB (Eaton 372237) Data Request/Analysis

- Keeper Groove Diameter data from final audit
- Minitab auto-calculates control limits which represents the red points being outside of what Minitab sets as a control limit
- All data points are within specifications
- Key point is the Cp value of 2.08



Verification of PCA:

- Impact testing of Silchrome 1 vs Silchrome lite materials at Central lab. ETC 8/6/21.
- High temperature fatigue strength of Sil1 is significantly higher than Sil lite.

EMS	Hardness (HRC)	Temperature (F)	10^7 Stress Limit (KSI)
322	30	800	70.7
322	40	1200	38.7 ←
1	30	800	74.3
1	40	1200	63.6 ←

- Implementation timing:
  - WERS concern approval and notice release: 8/13/21
  - PPAP timing TBD – Material change only. Eaton confirming timing est. Sept – Oct 2021

Workplan to continue side load investigation:

- Dyno lube survey on 3.0L Engine (8/27/21) – HLA gallery pressure under different conditions.
- Continue design change chronology and timing investigation for potential impact on lube system performance. (Vacuum pump deletion, Sump changes, PCV)
- RFF perpendicularity evaluation and effect on guide wear / RFF alignment at PFSL.