PE12-010

GM

6/22/2012

Q_07_1 Sharepoint

Cruze Discussion _ April 9, 2012#3526

Cruze Discussion – April 9, 2012

Agenda

-	Introduction/Purpose	Altman/Kemp
-	Description and Status of Investigation	Benavides
-	Proposed Direction and Process	Altman
-	Next Actions	Altman

Cruze Discussion – Proposed Next Actions

- Quickly provide all the needed data to respond to NHTSA IR PE 12-010, GM Investigation N 120081
- Time line: Response to NHSTA May 11, Target SMT evaluation complete April 20
- Two paths to encompass all issues
  - Priority Path to answer NHSTS Questions
  - Priority Path to answer all Tread Act Issues
- Map all Tread Data to:
  - Alleged Defects
  - SMT
- Product Investigation Team Response
  - Per standard practice, augmented with SMT analysis
- SMT Investigation
  - Need Single Point Contact's for each function of the organization
    - One Executive, One working team member, Need to Know Basis

Cruze Discussion – Proposed Next Actions

- SMT Investigation Process
  1. **Topic**: (from TREAD line items)
  2. **Summary of TREAD Records**: x Warranty, y Customer Complaints, z Field Reports, et
  3. **Product History:** DFMEA, PFMEA, Dev/Val PRTS, Warranty, Product Change History, Containment, Production fix, TSB's. If multiple changes exist time line of activity since SORP
  4. **Support for Risk Assessment:** verbatim analysis, returned parts, photos of example parts, photos of damaged parts, engineering explanation
  5. **Product Assessment (FPE supported):** Smoke only, Smoke/Melting, Burning Smell only, Smoke/True fire, etc
  6. **Read Across:** Repeat in all regions cross platform

- Data Base to assist with accumulating all the information
  - Project J/T based, Matt Gedris
  - Need single point owners for each SMT

- War Room Opened to document and meet

- Meeting Schedule
  - Team M, W & F War Room 4:30-5:30 PM

Cruze Discussion – Proposed Next Actions

Program Eng’g	Gary Altman	Bob VanArsdale
PT Eng LUJ	Bob Benedict	Stacy Kraysovic
PT Eng LUW	Curt Andreski	Stacy Kraysovic
PT AT MH8	Steve Saia	Stacy Kraysovic
PT MT M32	Mark Gilmore	Stacy Kraysovic
Chassis	Margaret Oswald	Paul Klain
Interior	Tim Brademeyer	
Exterior	Betsy Jackson	Cheryl Davis
HVAC/CRFM	Sean Stelzer	Paul Klain
Electrical	Regina Himmelspach	Tom Sayles

Cruze Discussion – April 9, 2012

Focus of NHSTA Investigation

2011/2012 Chevy Cruze   sold/leased in the U.S.

All Claims/Complaints/Information related to:

Alleged defect: Any one or more of the following symptoms or conditions:

1. Fuse block or TCM failure or malfunction, including all associated fault codes;
2. Allegations of overheated wiring in the engine compartment; or
3. Allegations of smoke or fire in the engine compartment.

Tread Data:

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6/22/2012

Q_07_1 Sharepoint

Cruze Discussion _ April 12, 2012#7B3E

Cruze Discussion – April 12, 2012

Agenda

- NHSTA Updates to Investigation	Benavides
- Plan of Action	Altman
- SMT Report of Status and Issues	SMT Champion
- Next Actions	Altman

Cruze Plan of Action

- Quickly provide all the needed data to respond to NHTSA IR PE 12-010, GM Investigation N 120081

- Time line: Response to NHSTA May 11, Target SMT evaluation complete April 20

- Two paths to encompass all issues and drive to one response
  - Priority Path to answer NHSTS Questions
  - Priority Path to answer all Tread Act Issues

- Map all Tread Data to:
  - Alleged Defects (In process, part of SMT evaluation and
  - SMT (Mapping complete April 10)

- SMT Investigation
  - Establish Single point contacts for each SMT (Complete April 10)
    - Executive Champion and Primary Lead/Contact

Cruze Plan of Action

- SMT Investigation to include (Complete April 9th, modifying daily)
    1. **Topic**: (from TREAD line items)
    2. **Summary of TREAD Records**: x Warranty, y Customer Complaints, z Field Reports, et
    3. **Product History:** DFMEA, PFMEA, Dev/Val PRTS, Warranty, Product Change History, Containment, Production fix, TSB's. If multiple changes exist time line of activity since SORP
    4. **Support for Risk Assessment:** verbatim analysis, returned parts, photos of example parts, photos of damaged parts, engineering explanation
    5. **Product Assessment (FPE supported):** Smoke only, Smoke/Melting, Burning Smell only, Smoke/True fire, etc
    6. **Read Across:** Repeat in all regions cross platform
- Cruze IR Sharepoint Web site ready with all issues mapped to SMT (Complete April 10th)
- War Room Opened to document and meet (April 10th)
- Meeting Schedule
    - Team Mon., Wed. War Room 4:30-5:30PM Friday 4-5:00 PM
    - Leadership Reviews - April 12, 3-4 PM War Room
      - April 19, 9-10 AM War Room

Cruze Plan of Action

- SMT to complete all data collection and assessments - April 20th
- Product Investigations to complete reviews and additional data requests - April 24th
- Significant issues are starting to be understood, Pre screen by PI team and engineering, raise to leadership team for direction with proposed Next Actions - April 12th Start
- Complete response May 11th

Cruze IR – Single Point Contacts

Function	Champion	Lead
Program Eng'g	Gary Altman	Bob VanArsdale
Program Quality	Matt Hurley	Bruce Cloud
PT Eng LUJ	Bob Benedict	Stacy Kraysovic
PT Eng LUW	Curt Andreski	Stacy Kraysovic
PT AT MH8	Steve Saia	Stacy Kraysovic
PT MT M32	Mark Gilmore	Stacy Kraysovic
Chassis	Margaret Oswald	Matt Scrase
Interior	Doug Houlihan	Jeff Ronne
Exterior	Betsy Jackson/Cheryl Davis	Al Pieczynski/Mike Sigelko
HVAC/CRFM	Sean Stelzer	Paul Klain
Electrical	Regina Himmelspach	Tom Sayles

Cruze IR – Single Point Contacts

Function	Champion	Lead
Product Investigation	Carmen Benavides	Dale Furney Dewayne Davidson Doug Wachtel
External Investigations	Dale Furney	Mark Deacon (Lead Investigation Engineer)
Tread Reporting	Dewayne Davidson	Mickey Sabol (Int Inv Eng'r) Paul Kelly (Tech Analyst)
Internal Investigations	Doug Wachtel	Brian Stouffer Jerry Hendler

PE12-012

GM

6/22/2012

Q_07_3 Oil Cap

E mail Oil Cap study set up

Josh Tavel/US/GM/GMC

04/17/2012 11:24 AM

To Stephen M Greene/US/GM/GMC, Curtis L Andreski/US/GM/GMC, Karie Garcia/US/GM/GMC@GM, Richard Janke/US/GM/GMC@GM, Kenneth L.

cc Gary F. Altman/US/GM/GMC

bcc Josh Tavel/US/GM/GMC

Subject Next investigation

History: This message has been forwarded.

Outcomes from the 9:30 discussion:

Run a vehicle with the cap mis-installed / not fully seated:

Provide max min (valve cover & cap) - **Curt Andreski**

Provide vehicle (LUJ) - X70029EX - **Josh Tavel**

Instrument with camera - ABAT to MPG engineering video imaging work request - other. ABAT 614900 written, Ken is picking up the car now.

Develop a schedule to simulate 12,000 miles - **Steve Greene**

Run schedule with cap installed at different angles - **Steve Greene**

HVI investigation

Karie Garcia will provide HVI assistance.

Review the current cap and provide any further input

Review the service procedure

Suggest better alternatives to installing the cap for service and owners manual

Use Jim Karlavage' vehicle (meeting today).

Oil Change Procedure Document ID 2171069.docx

Page 262 references adding oil but no instruction on cap.

Owners Manual.pdf

Regards,
Josh Tavel
Lead Development Engineer - Chevy Cruze
General Motors North America
Work / Cell: 248.891.3188

PE12-012

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6/22/2012

Q_07_3 Oil Cap

Exec Summary_12AP12-p

Cruze IR Executive Summary- Family 0 1.4T Engine Family 1 1.8L Engine

Curt Andreski / Bob Benedict

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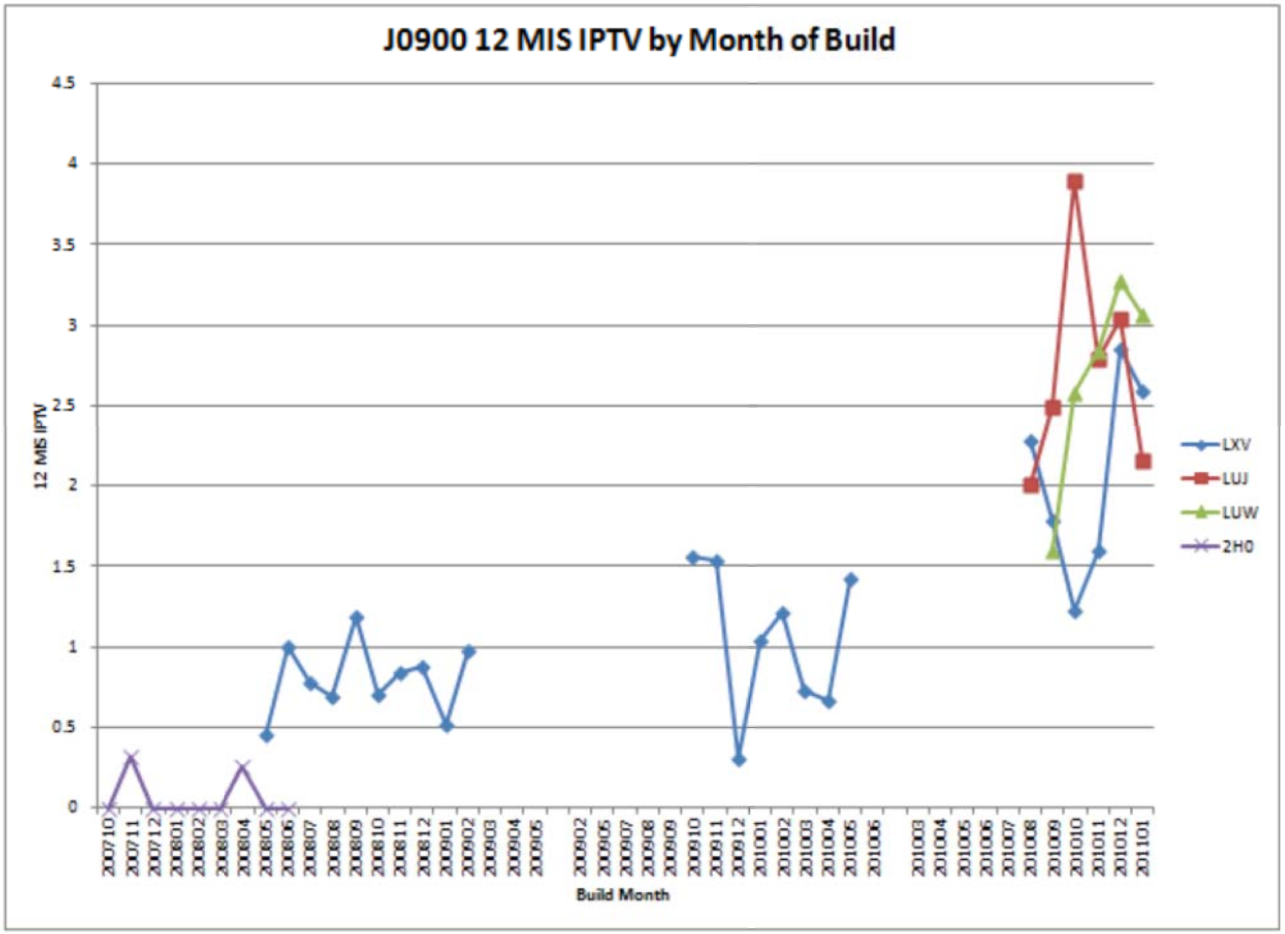
Cruze IR Executive Summary-
Family 0 1.4T Engine
Family 1 1.8L Engine

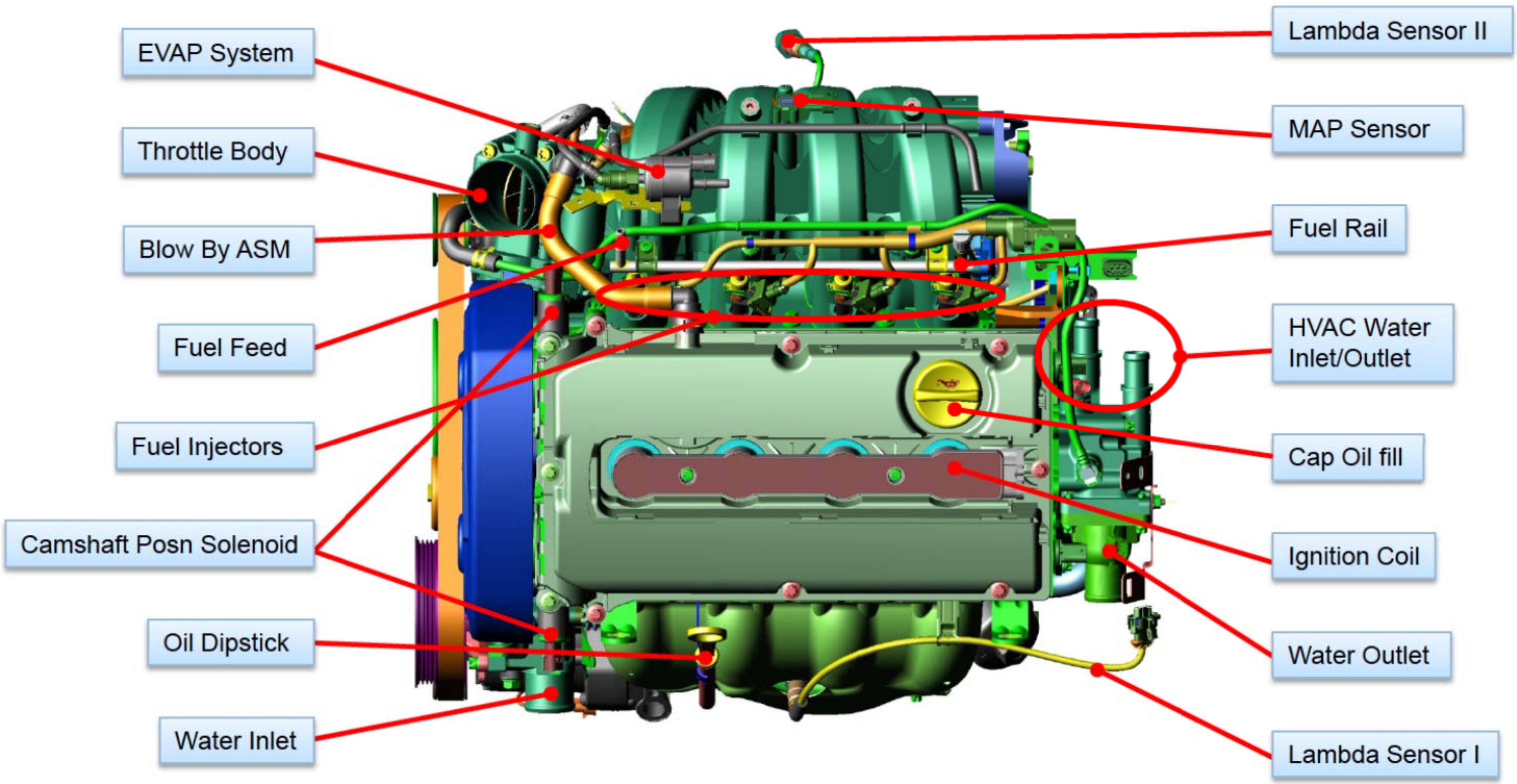
Preliminary information for back-up

Cruze Family 1 1.8L & Family 0 1.4T Engine Oil Fill Cap Warranty

2008 Astra 1.8L F1G3 2H0 (engine built Hungary) *Vehicles Sold 2008 = 29,000*
2009-20011 MY Aveo F1G3 1.6L LXV (engine built Korea & Mexico) *Vehicles Sold 189,000*
2011 MY Cruze 1.8L F1G3 LUW (engine built Mexico) *Vehicles Sold = 58,000*
2011 MY Cruze 1.4L F0G3 LUJ (engine built Austria / Flint) *Vehicles Sold = 151,000*



Cruze Family 1 1.8L Engine



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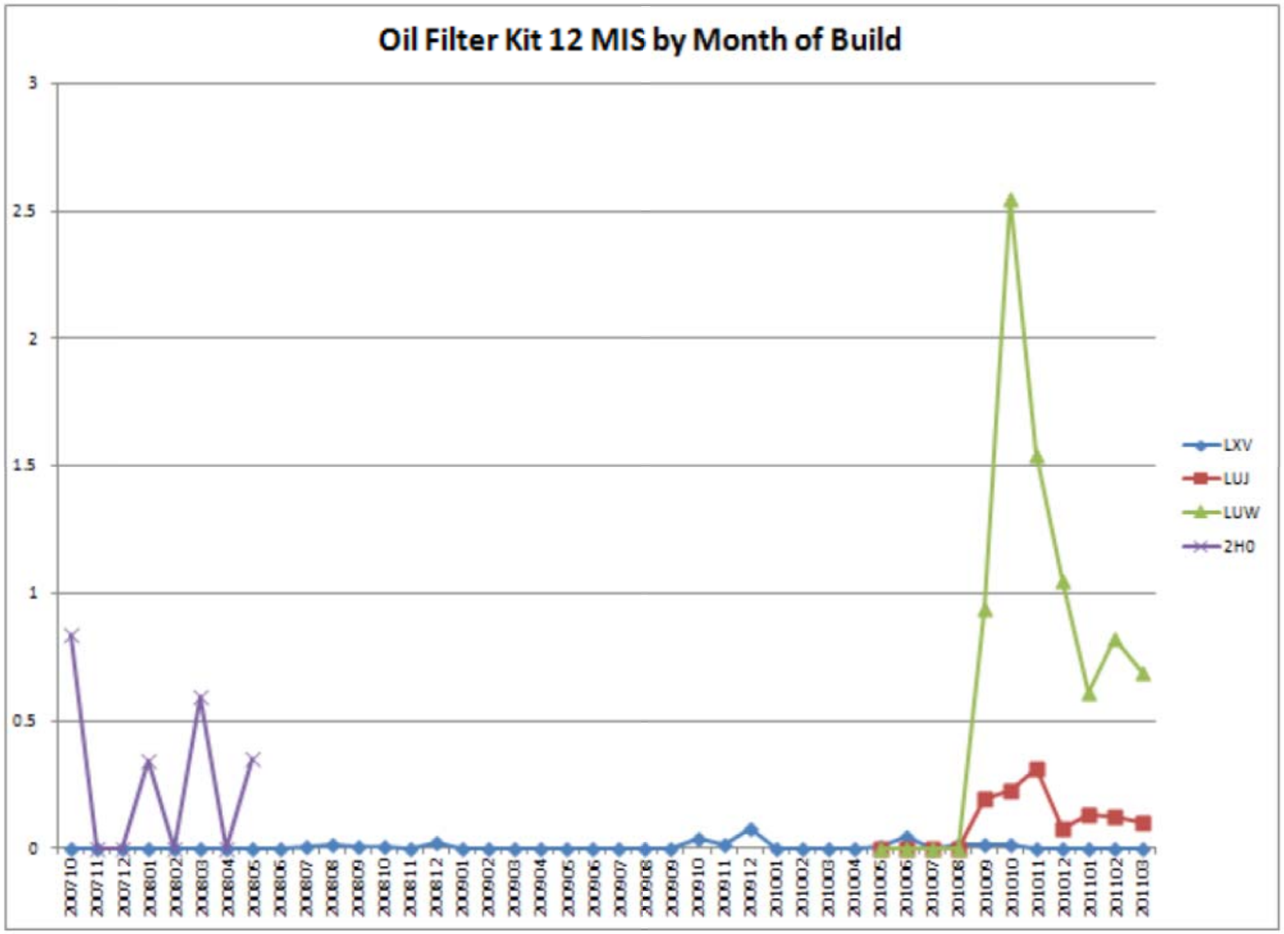
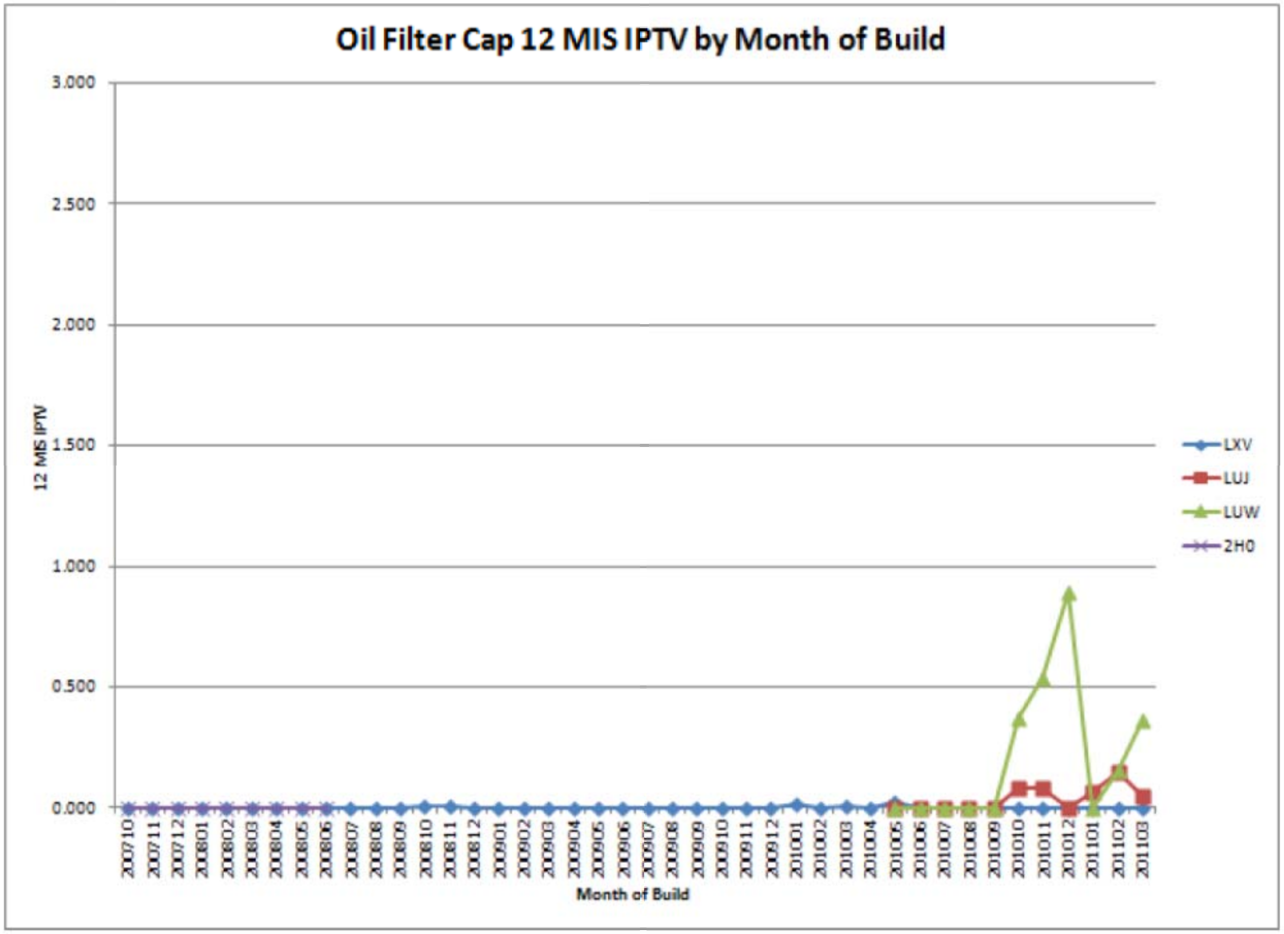
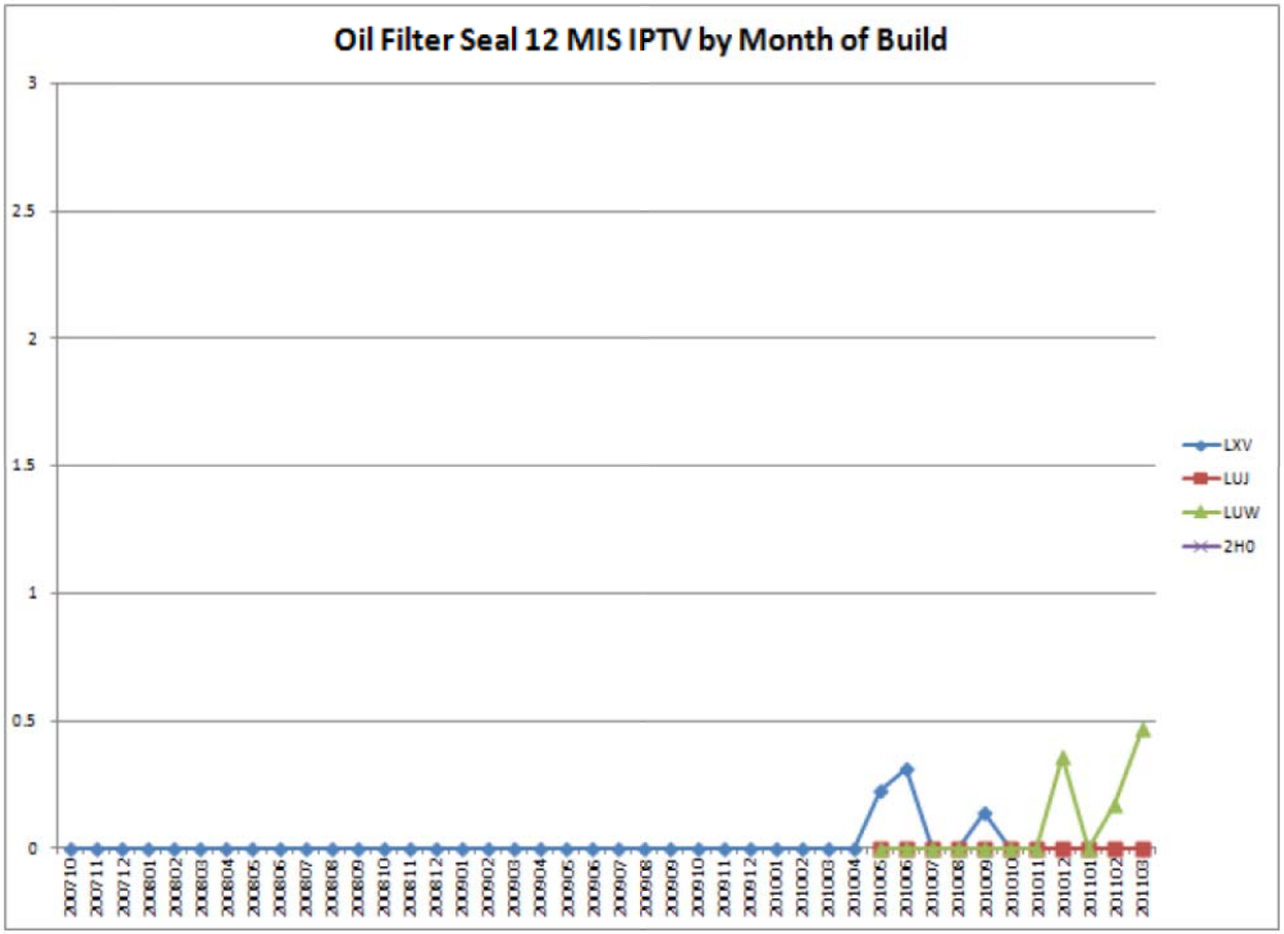
Cruze Family 1 1.8L & Family 0 1.4T Engine Oil Filter Kit Warranty (Kit = Filter & Seal)



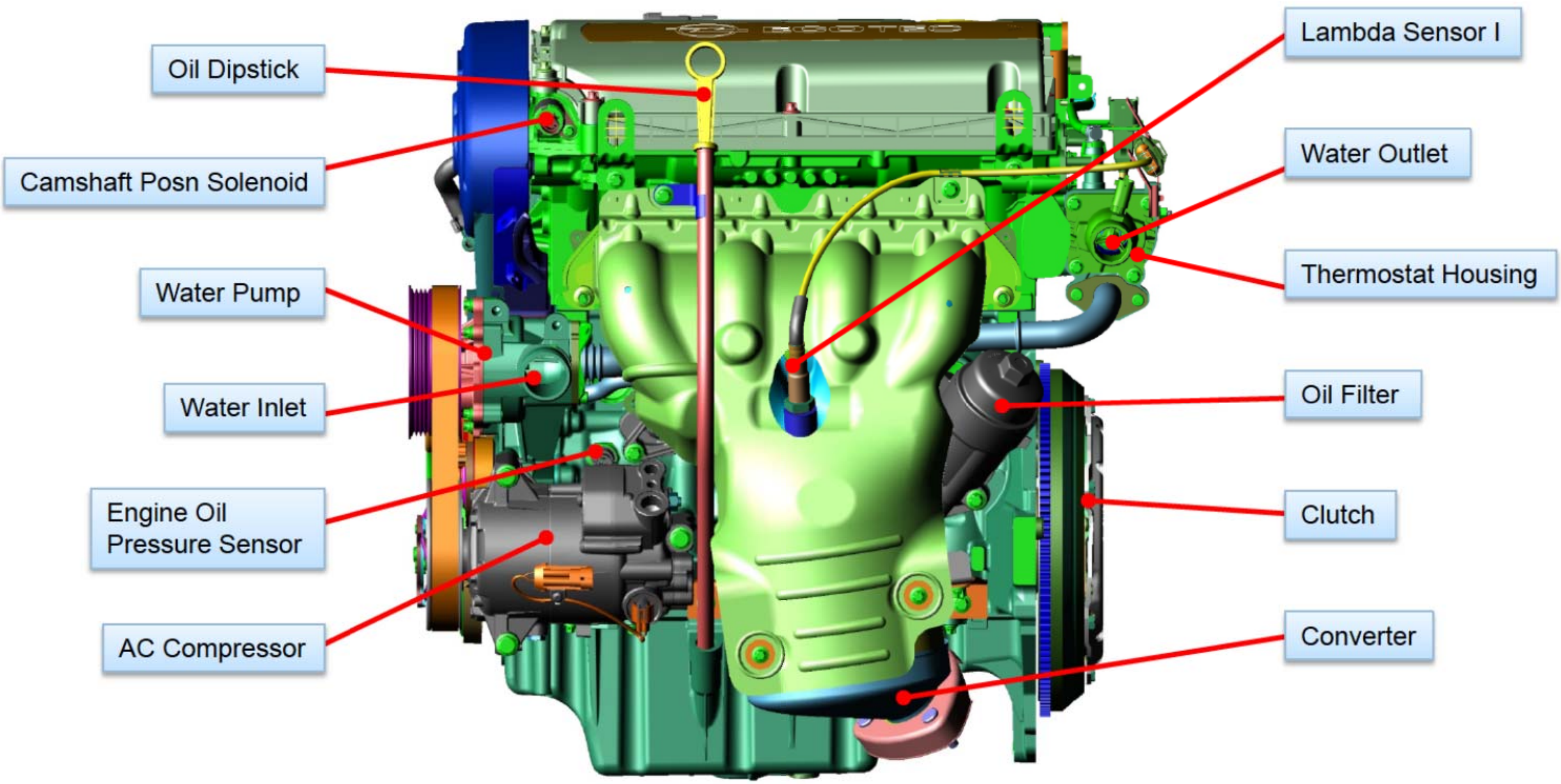
Cruze Family 1 1.8L & Family 0 1.4T Engine Oil Filter Cover Warranty



Cruze Family 1 1.8L & Family 0 1.4T Engine Oil Filter Seal Warranty



Cruze Family 1 1.8L Engine



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6/22/2012

Q_07_4 Oil Filter

20120414 F0 and 1 Cruze Oil Filter Cap-p

LUW (1.8) & LUJ (1.4T) @ Cruze

Data Collection – Oil Filter Cap

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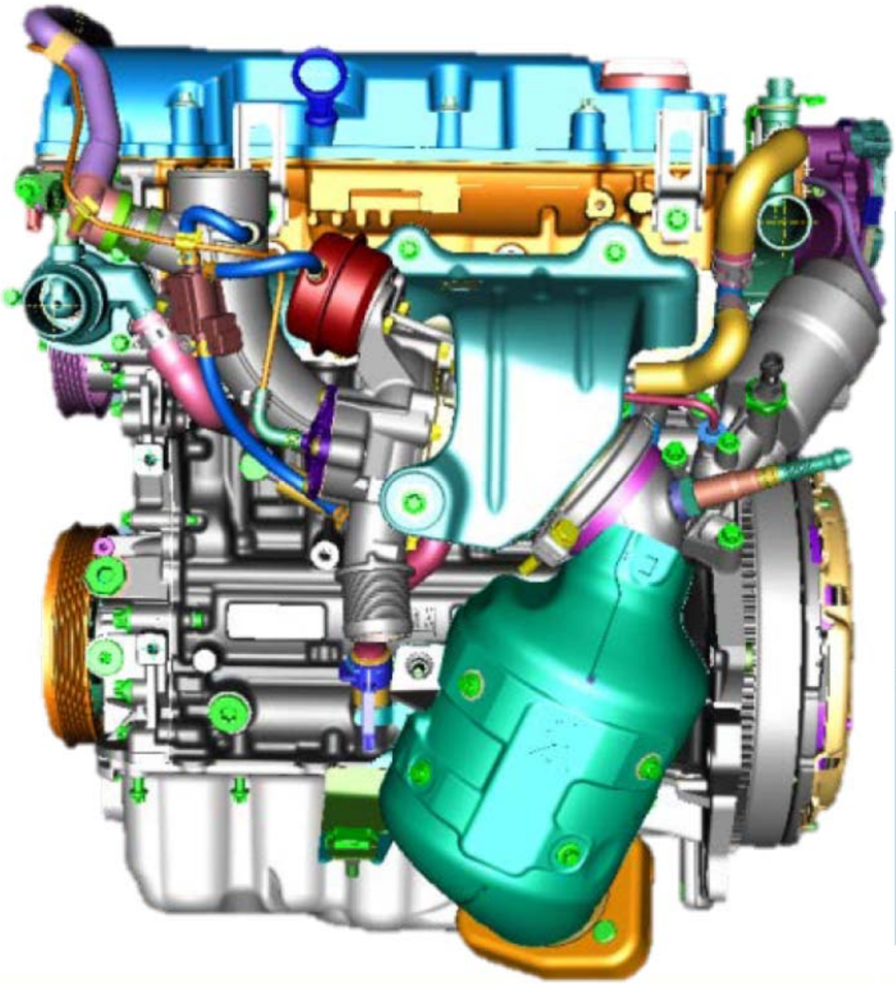
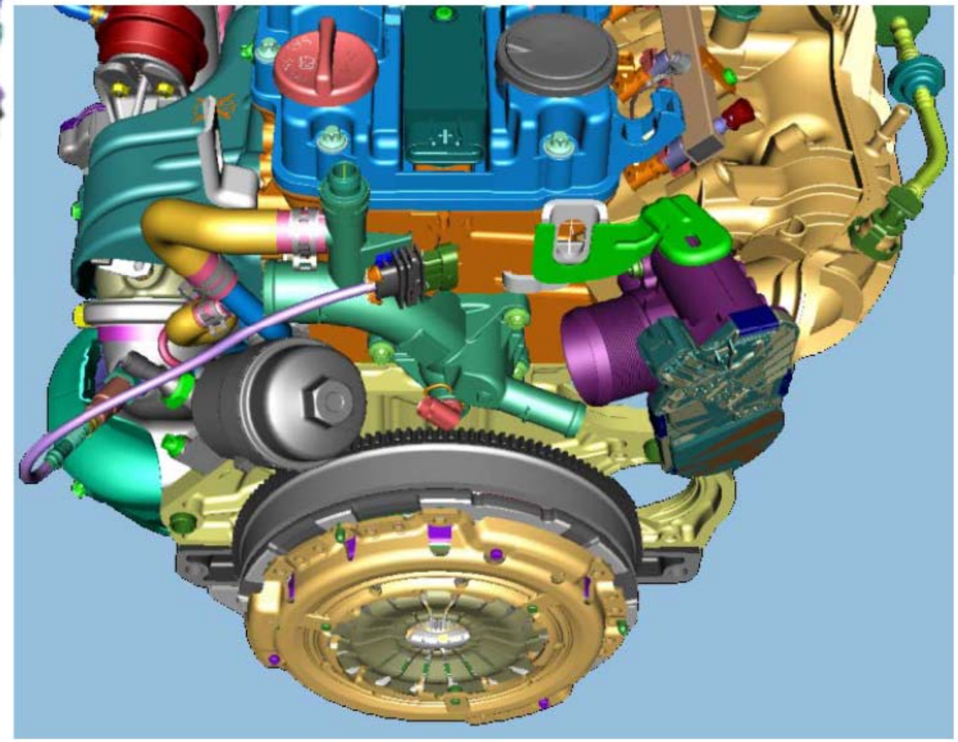
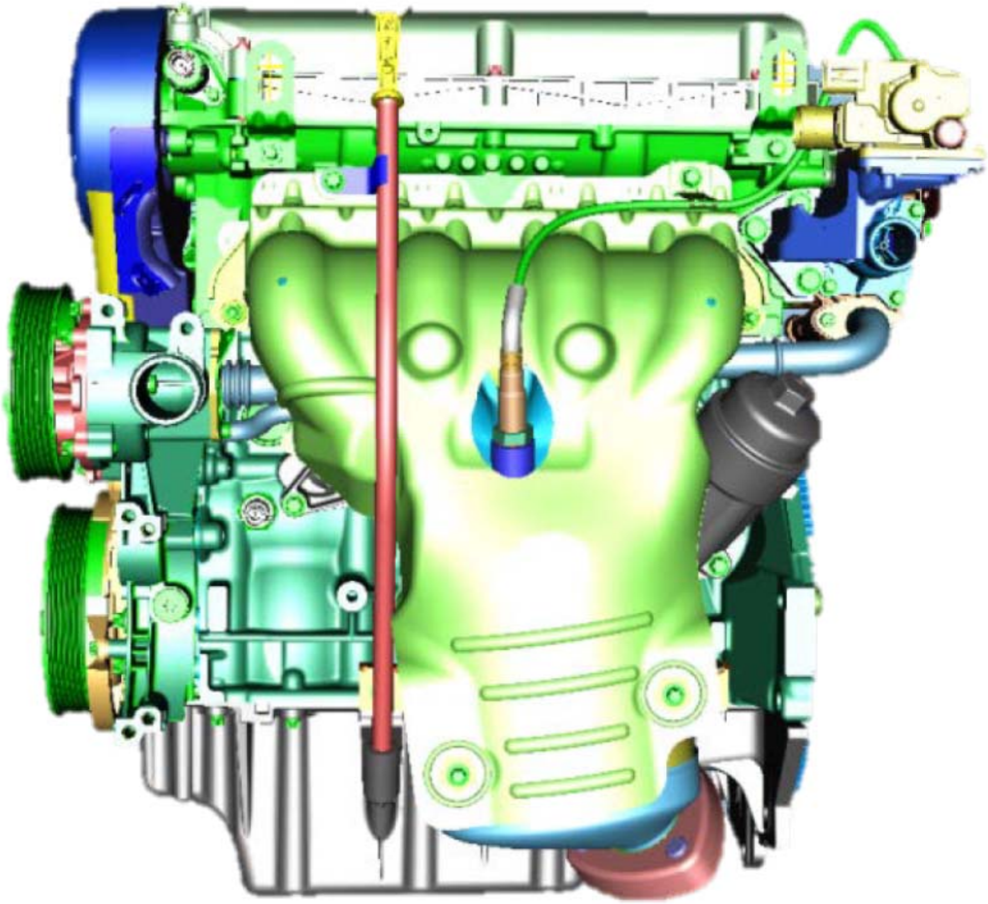
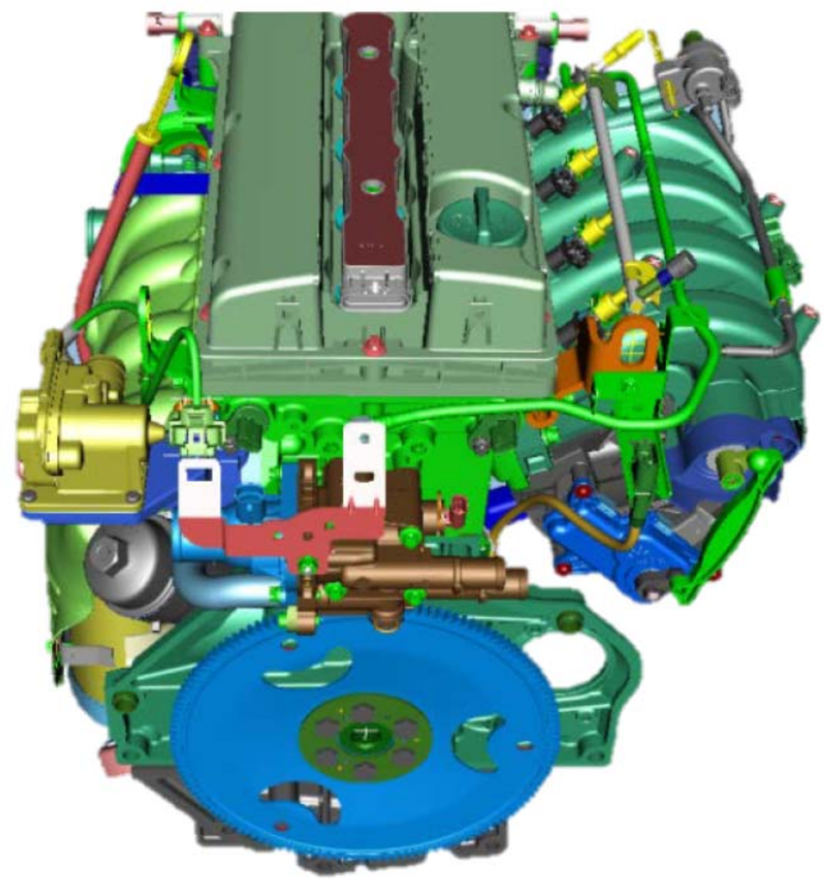
Oil Filter – LUJ 1.4T





Oil Filter – LUW 1.8





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PE12-012

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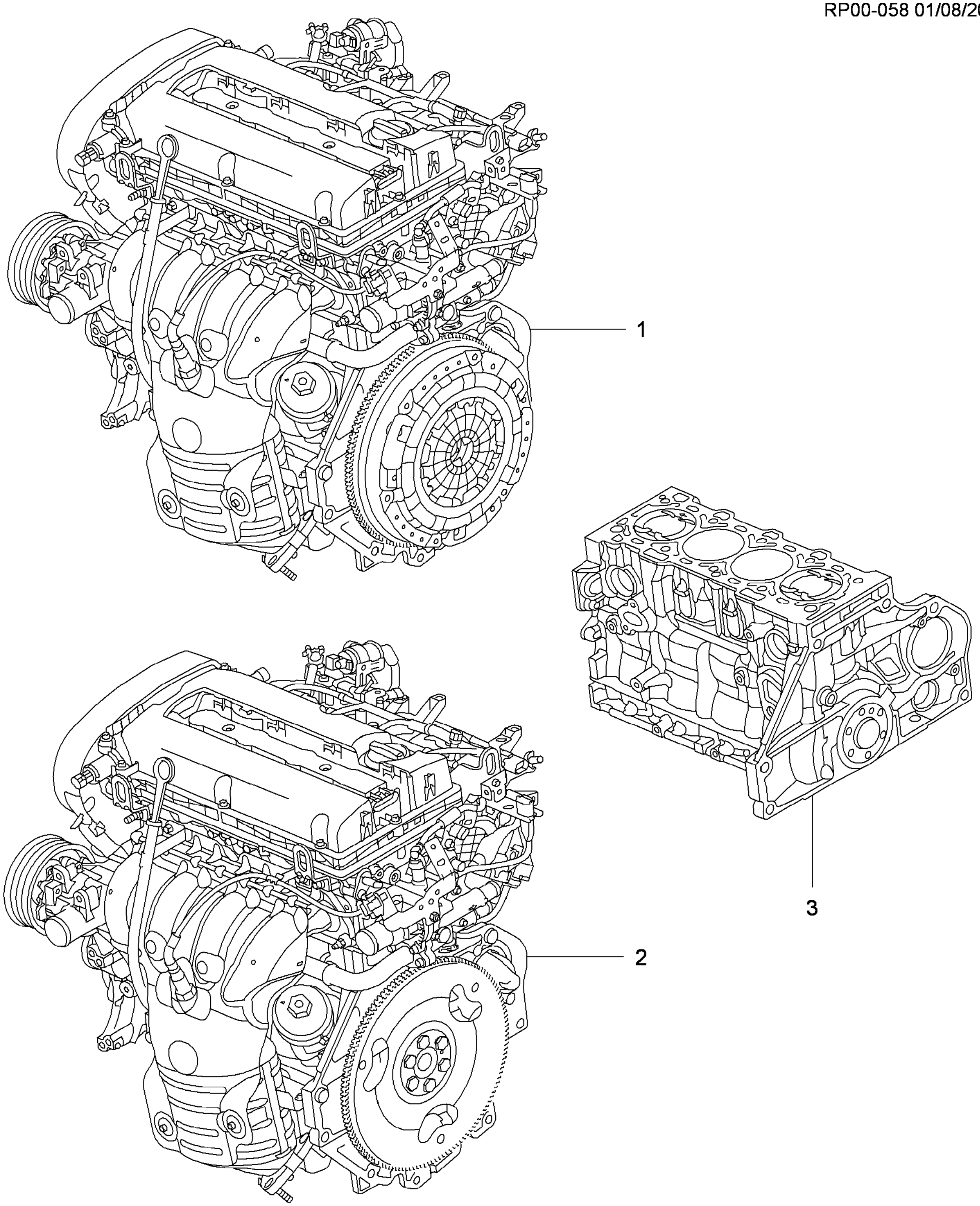
6/22/2012

Q_07_4 Oil Filter

Cruze 1.8L Oil Filter Illustration

RP00-058 01/08/2008



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6/22/2012

Q_07_4 Oil Filter

Cruze Revised Oil Change Procedure Pub Draft Final 15JN2012

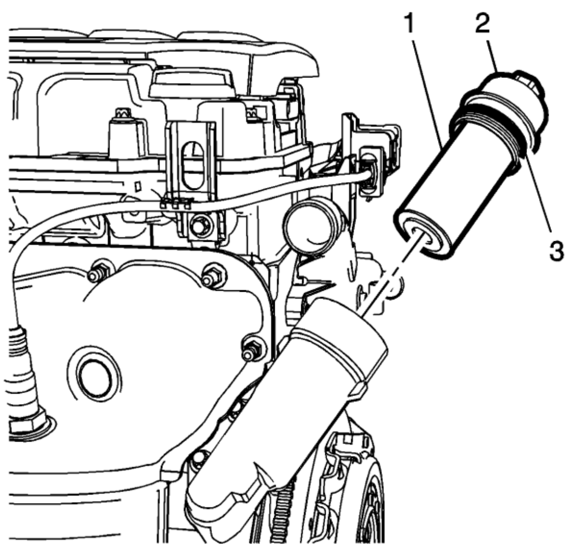
Engine Oil and Oil Filter Replacement

Removal Procedure

1. Open hood.
2. Place a drain pan below the vehicle.

   Caution: To prevent damage to oil filter cap ensure proper tool is used. Do not use an open end wrench which may cause damage to filter cap.

3. Using a 24mm socket or closed end wrench loosen oil filter cap. Unscrew filter cap 3 turns and let oil filter and cap assembly drain in housing for 30 seconds.



   Note: Use care when removing engine oil filter cap and filter to minimize fluid spillage. If fluid spillage occurs it must be cleaned with appropriate cleaner.

   Note: Inspect oil filter cap for any cracks or damage. If oil filter cap is damaged it must be replaced.

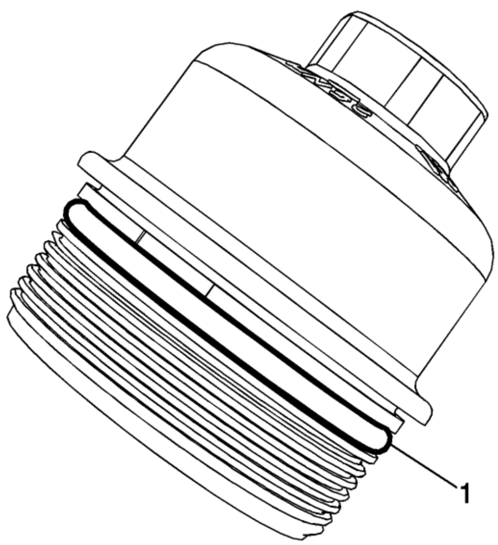
4. Remove the engine oil filter cap (2) with the engine oil filter cap seal ring (3) and the oil filter element (1).
5. Raise and support the vehicle. Refer to Lifting and Jacking the Vehicle .
6. Remove the oil pan drain plug and allow the oil to drain into the drain pan.

Installation Procedure

1. Clean the oil pan drain plug thread in the oil pan.
2. Install a NEW seal ring to the oil pan drain plug.

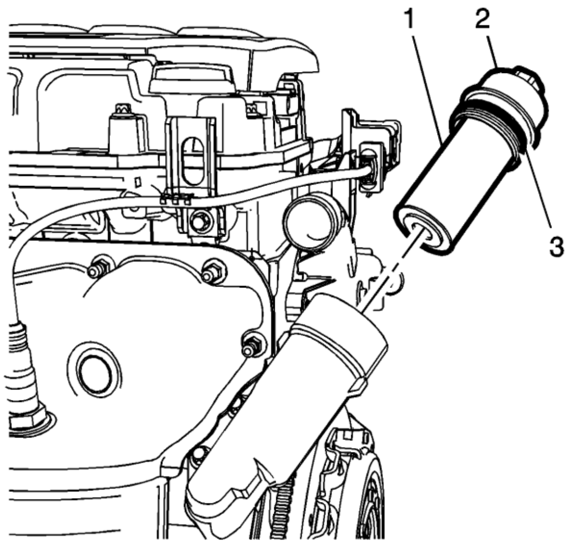
   Caution: Refer to Component Fastener Tightening Caution .

3. Install the oil pan drain plug and tighten to **14 N·m (10 lb ft)**.
4. Lower the vehicle.

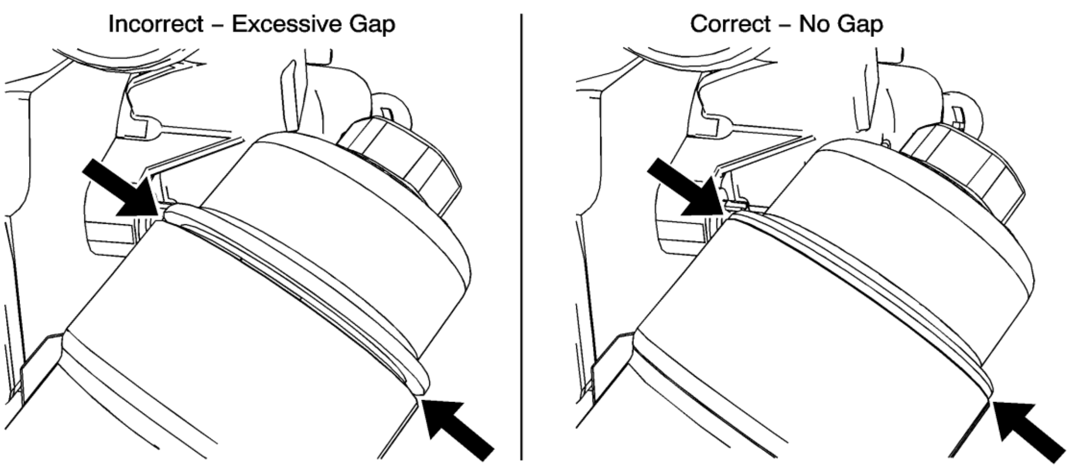


   Note: Clean oil filter cap and lubricate the NEW oil filter cap seal ring with clean engine oil. Ensure oil filter cap seal ring is in proper position as shown.

5. Install a NEW oil filter cap seal ring (1).



6. Install the engine oil filter cap (2) with NEW engine oil filter cap seal ring (3) and NEW oil filter element (1) hand tight.



Caution: Ensure oil filter cap is completely seated on oil filter housing. If not completely seated an oil leak may occur.

Caution: Over torquing the oil filter cap may cause damage to the oil filter cap resulting in an oil leak.

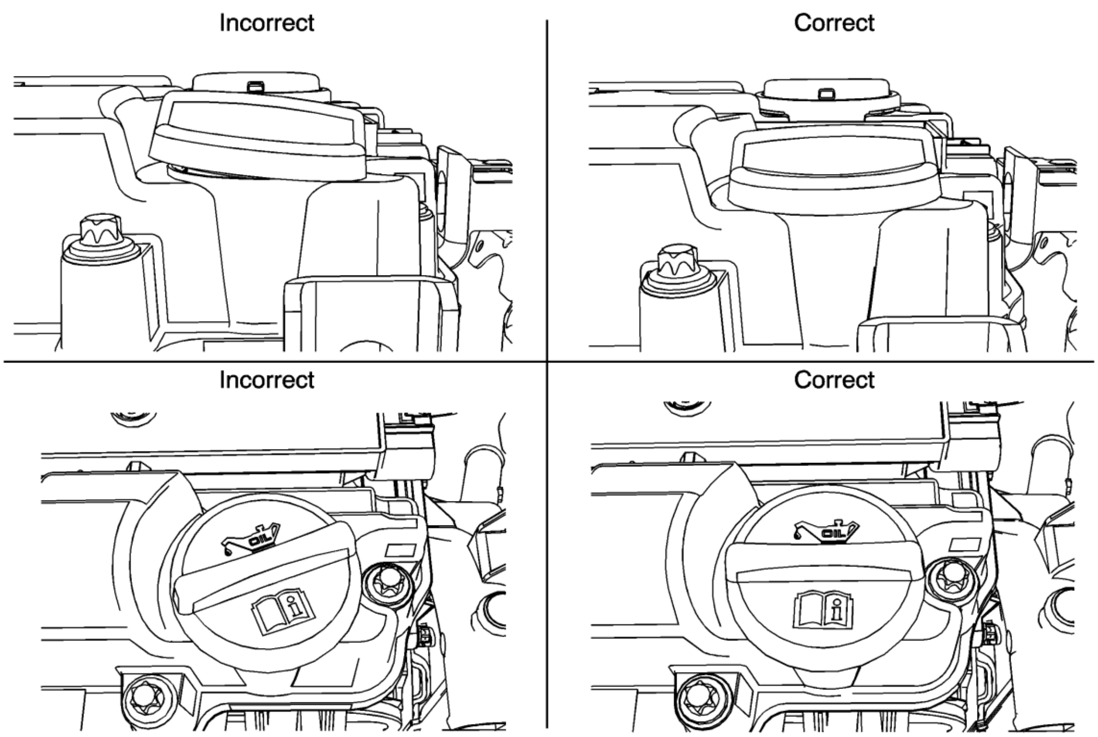
7. Using a 24mm socket or closed end wrench tighten the engine oil filter cap to **25 N·m (18 lb ft)**.

Caution: Using engine oils of any viscosity other than those viscosities recommended could result in engine damage.

Note: Do not overfill the engine with engine oil.

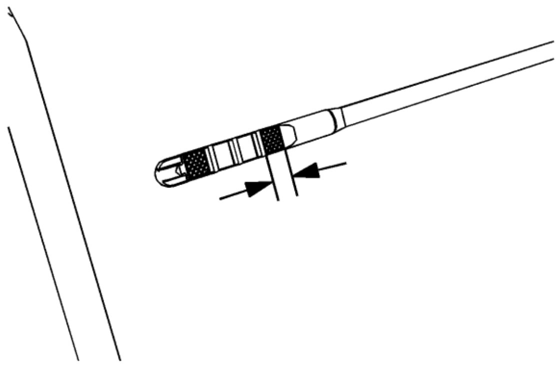
Note: Anytime engine oil is added (top off or oil changes) ensure all engine surfaces are completely free of residual oil. If there is oil on any engine surface clean as necessary.

8. Fill engine with NEW oil using Dexos™1 5W-30 specification.



Note: Oil fill cap must be properly seated and tightened during installation.

9. Install oil fill cap.
10. Start the engine and allow it to run until the oil pressure control indicator goes off. Inspect for any oil leaks around the drain plug, oil filter and oil fill cap.



11. Inspect the engine oil level. The oil level should be in the cross-hatched section of the oil level indicator as shown.
12. Close hood.
13. Reset the engine oil life system monitor.

PE12-012

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6/22/2012

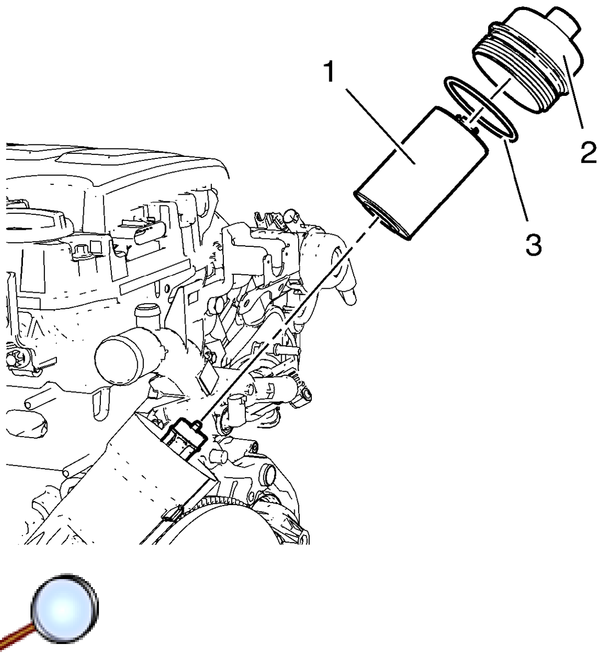
Q_07_4 Oil Filter

current oil change procedure in eSi 15JN2012

Engine Oil and Oil Filter Replacement

Removal Procedure

1. Place a drain pan below the vehicle.



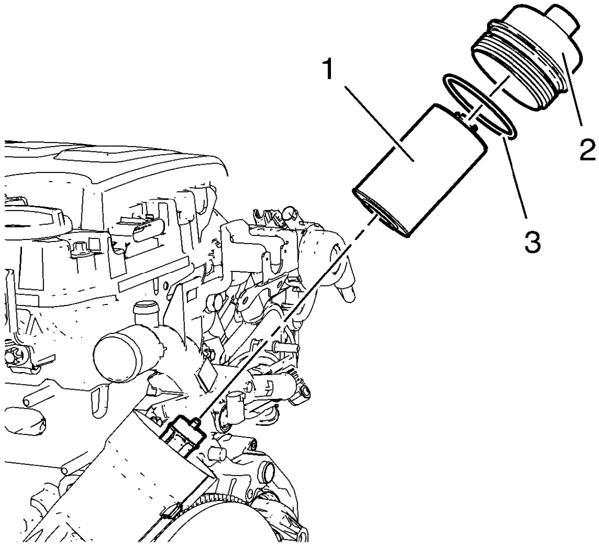
2. Remove the engine oil filter cap (2) in compound with the engine oil filter cap seal ring (3) and the oil filter element (1).
3. Raise and support the vehicle. Refer to Lifting and Jacking the Vehicle .
4. If equipped, remove the engine shield. Refer to Engine Shield Replacement .
5. Remove the oil pan drain plug and allow the oil to drain into the drain pan.

Installation Procedure

1. Clean the oil pan drain plug thread in the oil pan.
2. Install a NEW seal ring to the oil pan drain plug.

Caution: Refer to Fastener Caution .

3. Install the oil pan drain plug and tighten to 14 N·m (124 lb in).
4. If equipped, install the engine shield. Refer to Engine Shield Replacement .
5. Lower the vehicle.



Note: Lubricate the NEW oil filter cap seal ring with engine oil.

6. Install the engine oil filter cap (2) in compound with a NEW engine oil filter cap seal ring (3) and a NEW oil filter element (1).

Caution: Over torquing the oil filter cap may cause damage to the oil filter cap resulting in an oil leak.

7. Tighten the engine oil filter cap to 25 N·m (18 lb ft).

Caution: Using engine oils of any viscosity other than those viscosities recommended could result in engine damage.

Note: Do not overfill the engine with engine oil.

8. Fill in NEW engine oil. Refer to Engine Mechanical Specifications to find the specified viscosity and volume.
9. Start the engine and allow it to run until the oil pressure control indicator goes off.
10. Inspect the engine oil level.
11. Close hood.
12. Reset the service interval indicator.

PE12-010

GM

6/22/2012

Q_07_5 Clutch

Email belly pan MPG investigation info

Lisa K. Hackney/US/GM/GMC 04/18/2012 07:09 PM	To	Josh Tavel/US/GM/GMC@GM
	cc	Kevin Dunn/US/GM/GMC@GM, Clark J. Bay/US/GM/GMC@GM
	bcc	
	Subject	D1SC-N Splash Testing

History: This message has been forwarded.

Josh -

Completed PT Fluids Water Ingestion Testing for manual transmission fluid on vehicle X70077EX with modified belly pan per GMW14547 on 4/17/12. Expedited the SOT and EOT fluid samples through the Chemistry Lab today with the following results from before and after all exposures. Per our phone discussion, I am looking for the correct water ingestion requirement value to compare the results to for the BOT 303 transmission fluid.

sample	%water
Sample #1 - Trans Fluid (SOT)	0.04
Sample #2 - Trans Fluid (EOT)	0.18

Completed video under hood recordings of the trans vent area and FOD area on vehicles X70077EX (1.8L MT LT) and 1CPP4502 (1.4T MT LT RS) on 4/18/12 (both with baseline and modified belly pans) through the GMW16277 salt splash road and grit trough test conditions.

On vehicle X70077EX, the recordings show that the splash area around the engine and trans is a wet environment with both belly pans. The grit trough FOD videos show the most difference in splash with the modified belly pan vs baseline as attached below. Additional videos can be provided as needed.

Modified Belly Pan, Grit Trough at 15 kph, camera at FOD:

MOD BP X70077EX FOD Grit 15 18Apr12VID0024.AVI

Baseline Belly Pan, Grit Trough at 15 kph, camera at FOD:

Base BP X70077EX FOD Grit 15 18Apr12VID0010.AVI

On vehicle 1CPP4502, the recordings show that the splash area around the engine and trans is a wet environment with both belly pans as well. The videos of 1CPP4502 show more splash in that FOD area than vehicle X70077EX. Again the grit trough FOD videos show the most difference in splash with the modified belly pan vs baseline as attached below. Additional videos can be provided as needed.

Modified Belly Pan, Grit Trough at 15 kph, camera at FOD:

MOD BP 1CPP4502 FOD Grit 15 18Apr12VID0011.AVI

Baseline Belly Pan, Grit Trough at 15 kph, camera at FOD:

Base BP 1CPP4502 FOD Grit 15 18Apr12VID0035.AVI

Vehicle 1CPP4502 also had the service traction control light come on after completing most of the salt splash testing, but before starting the grit trough testing.

Vehicle 1BPP4209 (1.4T MT LT Eco) will be tested 4/19/12 for salt splash and grit trough.

Best regards -

Lisa Hackney
Splash Integration
(248) 953-6128

PE12-012

GM

6/22/2012

Q_07_6 PT Eng

Base Engine Replace 12MIS LUJ

GM Quality

2 MIS / 12 MIS Warranty Frequency Targets

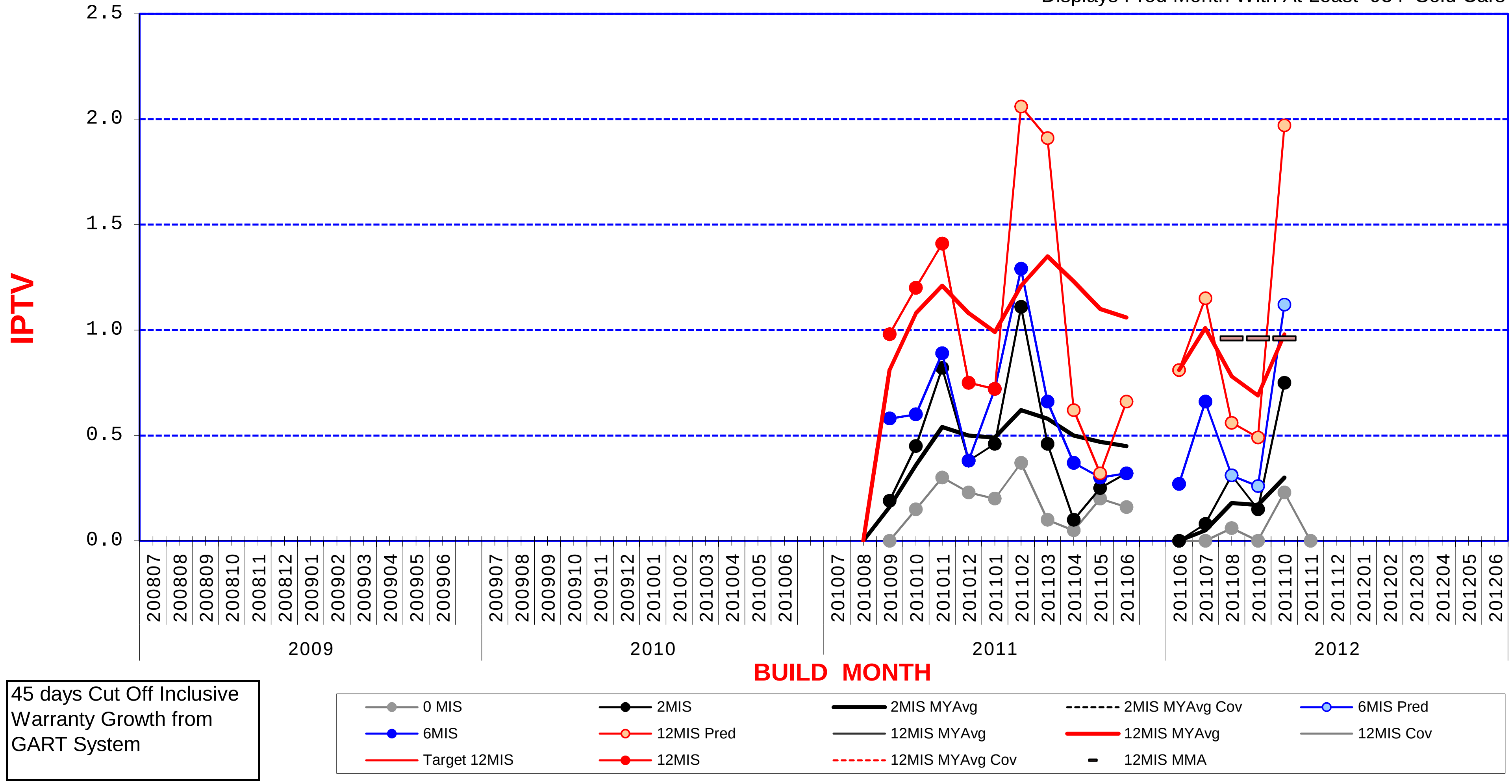
Status: Apr 2012 (W213)

GM Total - PMT E05 - Base Engine Replace

GM North America - Spec: Engine - Family 0 RPO:LUJ

				MY2012		
MYTD	2010	2011	3MMA	Target	MYTD	MYEnd
12 MIS	-	1.06	0.96	-	0.98	-
2 MIS	-	0.45	0.39	-	0.30	-

Displays Prod Month With At Least 934 Sold Cars



45 days Cut Off Inclusive
Warranty Growth from
GART System

PE12-012

GM

6/22/2012

Q_07_6 PT Eng

Cruze Discussion _ May 24, 2012 V2-p#6C01

Cruze Leadership Discussion – May 24, 2012

Agenda

- Introduction	Altman
- NHTSA IR	Benavides
- Plan of Action and Primary Contributors	Altman
- Pro, ert, Review	Altman
- 1.4l Auto, 1.8l Manual, Hoist Review	
- Detailed discussion of Issues	Altman
- Next Actions	Benavides

General Motors Company

DESIGN BUILD SELL

THE WORLD'S BEST VEHICLES

Chevy Cruze NHTSA IR PE12-010, GM

- Preliminary Evaluation to investigate allegations of fires originating in the engine compartment
- Unless otherwise stated in the text the followin_ definitions a_ _l_ to these information requests:
  - **Subject vehicles:** all MY 2011 through 2012 Chevrolet Cruze vehicle manufactured for sale or lease in the United States and federalized territories.
  - **Subject component:** Vehicle battery power and ground planes and all associated wiring and connectors manufactured for use as original equipment or service replacement parts for the subject vehicles.
  - **Subject bulletin:** Technical service bulletin SB-10043320-6819, "MIL Setting DTC U0101 Current or History"
- Alleged defect: An_ one or more of the followin_ s_m_toms or conditions:
  1. Fuse block or TCM failure or malfunction, including all associated fault codes;
  2. Allegations of overheated wiring in the engine compartment; or
  3. Allegations of smoke or fire in the engine compartment.
- Initial response to NHTSA May 11
  - Partial response delivered May 11, all reports and records
  - Final response due June 22, all engineering analysis and risk assessment

GM General Motors Company

DESIGN BUILD SELL THE WORLD'S BEST VEHICLES

Cruze Response

- Core Team formed April 2
  - Product Investigation and Reporting Functions, Program Team and SMT's
  - Executive Champion and Single Point Contact
- 417 Specific Tread re, r d i s nd 17,0 iti nal rel is p ll fr m or,aniza ion / bases (PI, Legal, FPRD, CTF, CVEP, EQF, TAC, CAC, PAR, PRTS, Warranty, MIC, UWC) were investigated
- Investigation included
  1. Issue
  2. Summary of TREAD Records: x Warranty, y Customer Complaints, z Field Reports, et
  3. Product History: DFMEA, PFMEA, Dev/Val PRTS, Warranty, Product Change History, Containment, Production fix, TSB's. If multiple changes exist time line of activity since SORP
  4. Support for Issue Assessment: verbatim analysis, returned parts, photos of example parts, photos of damaged parts, engineering explanation
  5. Issue Assessment (FPE supported): Smoke only, Smoke/Melting, Burning Smell only, Smoke/True fire, etc
  6. Product actions to be taken, Closure to all issues, regardless of relation to the IR
  7. Read Across: Repeat in all regions cross platform
- Cruze IR Sharepoint Web site to house all the SMT Data (template from Project J,T & E)
- Stage 1 SMT response complete April 20th
- Stage 2 Product Investigations Response to NHTSA May 11

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Cruze Response

- Incident Summary
  - Total Incidences Identified in US

	May 1 NHTSA Data Pull	Post Data Pull
Total Incidences Identified in US	28	37
• Exhaust to Belly Pan (No recent indication of Oil Change)	4	+2
• Exhaust to Belly Pan (Recent Oil Change)	12	+4
• Oil Fill Cap Missing	1	0
• MT Clutch Abuse Belly Pan	1	+2
• Under Investigation (Back of Engine Pass Side)	3	0
• Collision Damage	2	0
• Unknown (no trace history)	5	+1

- Discussion of Product Actions
  - Engine Oil Filter Cap
  - Engine Oil Fill Cap
  - Engine Oil Change Procedure
  - MT Clutch
  - Belly Pan

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Cruze IR Issue: Oil Filter Cap

- Back-u : Oil Filter Ca O-Rin anal sis of local materials

Label	Manufacturer	Part Number	Service Establishment	O ring Material
OEM	Hengst FILTER	GM P/N 93185674	OEM	VMAC [AEM]
Service Champ	FRAM	CF5839	Uncle Ed's OIL SHOPPE 10 MINUTE OIL CHANGE	VMAC [AEM]
Purolator-Group 7	Purolator	V5839	Valvoline	Nitrile
NAPA Gold	WIX FILTERS	7674	NAPA	VMAC [AEM]
AC	Hengst FILTER	PF2257g, Filter Kit (filter & oring) 93185674	CHEVROLET	VMAC [AEM]
Performax	Purolator	PO-171	PENNZOIL 10 MINUTE OIL CHANGE	Nitrile
Mighty Max	Purolator	M981	LUBE TECH DRIVE THRU OIL CHANGE	Nitrile

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Cruze IR Issue: Under Investigation

Description of Issue:

- Three vehicles appear to have a different source of ignition, Passenger right rear

Solution:

- TBD

Timing:

- Vehicles available for analysis

14May12

Back Up

Cruze IR – Single Point Contacts

Function	Champion	Lead
Program Eng'g	Gary Altman	Bob VanArsdale
Program Quality	Matt Hurley	Bruce Cloud
PT Eng LUJ	Bob Benedict	Stacy Kraysovic
PT Eng LUW	Curt Andreski	Stacy Kraysovic
PT AT MH8	Steve Saia	Stacy Kraysovic
PT MT M32	Mark Gilmore	Stacy Kraysovic
Chassis	Margaret Oswald	Matt Scrase
Interior	Doug Houlihan	Jeff Ronne
Exterior	Betsy Jackson/Cheryl Davis	Al Pieczynski/Mike Sigelko
HVAC/CRFM	Sean Stelzer	Paul Klain
Electrical	Regina Himmelspach	Tom Sayles

Cruze IR – Single Point Contacts

Function	Champion	Lead
Product Investigation	Carmen Benavides	Dale Furney
		Dewayne Davidson
		Doug Wachtel
External Investigations	Dale Furney	Mark Deacon (Lead Investigation Engineer)
Tread Reporting	Dewayne Davidson	Mickey Sabol (Int Inv Eng'r)
		Paul Kelly (Tech Analyst)
Internal Investigations	Doug Wachtel	Brian Stouffer
		Jerry Hendler

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PE12-012

GM

6/22/2012

Q_07_6 PT Eng

Engine Report

U14NET19VV8033-p

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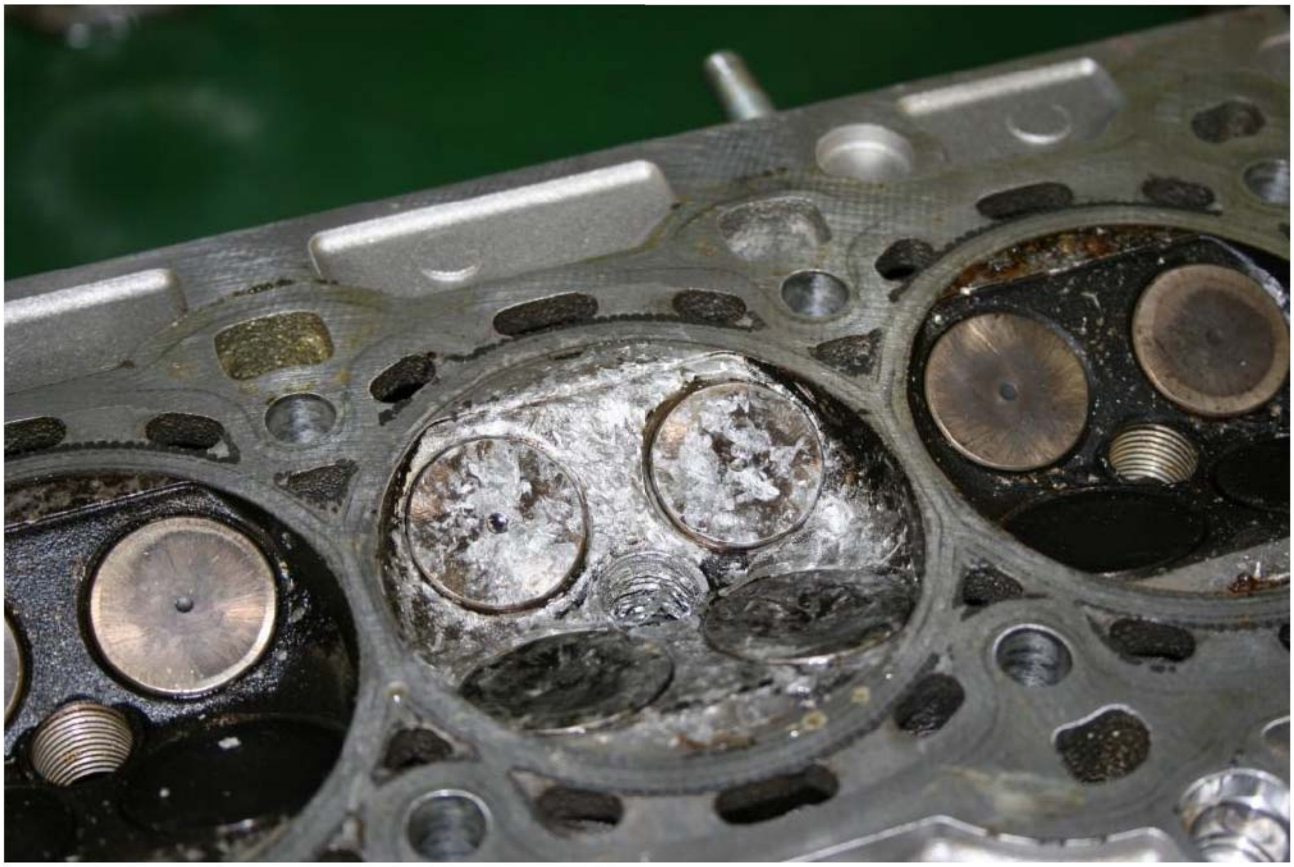

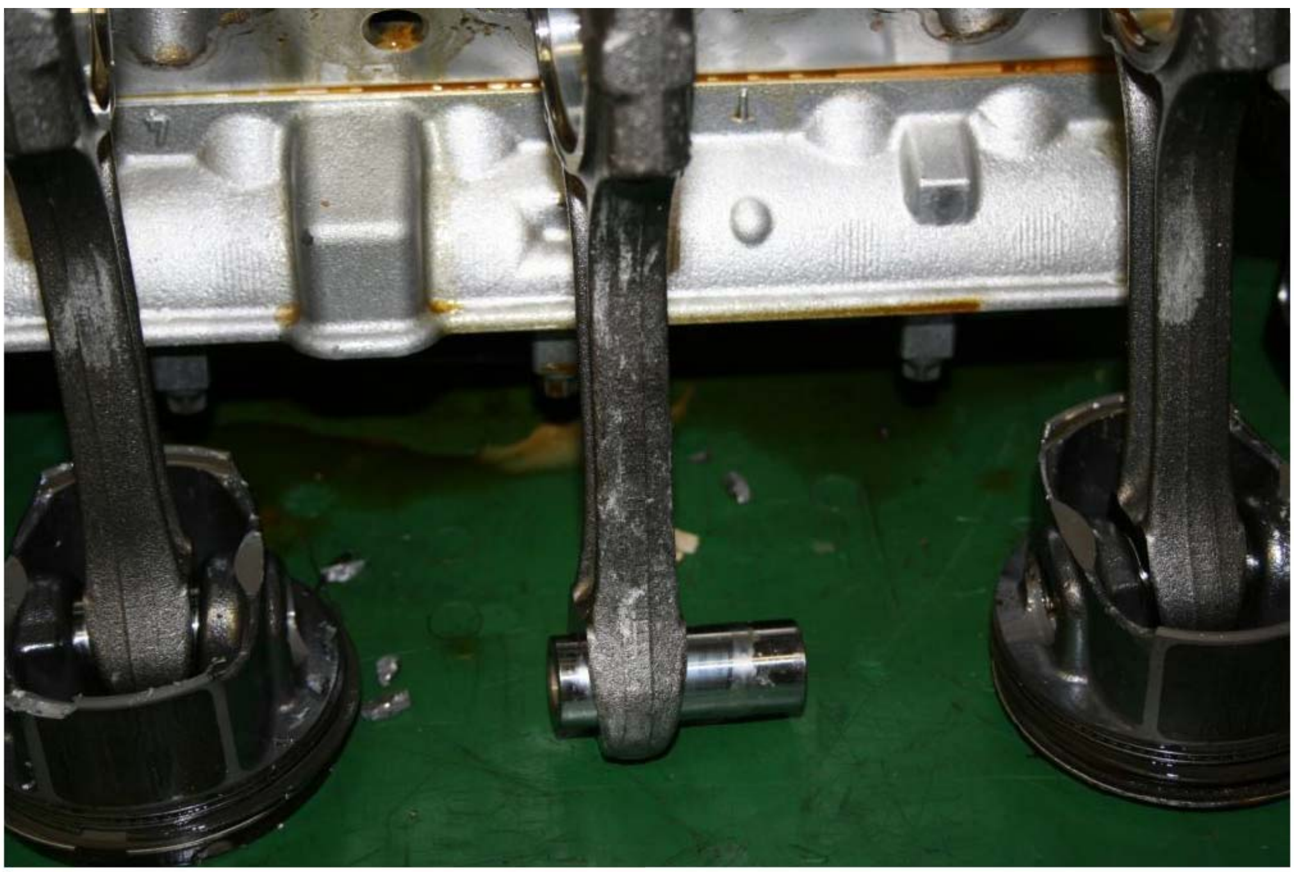

PE12-012

GM

6/22/2012

Q_07_6 PT Eng

Executive Summary Chevy Cruze 12_04-20_GB-p

Cruze IR Executive Summary- Gasoline Engines

Fam.0 1,4l Turbo
Fam.I 1,8l NA

Status Apr20th, 2012

Redacted for Privacy

Redacted for Privacy

Redacted for Privacy

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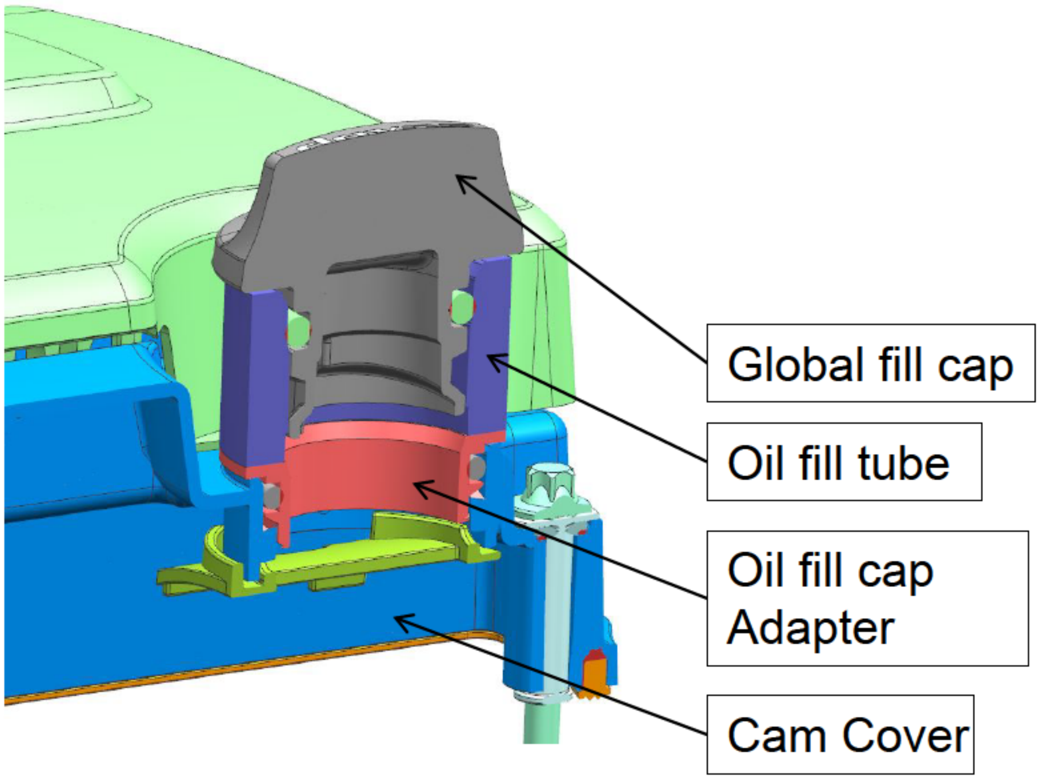
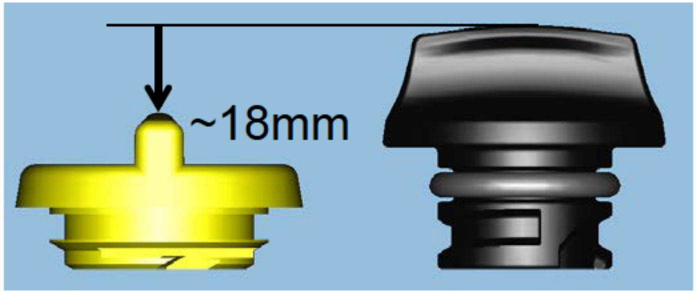
Chevy Cruze

1. Oil Fill Cap - Service problems and possible improvements
Study – Potential Concept "Retrofit"



Common design for 1.4T and 1.8l



Current proposal

- Implementation Timing: ~ 9 month including design, sourcing, tooling & testing
- Material Cost: { ** } tbc.
- Tooling { ** },
- ME invest: tbd

Chevy Cruze

1. Oil Fill Cap - Service problems and possible improvements

Next steps:

- finalize design concept, cw18
- Kick-off sourcing, cw18
- confirm effectiveness, cw 20
- Final evaluation of ME impact US/GME, cw20
- Work on an improved service instruction (e.g. check list), cw20 tbc

Chevy Cruze

2. Oil Filter Cap - Service problems and possible improvements

Indications of wrongly serviced oil filters (60 verbatims from dealers)

Detailed description of possible service failures:

- wrong installation of O-ring seal, damaged O-ring, 2 O-rings, or no seal ring present.

- several cracked filter caps due to usage of wrong tools like belt wrench or pipe wrench (instead of hex. nut drive).

This can result in more or less high oil spill through the filter cap.

New learning from the US market – these issues are not known from European or Asian applications.

Countermeasures under investigation:

1. More robust design of the filter cap.
2. Improvements of service instructions.

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Chevy Cruze

3. Turbo oil feed and drain pipes - possible improvements

Indications of oil feed pipe clogging –> turbo charger overheating –> drain pipe melting as consequence.

Detailed description of possible root cause:

- oil coking and clogging due to high temperatures in oil feed pipe.
- due to the turbo charger overheating, the return pipe sees higher temperatures and melts.

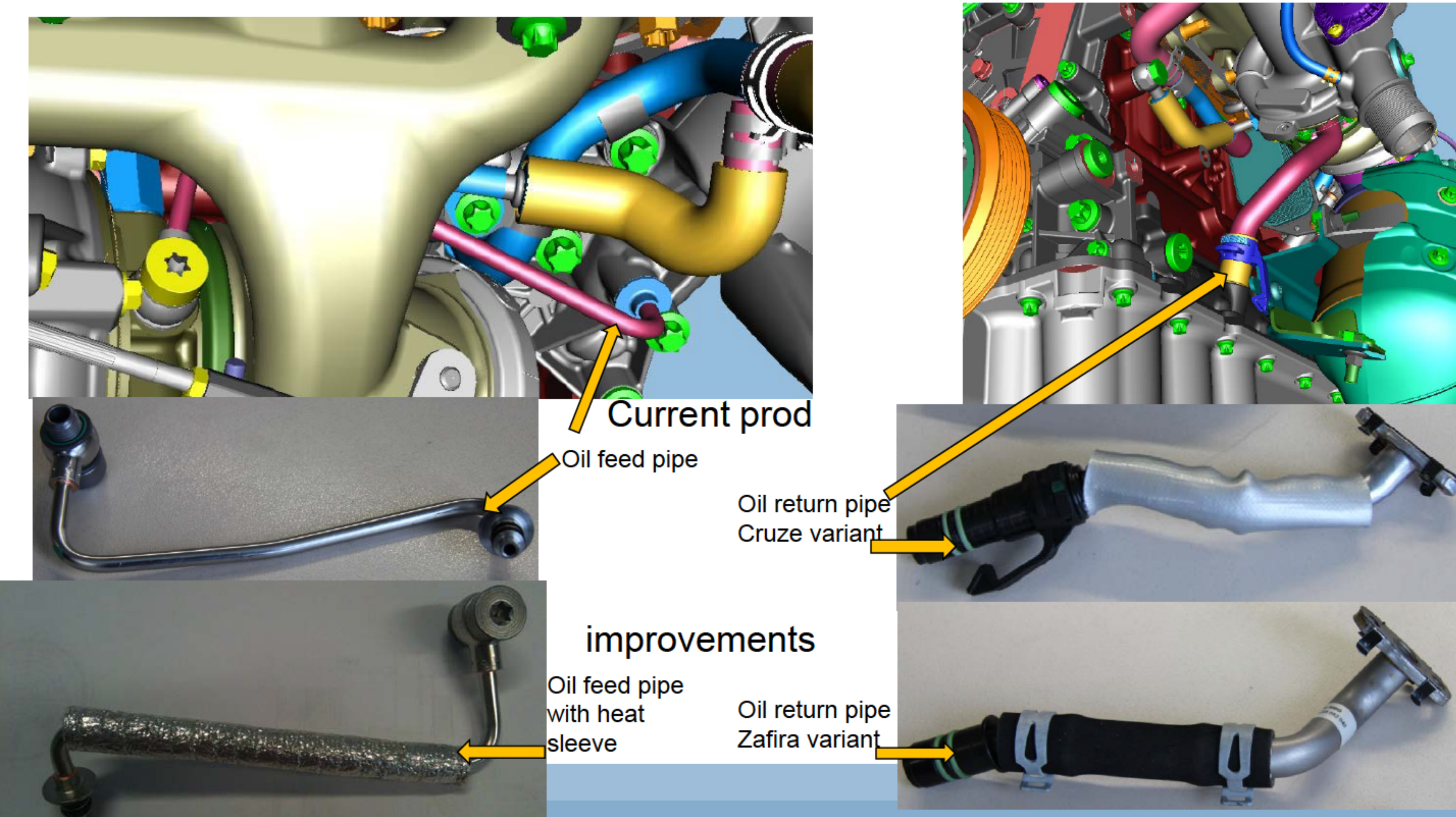
This can result in an oil spill through the oil return pipe.

Countermeasures under investigation:

1. Temperature protection of the oil feed pipe
(heat protection sleeve reduces temp by 40 to 55°K & avoids oil cocking)
2. Alternative design of drain pipe (Zafira application) with high temp material properties

Chevy Cruze

3. Turbo oil feed and return pipes - possible improvements



Chevy Cruze

3. Turbo oil feed and return pipes - possible improvements

Timing:

- 6 weeks (drain pipe)
- 3 months (feed pipe)

Cost:

- { ** } on cost (drain pipe)
- { ** } material on cost (feed pipe)
- no investment

Next steps:

- Verify component temperatures & countermeasure for the Cruze, cw17
- Finalize validation, cw23
- Kick-off production order

Cruze IR Executive Summary-Family 0 1.4T Engine

76 Line items, 18 Categories, 51 unique VINs

Issue Category	#	IR Related	Status	Comments
Turbocharger Oil Feed Pipe Clogged	27	Yes	Open	Known fixes to address oil coking already in place; additional RC work in process, redesign under investigation *Evidence indicates a fire was not present*
Oil Fill Cap	4	Yes	Open	Redesign under investigation *Evidence indicates a fire was not present*

GME Family 0 team providing necessary documents

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PE12-012

GM

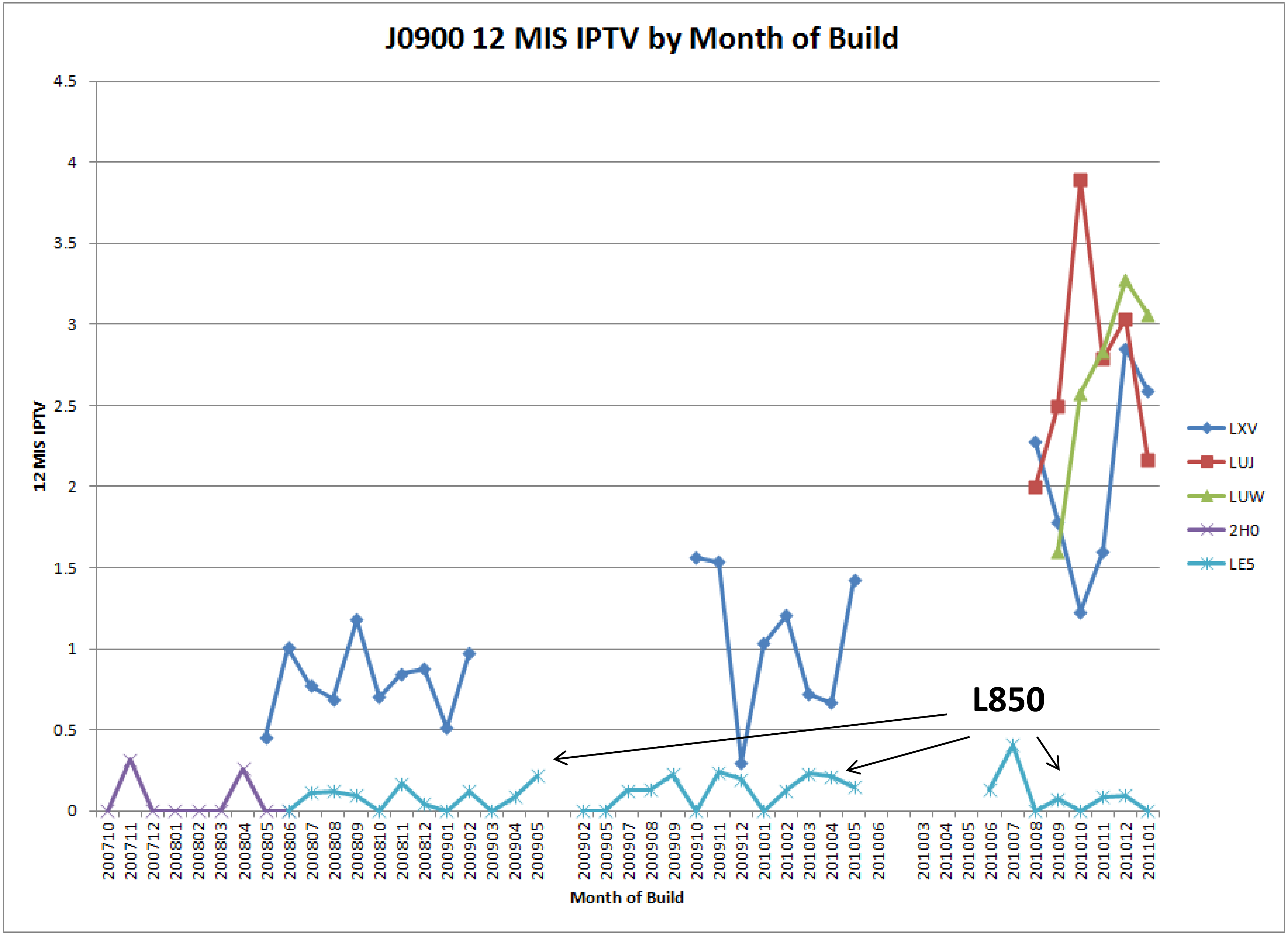
6/22/2012

Q_07_6 PT Eng

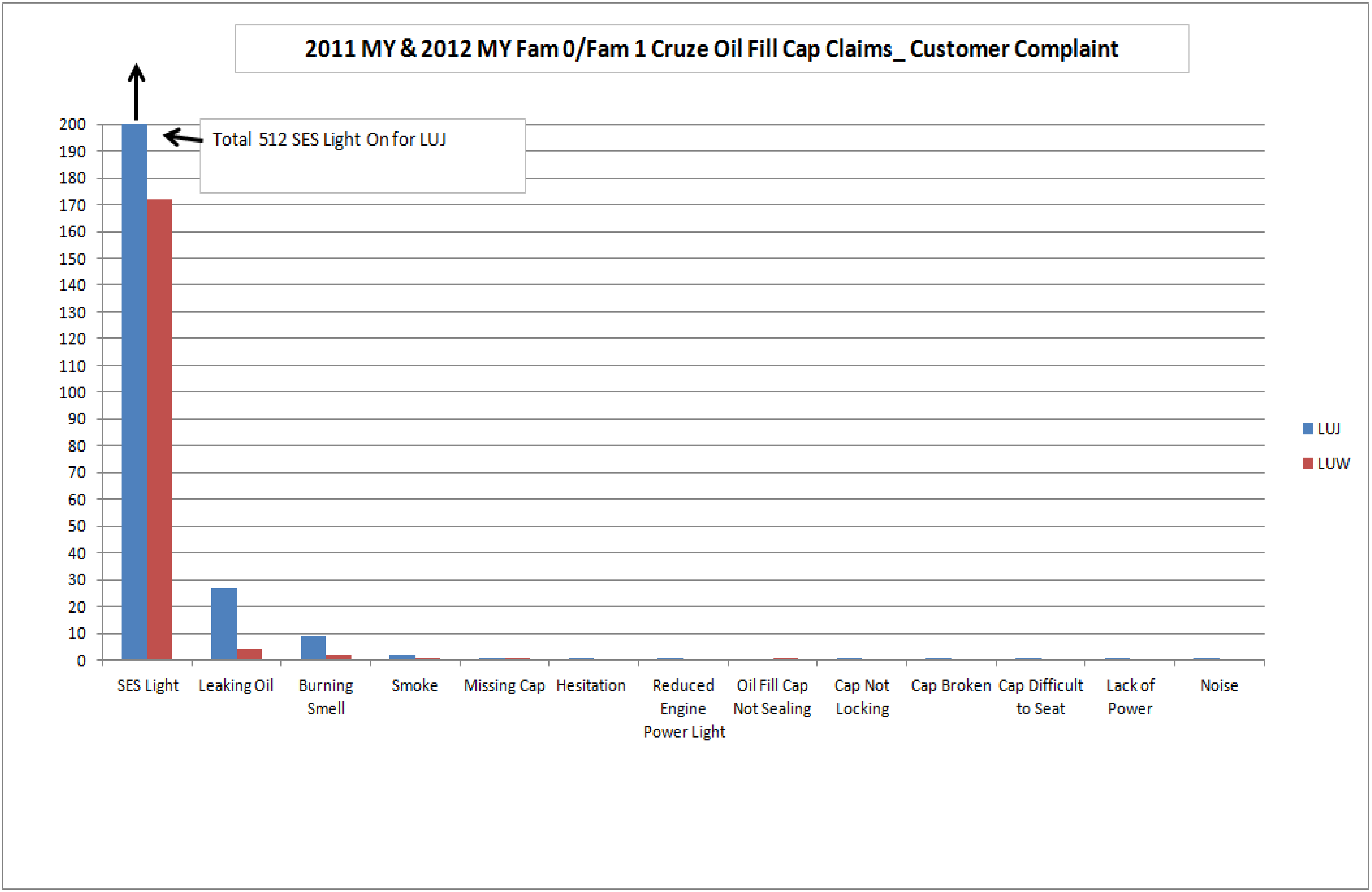
Oil Fill Cap_GMNA_Warranty Data_4-16-12

Fam 0 and Fam 1 Oil Fill Cap Warranty J0900 Oil Fill Cap Replacement Labor Code Summary

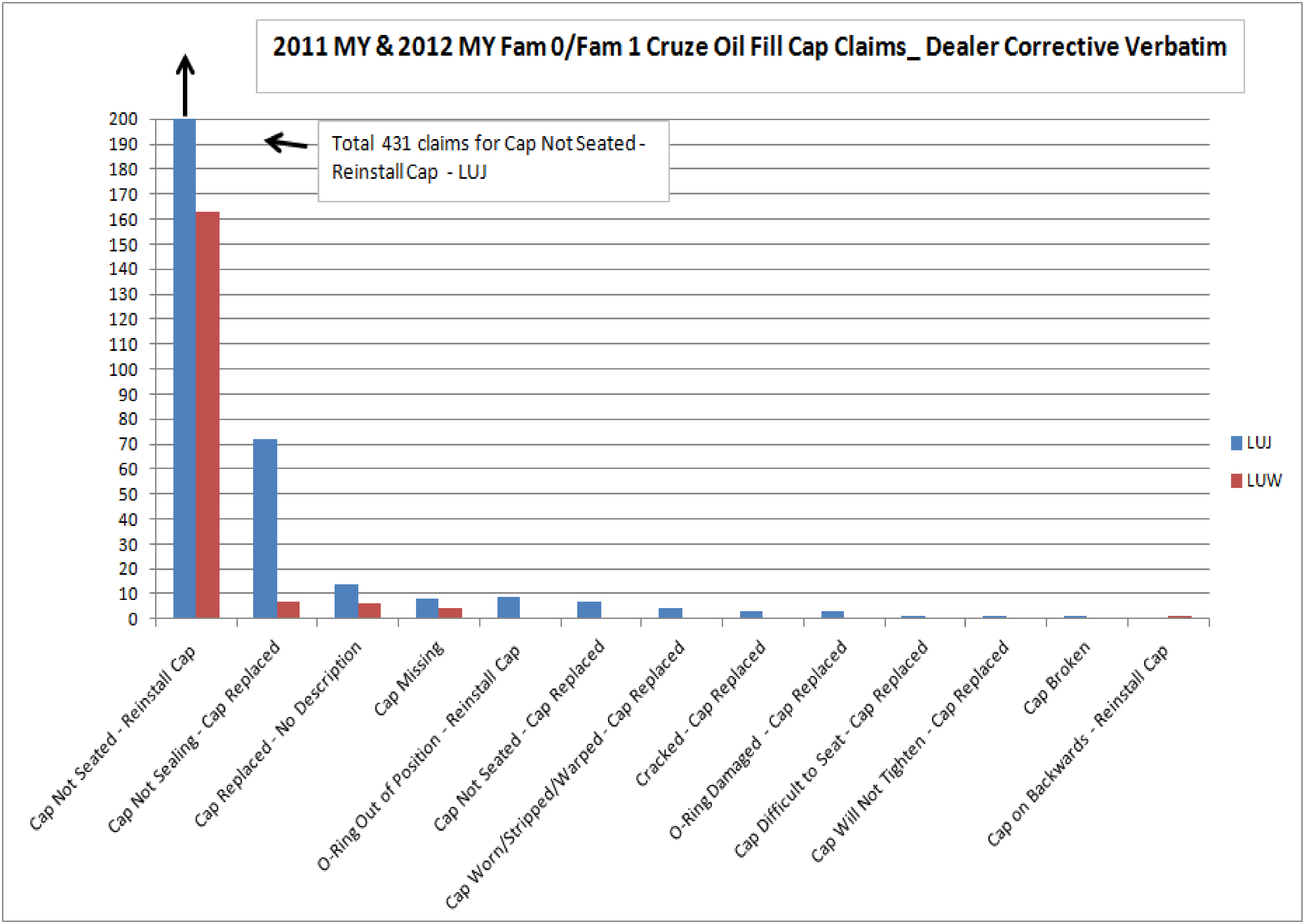
4-17-12



J0900 12 MIS IPTV by Month of Build
12 MIS IPTV
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
200710
200711
200712
200801
200802
200803
200804
200805
200806
200807
200808
200809
200810
200811
200812
200901
200902
200903
200904
200905
200902
200905
200907
200908
200909
200910
200911
200912
201001
201002
201003
201004
201005
201006
201003
201004
201005
201006
201007
201008
201009
201010
201011
201012
201101
Month of Build
LXV
LUJ
LUW
2H0
LE5
L850



2011 MY & 2012 MY Fam 0/Fam 1 Cruze Oil Fill Cap Claims_ Customer Complaint
Total 512 SES Light On for LUJ
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
SES Light
Leaking Oil
Burning Smell
Smoke
Missing Cap
Hesitation
Reduced Engine Power Light
Oil Fill Cap Not Sealing
Cap Not Locking
Cap Broken
Cap Difficult to Seat
Lack of Power
Noise
LUJ
LUW


2011 MY & 2012 MY Fam 0/Fam 1 Cruze Oil Fill Cap Claims_ Dealer Corrective Verbatim
Total 431 claims for Cap Not Seated - Reinstall Cap - LUJ
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
Cap Not Seated - Reinstall Cap
Cap Not Sealing - Cap Replaced
Cap Replaced - No Description
Cap Missing
O-Ring Out of Position - Reinstall Cap
Cap Not Seated - Cap Replaced
Cap Worn/Stripped/Warped - Cap Replaced
Cracked - Cap Replaced
O-Ring Damaged - Cap Replaced
Cap Difficult to Seat - Cap Replaced
Cap Will Not Tighten - Cap Replaced
Cap Broken
Cap on Backwards - Reinstall Cap
LUJ
LUW

Engineering Investigation - GMNA Cruze Warranty –2 Minute Drill – Sept 1, 2011

•**Issue Description:** Check engine light – P0171
High number of claims (J0900) for loose or leaking oil fill caps.
High percentage (60%) of claims state oil fill cap loose.

•**Root Cause: Oil fill caps not installed properly after oil changes**

- •Conducted Engineering Investigation – 53 total calls –
  - 44 - Oil fill cap not seated after oil change
  - 3 - Oil dipstick not fully seated
  - 1 - 70% alcohol in fuel
  - 1 – Oil pressure switch failure
  - 4 – could not determine root cause

Not seated fully

- •Install “suspect” oil fill cap on vehicle and check lean values – Complete July 13. Values within normal range.
- •Send oil fill caps to Europe for analysis – Complete – Parts within spec.
- •Investigating hardware stack up – Complete. NTF.
- •Review calibration limits – complete.

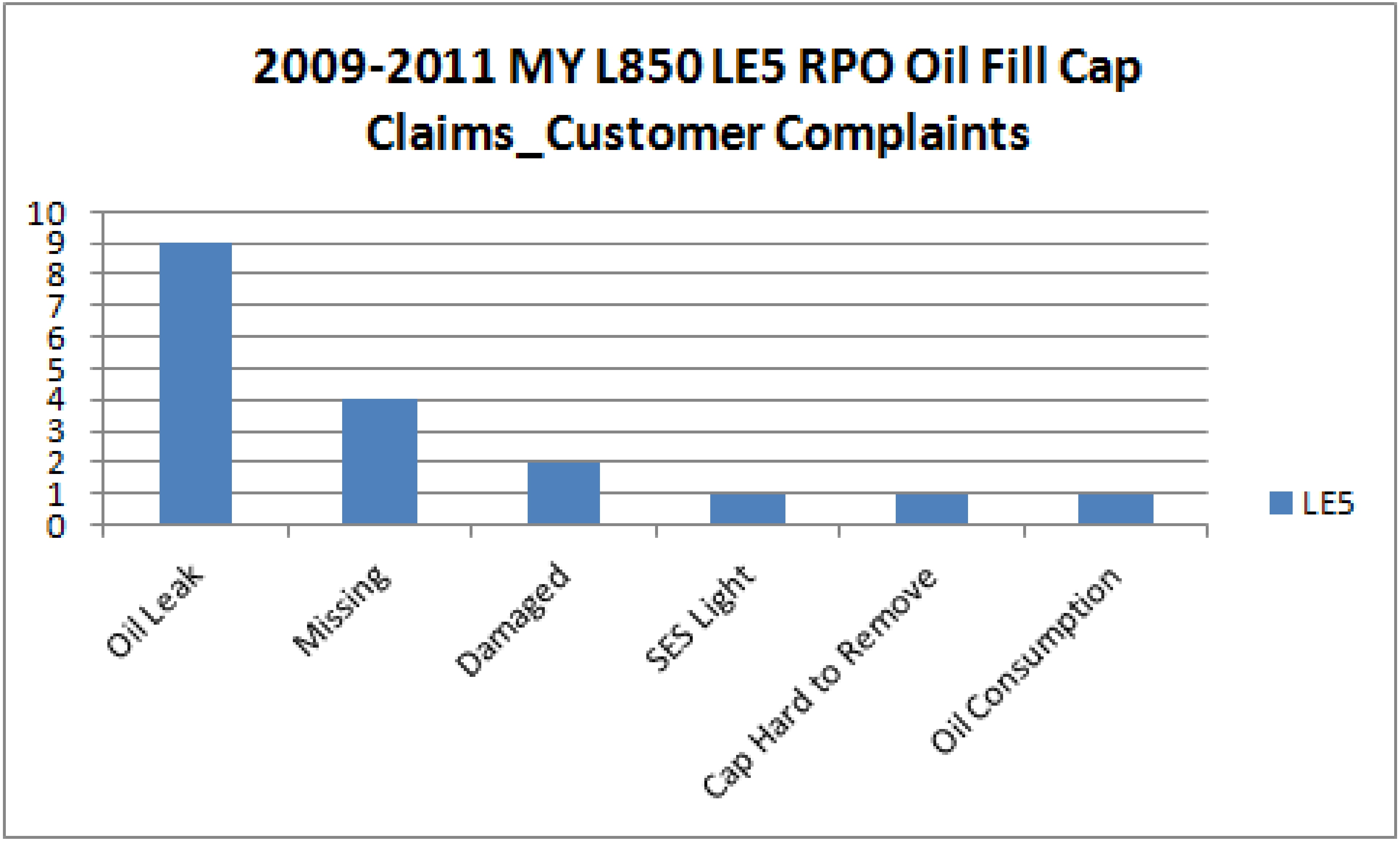
Not seated fully

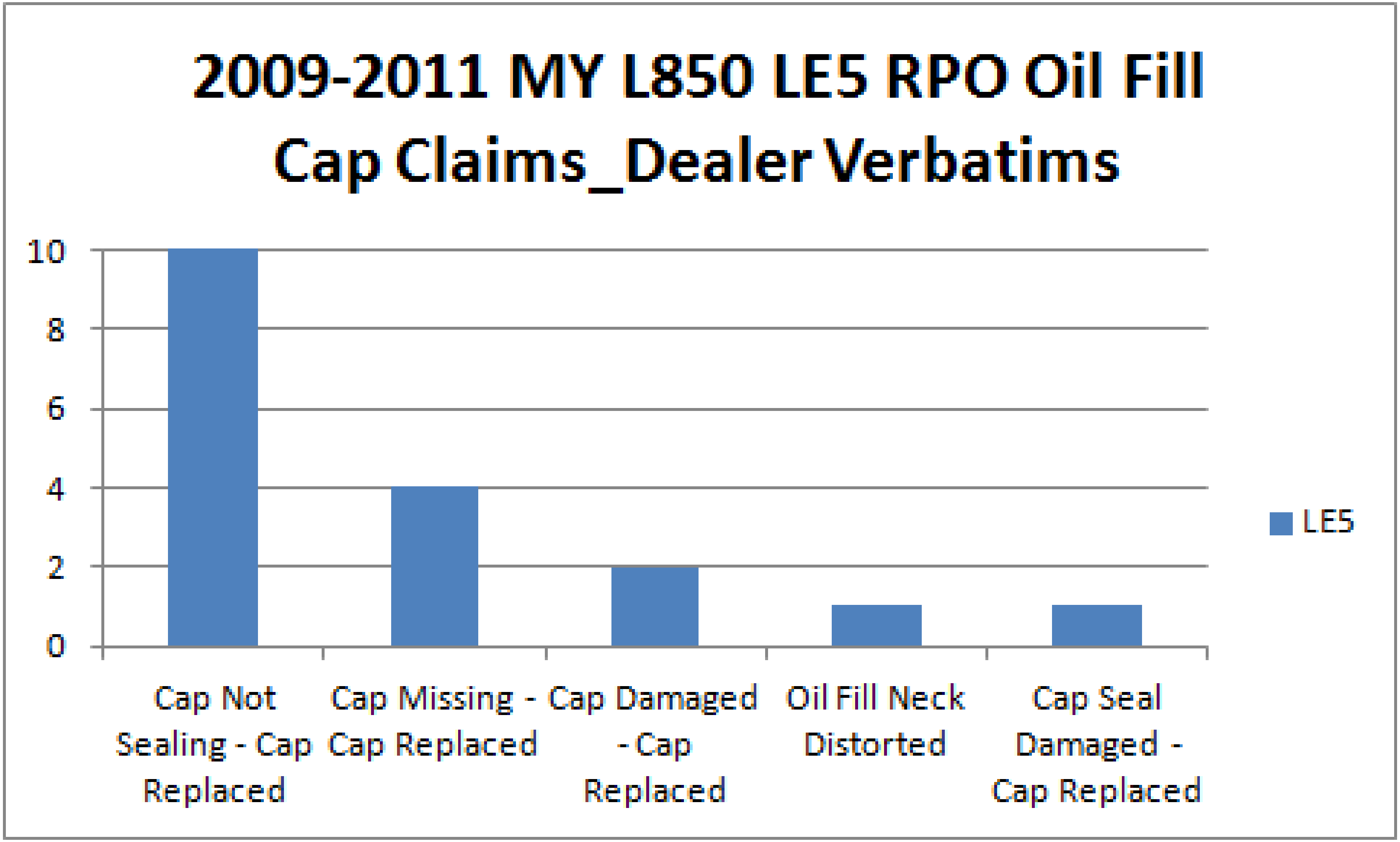
•**Containment/Estimated Effectiveness/Permanent Fix:**

- •PI Bulletin being issued for dealerships – J. Kropp – Sept 6.
- •Communication sent to “Oil and Lube News” for quick change oil companies – Complete.

•**Next Actions/Owners/Timing:** Investigate cost effective solution to prevent cross threading.

•**Roadblocks:** *Redesign of oil fill cap would require redesign of cam cover.*


2009-2011 MY L850 LE5 RPO Oil Fill Cap Claims_Customer Complaints
10
9
8
7
6
5
4
3
2
1
0
Oil Leak
Missing
Damaged
SES Light
Cap Hard to Remove
Oil Consumption
LE5


2009-2011 MY L850 LE5 RPO Oil Fill Cap Claims_Dealer Verbatims
10
8
6
4
2
0
Cap Not Sealing - Cap Replaced
Cap Missing - Cap Replaced
Cap Damaged - Cap Replaced
Oil Fill Neck Distorted
Cap Seal Damaged - Cap Replaced
LE5

PE12-012

GM

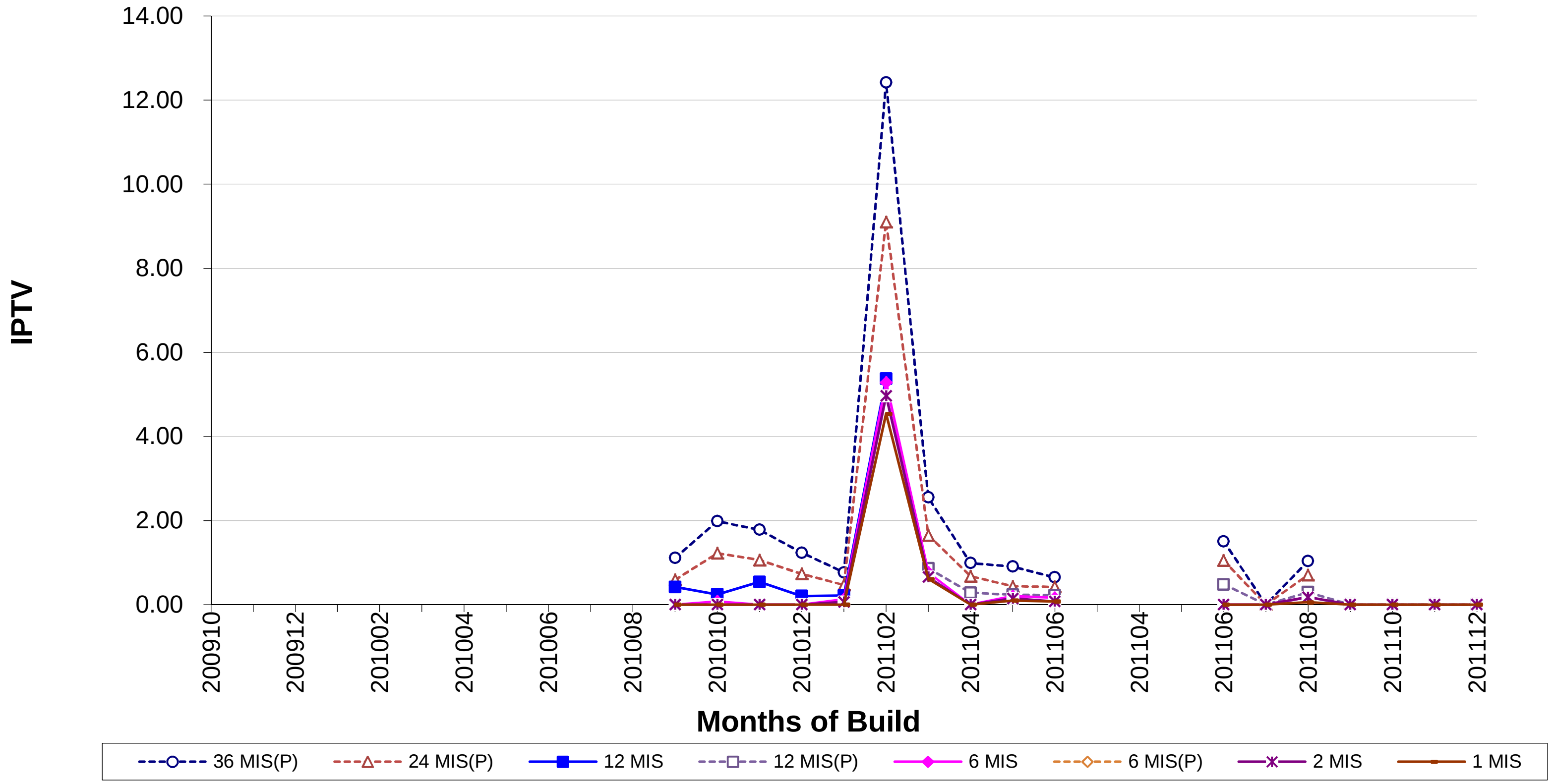
6/22/2012

Q_07_6 PT Eng

TREND_2011_2012_MY_Cruz
eLUJ_J1120_Claims__13-04-
2012

TREND 2011 2012 MY CruzeLUJ J1120 Claims 13-04-2012

Trend Chart -Incidents per Thousand Vehicles



Analysis Date:13-04-2012	MY:2012,2011 | Exposure:36 MIS	
Build Region:GMNA	Sales Region:GMNA	Sales Country:AG,AW,BS,BB,BZ,BM,VG,CA,KY,CR,CU,DM,DO
Plant:N/A	Rep Region:N/A	Rep Country:N/A
Prod Filter:2011 2012 MY Cruze		
Claim Filter:J1120 Claims		Beg. MOB:N/A To End MOB:N/A
Trace Filter:N/A		Last Data Update:07-04-2012
RPO Filter:LUJ		User:William Whited(SZCYNS)

PE12-012

GM

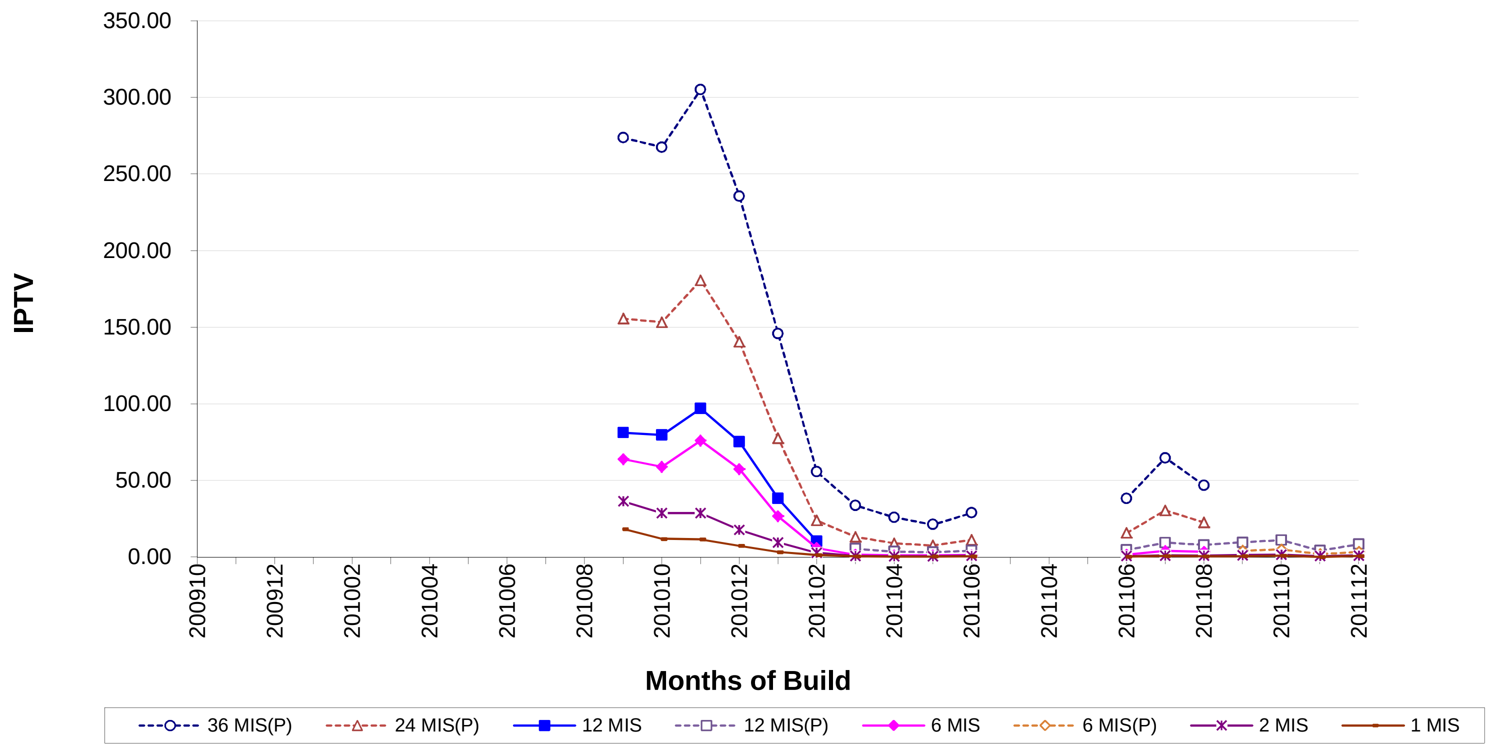
6/22/2012

Q_07_6 PT Eng

TREND_2011_2012_MY_Cruz
eLUJ_Thermostat_J_Codes__1
3-04-2012

TREND 2011 2012 MY CruzeLUJ Thermostat J Codes 13-04-2012

Trend Chart -Incidents per Thousand Vehicles



Analysis Date:13-04-2012	MY:2012,2011 | Exposure:36 MIS	
Build Region:GMNA	Sales Region:GMNA	Sales Country:AG,AW,BS,BB,BZ,BM,VG,CA,KY,CR,CU,DM,D(
Plant:N/A	Rep Region:N/A	Rep Country:N/A
Prod Filter:2011 2012 MY Cruze		
Claim Filter:Thermostat J Codes		Beg. MOB:N/A To End MOB:N/A
Trace Filter:N/A		Last Data Update:07-04-2012
RPO Filter:LUJ		User:William Whited(SZCYNS)

PE12-012

GM

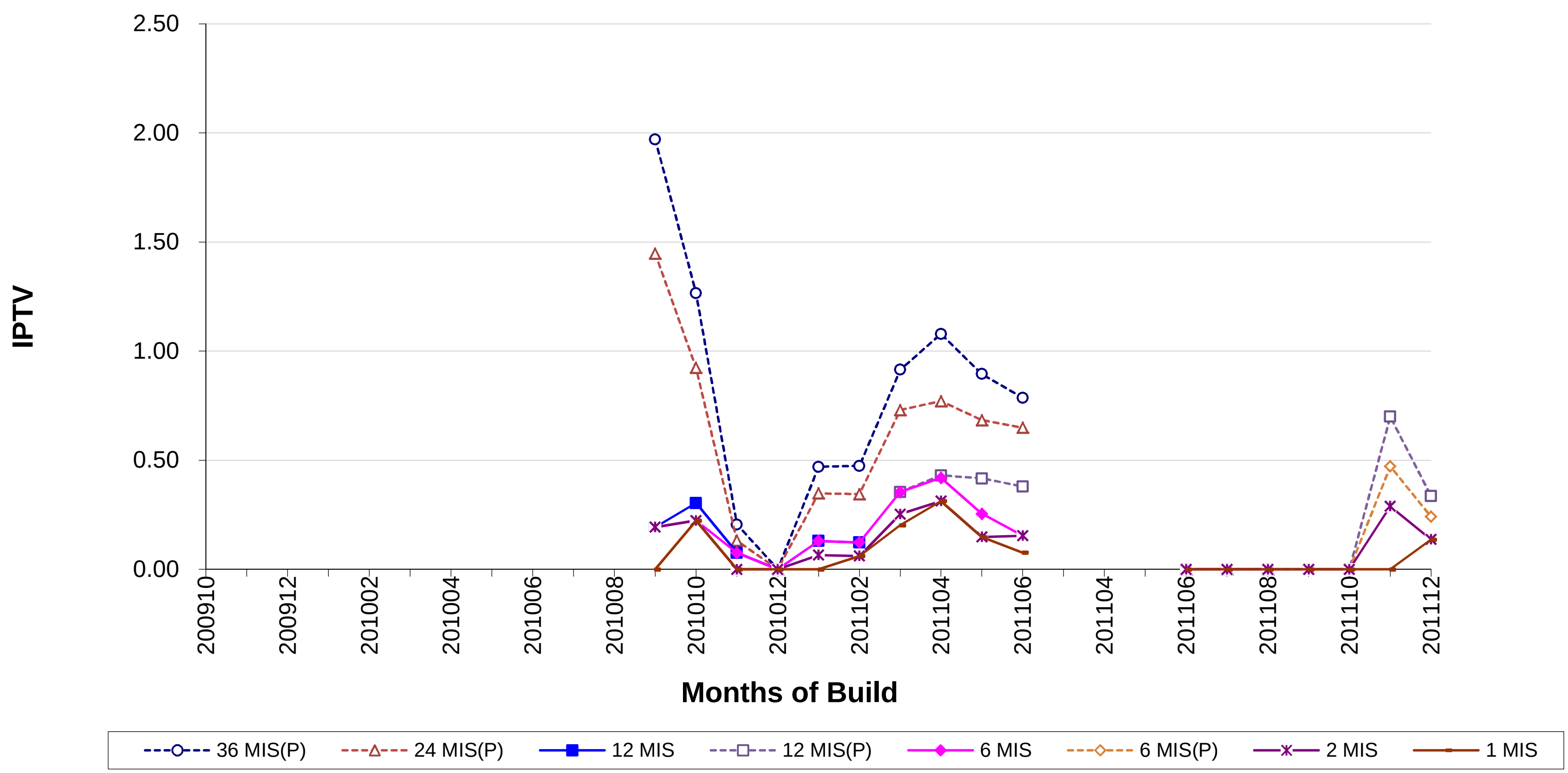
6/22/2012

Q_07_6 PT Eng

TREND_2011_2012_MY_CruzeLUJ_Turbocharger_Oil_Return_Pipe_Claims__13-04-2012

TREND 2011 2012 MY CruzeLUJ Turbocharger Oil Return Pipe Claims 13-04-2012

Trend Chart -Incidents per Thousand Vehicles



Analysis Date:13-04-2012	MY:2012,2011 | Exposure:36 MIS	
Build Region:GMNA	Sales Region:GMNA	Sales Country:AG,AW,BS,BB,BZ,BM,VG,CA,KY,CR,CU,DM,DC
Plant:N/A	Rep Region:N/A	Rep Country:N/A
Prod Filter:2011 2012 MY Cruze		
Claim Filter:Turbocharger Oil Return Pipe Claims		Beg. MOB:N/A To End MOB:N/A
Trace Filter:N/A		Last Data Update:07-04-2012
RPO Filter:LUJ		User:William Whited(SZCYNS)

PE12-012

GM

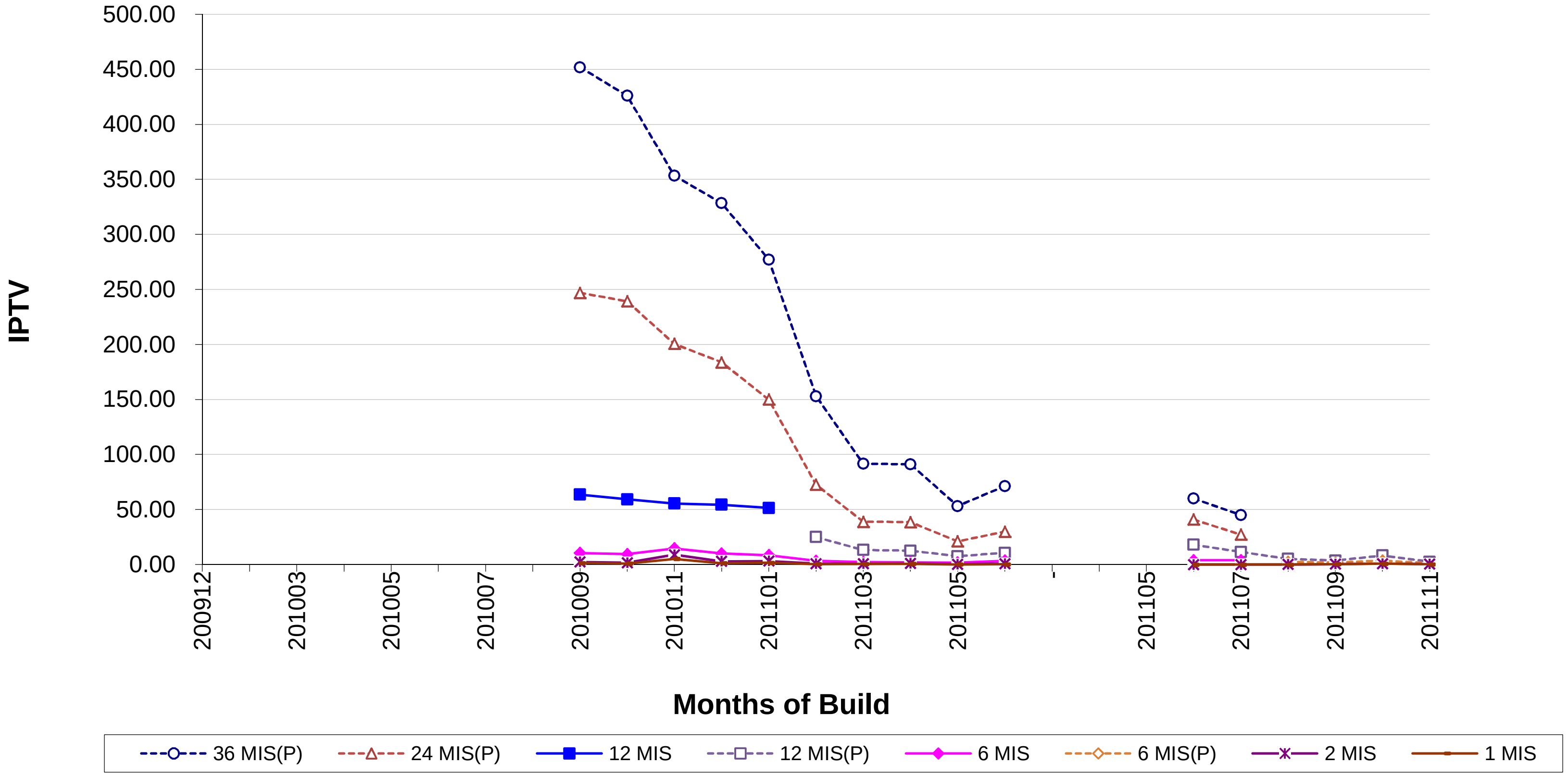
6/22/2012

Q_07_6 PT Eng

TREND_2011_2012_MY_Cruz
eLUW_Thermostat_J_Codes__
13-04-2012

TREND 2011 2012 MY CruzeLUW Thermostat J Codes 13-04-2012

Trend Chart -Incidents per Thousand Vehicles



Analysis Date:13-04-2012	MY:2012,2011 | Exposure:36 MIS	
Build Region:GMNA	Sales Region:GMNA	Sales Country:AG,AW,BS,BB,BZ,BM,VG,CA,KY,CR,CU,DM,DO
Plant:N/A	Rep Region:N/A	Rep Country:N/A
Prod Filter:2011 2012 MY Cruze		
Claim Filter:Thermostat J Codes		Beg. MOB:N/A To End MOB:N/A
Trace Filter:N/A		Last Data Update:07-04-2012
RPO Filter:LUW		User:William Whited(SZCYNS)

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GM

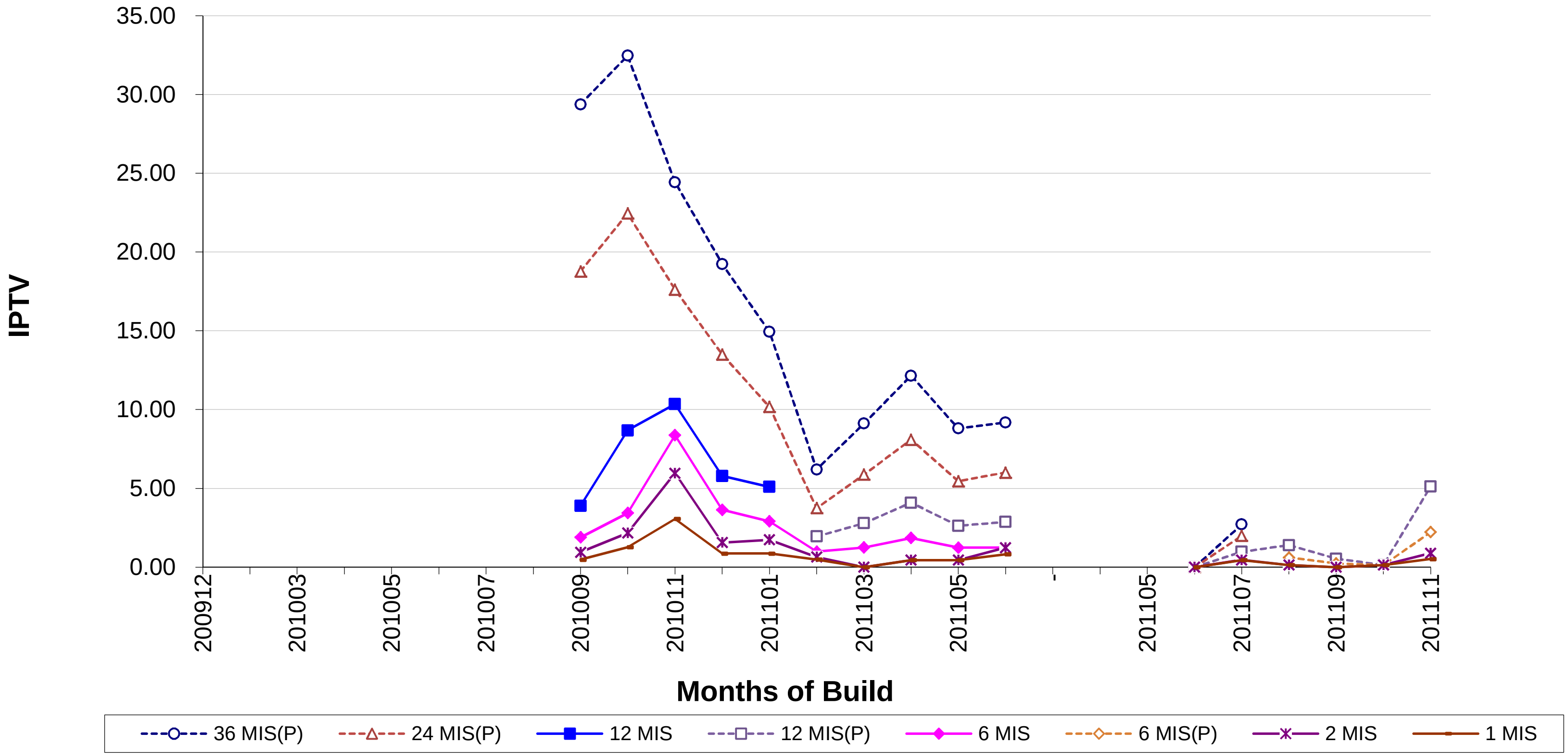
6/22/2012

Q_07_6 PT Eng

TREND_2011_2012_MY_Cruz
eLUW_Wiring_Harness_Repla
ce__13-04-2012

TREND 2011 2012 MY CruzeLUW Wiring Harness Replace 13-04-2012

Trend Chart -Incidents per Thousand Vehicles



Analysis Date:13-04-2012	MY:2012,2011 | Exposure:36 MIS	
Build Region:GMNA	Sales Region:GMNA	Sales Country:AG,AW,BS,BB,BZ,BM,VG,CA,KY,CR,CU,DM,DO
Plant:N/A	Rep Region:N/A	Rep Country:N/A
Prod Filter:2011 2012 MY Cruze		
Claim Filter:Wiring Harness Replace		Beg. MOB:N/A To End MOB:N/A
Trace Filter:N/A		Last Data Update:07-04-2012
RPO Filter:LUW		User:William Whited(SZCYNS)

PE12-012

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6/22/2012

Q_07_6 PT Eng

Warranty,Dealer Visit 04

Fw: Warranty,Dealer Visit 04 17 2012 R. Mason - Cruze oil change

Jerry Hendler to: Gary F. Altman, Doug Wachtel, Dale A. Furney, Mark Deacon, Brian Stouffer, Louis Carlin, Gary Smits 04/18/2012 06:37 AM

From: Jerry Hendler/US/GM/GMC
To: Gary F. Altman/US/GM/GMC@GM, Doug Wachtel/US/GM/GMC@GM, Dale A. Furney/US/GM/GMC@GM, Mark Deacon/US/GM/GMC@GM, Brian Stouffer/US/GM/GMC@GM, Louis Carlin/US/GM/GMC@GM, Gary Smits/US/GM/GMC@GM

Interesting development you may (or may not) have heard about yesterday. Reesa had an oil change at a 3rd party oil change establishment, later smelled an oil odor, took the Cruze to her dealership to investigate, found an oil filter housing leak.

Per the attached, Al Miller has collected Reesa's parts and has some preliminary observations. He also purchased unused aftermarket parts from that same establishment, and the virgin o-ring is with our materials folks for analysis.

Thanks,

Jerry
----- Forwarded by Jerry Hendler/US/GM/GMC on 04/18/2012 06:31 AM -----

From: Alan S. Miller/US/GM/GMC
To: curtis.andreski@gm.com, James B. Lewis/US/GM/GMC@GM, Thorsten Kniesa/DE/GM/GMC@GME
Cc: Jerry Hendler/US/GM/GMC@GM
Date: 04/17/2012 08:35 PM
Subject: Warranty,Dealer Visit 04 17 2012 R. Mason

See attached.ppt. per Curt Andreski, I,

- travelled to dealership to get oil filter and oring from Reesa Mason's vehicle.
- have in my possession the o ring and filter. Oring has significant compression set, evident by square edges and hardness of material..
- travelled to Coruso's oil exchange center, place of last oil change, and purchased what they installed for Reesa's vehicle. product-Purolator filter and o ring
- will have John Beckett identify material for [1]oring from Reesa's vehicle, [2] new Purolator o ring from oil change facility that Reesa Mason had recently had oil change [about 2 weeks], and [3] new AC Brand Oring.

Thorsten,

- see attached.ppt, Can you contact Hengst and find out if Hengst supplies filters and o rings to the brand names identified?
- if you decide to a o ring on for life, Karl suggests having Teflon on seal.

Alan

Warranty.DealerVisit.04172012_RMason.ppt

PE12-012

GM

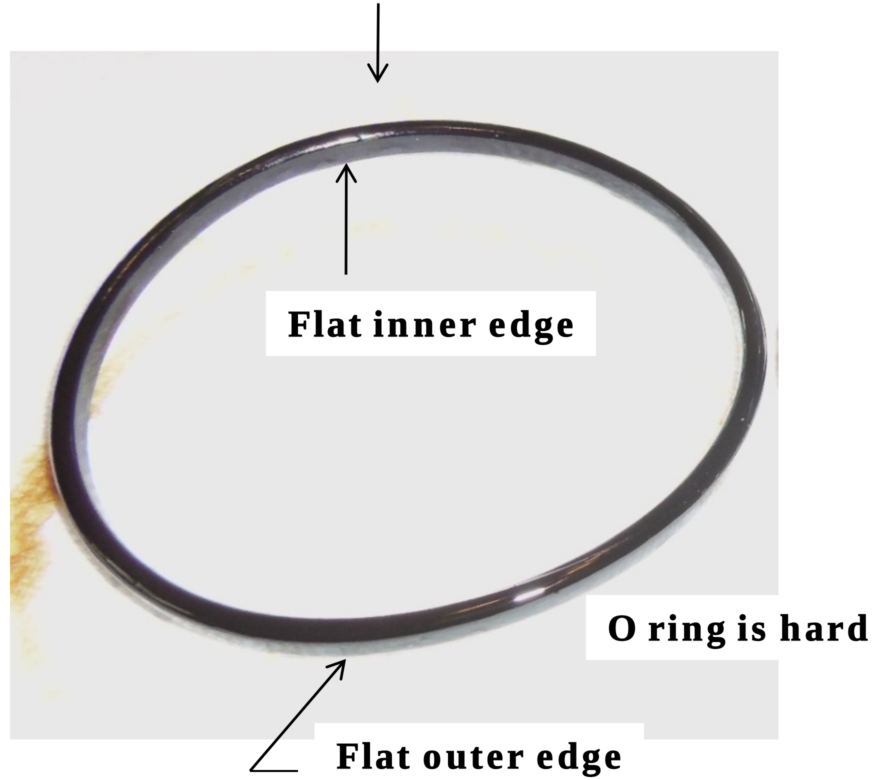
6/22/2012

Q_07_6 PT Eng

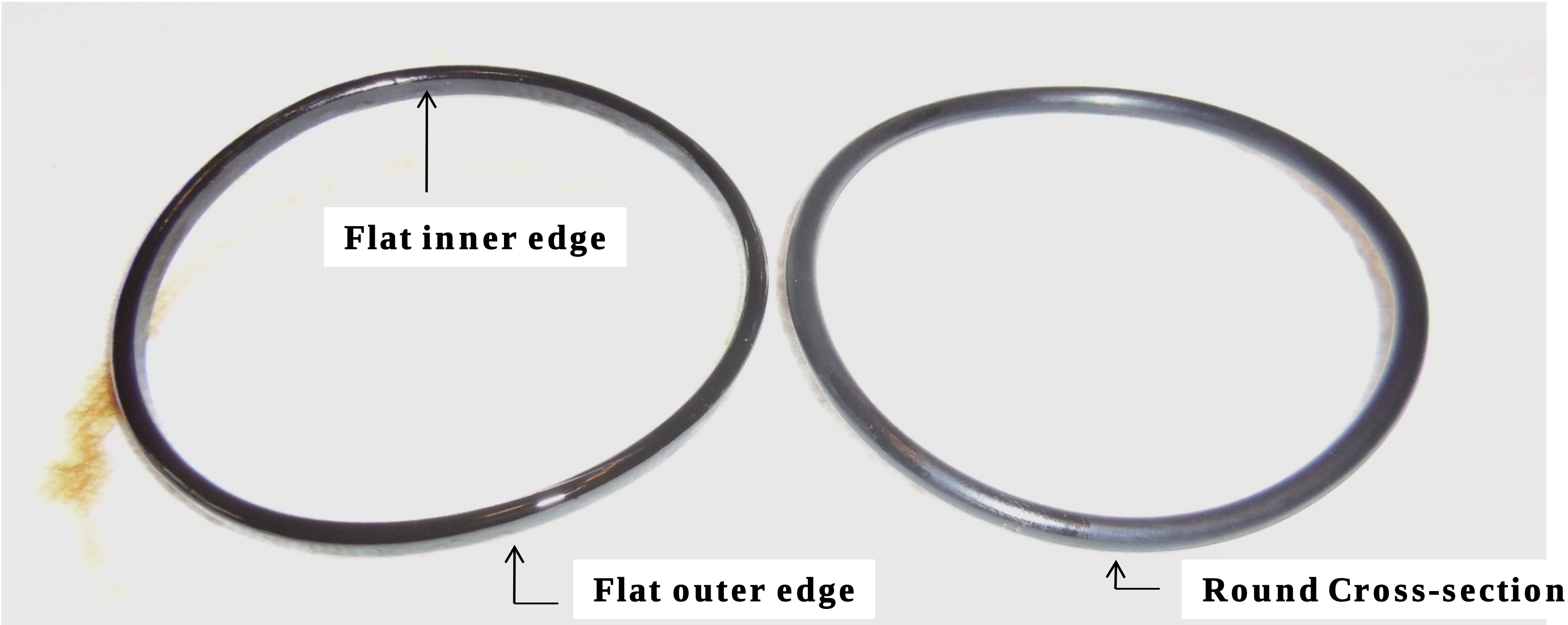
Warranty.DealerVisit.04172012
_RMason

Oil filter with Oring box from Coruso's Valvoline Oil change
On Hayes Road between 22 and 23 mile road

Oil Filter cap Seal from vehicle
with oil leak at GM Dealership

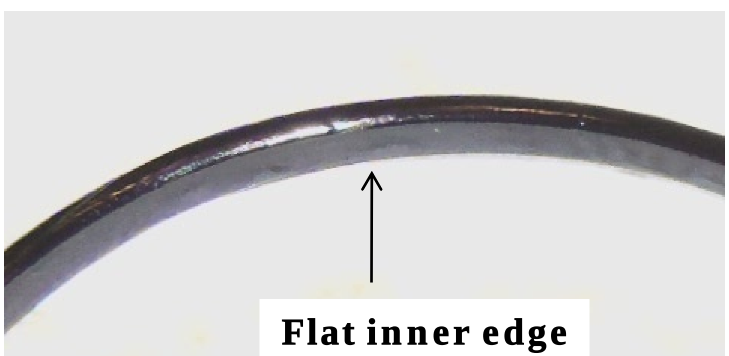


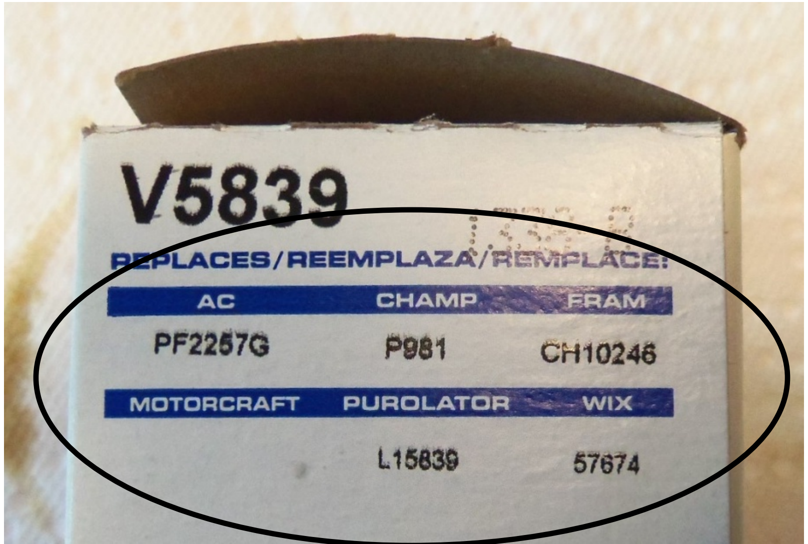
Customer verbatim, oil was changed
At Coruso's Oil change on Hayes Road
Between 22 and 23 mile road



Oil Filter Cap Seal **from vehicle with oil leak at GM Dealership**

New Oil Filter Cap Seal from Valvoline Oil Exchange





Replacement filters numbers for different brands

Brand-AC

Brand-Purolator

Leak Oil filter Cap

Oring with compression

Insufficient Sealing

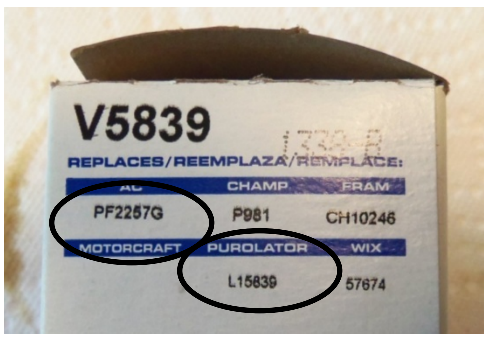
Leak Error Proofing Groove

Countermeasures to minimize

Remove Error Proofing Tab

O ring good for engine life, Do not replace at each oil change

Seal=Purolator, V5839



After Market Brands

Who Does Hengst Supply?

Material Analysis of O ring

Vehicle w. Leak

New Purolator

New AC

PE12-010

GM

6/22/2012

Q_07_8 Exterior

2011 belly pan change break point email

Fw: 10/21/2011 belly pan modification breakpoint at Lordstown, done before SOP on Verano

Mickey Sabol to: Mark Deacon 04/02/2012 12:00 PM

From: Mickey Sabol/US/GM/GMC
To: Mark Deacon/US/GM/GMC@GM

----- Forwarded by Mickey Sabol/US/GM/GMC on 04/02/2012 12:00 PM -----

(37)

10/21/2011 belly pan modification breakpoint at Lordstown, done before SOP on Verano

Jerry Hendler to: Carmen Benavides, Dale A. Furney, Paul S. Kelly, Mickey Sabol, Dwayne Davidson 03/23/2012 10:41 AM

10/21/2011 is the breakpoint date I have in my files for GMNA Cruze.

PE12-010

GM

6/22/2012

Q_07_8 Exterior

circuit breaker confirm 00-p

J300 Circuit breaker specification

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PE12-012

GM

6/22/2012

Q_07_9 HVAC

2012-01-0984

2012-01-0984
Published 04/16/2012

doi:10.4271/2012-01-0984
saematman.saejournals.org

Hot Surface Ignition and Fire Propagation Characteristics of R134a and R1234yf Refrigerants

Jon Olson
Superior Forensic Engineering, LLC

Steven Lambert
Ford Motor Company

ABSTRACT

This paper summarizes hot surface ignition characteristics of R134a and R1234yf automotive air conditioning fluids on typical under-hood automotive surfaces that possess sufficient heat to ignite flammable or combustible fluids. It further investigates the effect, if any, that these two different fluids may have on the propagation of a fire in two identically equipped vehicles under similar test conditions. This testing, in part, is in response to the United States Environmental Protection Agency's proposal which seeks comments concerning the proposed replacement of the current R134a air conditioning refrigerant with R1234yf

R134a is currently regarded as the global choice for automotive air conditioning systems however the EPA classifies it as an ozone depleting substance (ODS) and is tasked with proposing and reviewing alternatives that do not contribute to stratospheric ozone depletion. R1234yf refrigerant is classified as a non-ozone depleting gas by the EPA and has been proposed as an acceptable alternative to R134a through the authority of the Clean Air Act and the Significant New Alternatives Policy (SNAP) program. The SNAP program sets forth criteria for the implementation of R1234yf refrigerant and has indicated that the proposed alternative refrigerant does not have to be risk free to be found acceptable for use. European Union (EU) countries have developed Directive 2006/40/EC that mandates a 100-year CO_2 Global Warming Potential (GWP) of less than 150. R134a is nearly 10 times this level with a rating of 1430 GWP. R1234yf has a GWP rating of 4.0 or approximately 0.3% of the current R134a refrigerant [1].

Hot surface ignition testing of R134a and R1234yf mixtures with PAG 46 oil were evaluated in the first part of this paper. Typical under-hood automotive surfaces at maximum operating temperatures were established, along with a functional AC system to evaluate the ignition characteristics of the refrigerant and lubricant mixtures. Tightly controlled test parameters and conditions were utilized to minimize test to test variation. The results obtained in this testing were compared to the published auto ignition properties of the refrigerants and other automotive fluids. The second part of this paper assesses the potential effects that the changing from R134a to R1234yf may have on fire propagation in a motor vehicle.

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INTRODUCTION

Modern vehicle designs consist of a variety of different fluids and materials located throughout the vehicle, some of which are classified as flammable or combustible as defined by National Fire Protection Association Standard (NFPA) 921. Many of these fluids or materials are chosen because of the benefits they provide relative to safety, environmental, weight, and durability performance characteristics. In the unlikely event of a vehicle fire, some of these materials or fluids may contribute to the initiation and/or the propagation of fire within a vehicle. R134a and R1234yf refrigerants do not provide adequate lubrication for moving parts within the AC system and require PAG oil to be dispersed within the refrigerant. Pure R134a is classified as non-flammable [2] however when it is mixed with the compressor oil, the mixture may ignite in the presence of a competent ignition source. R1234yf has been classified by Honeywell as a flammable gas [3] and also requires the same type of compressor oil as R134a for automotive use. Modern vehicles that include R134a refrigerant and compressor oil have been deemed safe and do not represent an unreasonable risk to automotive safety.

Automotive manufacturers as well as the National Highway Traffic Safety Administration have promulgated standards that are intended to apply objective measures of vehicle safety as it relates to fires in motor vehicles. Federal Motor Vehicle Safety Standard (FMVSS) 301 specifies fuel spillage rates after a vehicle is subjected to impacts from the front, side, and rear as well as a post-test static roll procedure [4]. This standard does not apply to other fluids typically contained within motor vehicles. Additionally, burn rates of combustible materials within the passenger compartment of motor vehicles are regulated by FMVSS 302, Flammability of Interior Materials [5]. These standards state that their purpose is to reduce the death and injuries to motor vehicle occupants caused by vehicle fires.

Applying a burn rate standard similar to the FMVSS 302 standard at a vehicle level may prove impractical due to a number of considerations which include significant variations in overall vehicle design, mass, and architecture as well as variations of potential fuel loads from vehicle to vehicle. Any or all of these variables would most likely change the way a fire progresses through a vehicle. Other real world considerations such as the area of the fire's origin, wind and weather, or even vehicle orientation or condition at the time of the fire will also alter the rate of fire progression in a vehicle. This paper does not attempt to develop or specify an acceptable or reasonably safe rate of fire progression in a vehicle (similar to FMVSS 302). The intent is to compare the ignition and fire propagation characteristics of the two refrigerants in an identically equipped vehicle in order to provide an objective comparison in the rate of fire propagation between the two.

HOT SURFACE IGNITION TEST INTRODUCTION

The published auto ignition temperature (AIT) values for typical automotive fluids under various test conditions are widely discussed and reviewed with a number of technical papers and industry standards, including; LaPointe, Adams, Washington [6], Arndt, Stevens, Arndt [7], Santrock, Kononen [8], Colwell [9]. Research conducted in these papers reflects a wide variation of published auto ignition temperatures of these fluids based on test conditions. The AIT is defined by NFPA 921 as, “The lowest temperature at which a combustible material ignites in air without a spark or flame”. The upper and lower flammability limits (UFL and LFL respectively) are defined by NFPA 921 as, “The upper or lower concentration limit at a specified temperature and pressure of a flammable gas or vapor of an ignitable liquid and air, expressed as a percentage of fuel by volume that can be ignited [10]. Above the UFL, the mixture is too rich and below the LFL the mixture is too lean to support combustion. At a standard temperature of 21 ° C (70° F), the LFL is 6.2% and UFL is 12.3% for the R1234yf refrigerant [3]. Higher and lower temperatures can alter these percentages. Since R134a is nonflammable, these limits for ULF and LFL do not exist (see Table A for a comparison of other common under hood fluids).

Table A. Typical Under Hood Fluids Properties, Honeywell MSDS [2, 3, 11, 12], NFPA 921, 2008 Edition [10]

FLUID	LFL (%)	UFL%	Auto Ignition Temperature (°F)
$R134a_2$	NA	NA	>1369
$R1234yf_3$	6.2	12.3	761
$R152a_{11}$	3.7	18.0	851
$R32_{12}$	12.7	33.4	>1369
$Gasoline_{10}$	1.4	7.6	495 - 536
Washer $Fluid_{10}$	6.0	36.0	867 - 903
Diesel $Fuel_{10}$	0.4	7.0	489 - 500
Trans $Fluid_{10}$	1.0	7.0	626 - 716
$P/Steering_{10}$	0.9	7.0	680 - 720
Brake $Fluid_{10}$	NA	NA	210 - 550
Motor Oil_{10}	1.0	7.0	644 - 680

HOT SURFACE IGNITION TEST METHODOLGY OVERVIEW

The next section of this paper focuses on hot surface ignition properties of R134a and R1234yf refrigerants on typical exhaust system surfaces and includes a description of the testing methodology for the vehicle buck and the A/C system bench stand. This testing methodology varies from joint research previously conducted by Marc Spatz (Honeywell) and Barbara Minor (DuPont) which studied the auto-ignition properties of various refrigerants, including R1234yf, and was presented the SAE World Congress in 2008 [13]. The research described in that study documented auto-ignition properties of R1234yf both with and without PAG oil in a laboratory environment. The test methodology described in this paper reflects conditions that are more representative of the refrigerant/oil mixtures and under hood environments in a typical automobile.

There were two main test apparatus for this testing. The first was the vehicle buck that the refrigerant mixture was released onto (shown in Figure A). The second was the operational A/C system bench stand that released the refrigerant, (shown in Figure F) with the appropriate volume, orientation, and condition of AC refrigerant/PAG 46 oil mixture in a typical automobile.

The control variables for this testing were the R134a and R1234yf refrigerants and the under hood exhaust system surface temperatures. Prior to the start of the testing, a number of safety precautions were developed and incorporated during the testing process. These precautions were incorporated to provide the maximum level of safety for on-site personnel as well as the test facility and equipment. They did not influence the results of the testing.

VEHICLE TEST BUCK

For the purpose of this testing, a 2011 Ford Taurus SHO with a 3.5L, 24V, V6 EcoBoost™ engine was used. Prior to this test, this fully functional vehicle had accumulated approximately 14,000 miles. All under hood fluids were drained and removed prior to the test. The under hood appearance and arrangement of components were kept intact with the exception of a 25 mm by 35 mm nozzle that was added for fire suppression capabilities. A heat input manifold was installed to the exhaust manifold that facilitated the introduction of heat to the vehicle's exhaust system. Finally, thermocouples were added at various under hood locations to record test temperatures. A photo of this test buck is shown in Figure A.

Figure A. Exterior of 2011 Ford Taurus SHO Vehicle Buck

Twelve thermocouples were welded to various locations in the immediate area from the exhaust manifold to the start of the exhaust down tube pipe of the Taurus SHO. The locations of these thermocouples were selected due to their relative proximity to the A/C system and because they represent some of the highest temperatures observed during Ford's thermal testing of the Taurus SHO. The thermocouple locations are described as follows:

1. Exhaust manifold flange
2. Heat tube near torch rosebud at collector
3. Manifold tube
4. Bottom of light off catalytic
5. Top of light off catalytic
6. Exhaust manifold
7. Exhaust turbo body
8. Turbo left front
9. Turbo outlet
10. Turbo inlet flange
11. Turbo bottom
12. Turbo piping connector

Figure B depicts a number of thermocouple locations with the heat shield removed for clarity. Figure C depicts the test condition with the heat shield reattached. The large red arrows shown in Figures B and C indicate the direction of the refrigerant mixture being discharged on the hot exhaust system. The A/C line and portions of the exhaust system can be seen near the engine oil filter. The direction and location of the simulated leak near the exhaust system was selected because it represented the highest potential of ignition of the released refrigerant/PAG oil mixture.

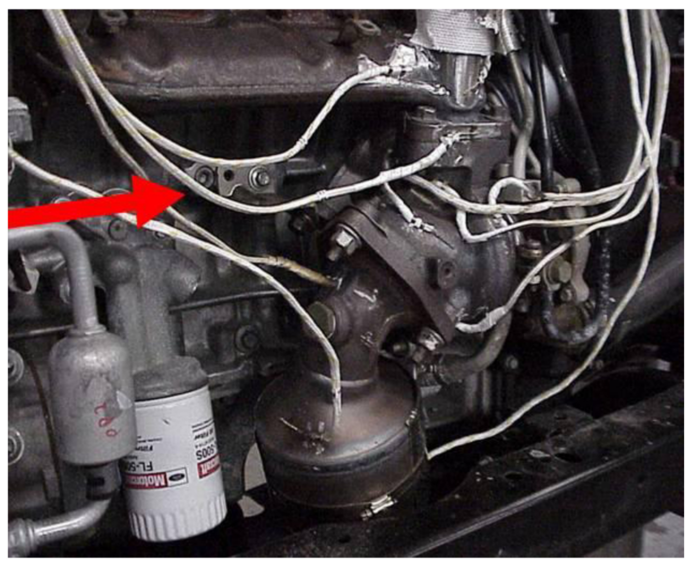

Figure B. Thermocouples (Heat Shield Removed)

Once the thermocouples were installed, the production heat shield was reinstalled over the exhaust system. The thermocouple wires were routed in a manner so that they did not block the surface of the exhaust system from the refrigerant being dispersed. Figure C shows the production exhaust manifold shield reinstalled.

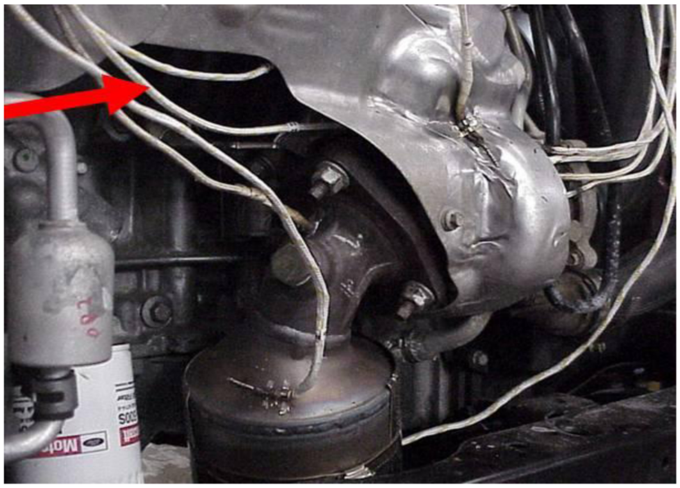

Figure C. Test Condition (Heat Shield Reinstalled)

Because the engine in the test buck was not capable of running, an alternative method of introducing heat into the engine's exhaust system was developed. This method allowed precise control of the exhaust system surface temperatures while maintaining the integrity of the exhaust system surfaces. The gas chosen to heat the vehicle's exhaust system was HGX mixed with oxygen. The gas was delivered through a torch that was inserted into the front exhaust system manifold (see Figure D). The flame was not exposed to the outside of the exhaust system and the cap prevented refrigerant from entering into the exhaust system.

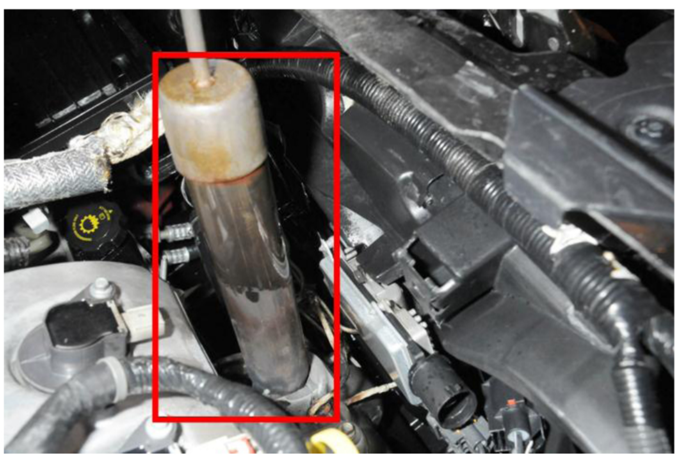

Figure D. Heat Tube and Top Cap.

The heat that was introduced into test buck's exhaust system was allowed to move through the system. Figure E reflects the routing of the exhaust system underneath the front passenger compartment of the buck and illustrates the point at which heat exited the system.

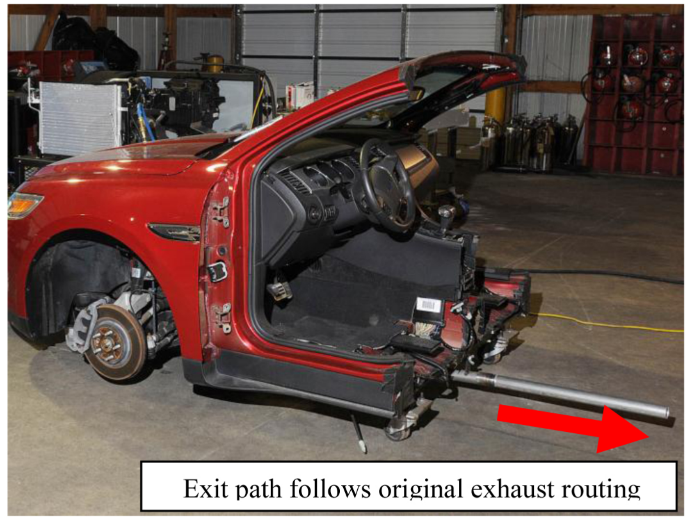

Figure E. Exit Path for Heated Exhaust

The maximum temperatures selected for this test were determined from internal heat management data from Ford. The intent of the heat management test is to verify that under severe operating conditions, the level of heat generated will not exceed the capabilities of materials in and around the exhaust system. The highest surface temperatures reflected in this test represent the maximum temperatures recorded during heat management testing at Ford Motor Company and do not represent typical operating surface temperatures of exhaust systems. Actual exhaust system surface temperatures can vary depending on a number of factors including, engine size, drive cycle, condition of the vehicle, ambient temperatures, etc. Lower exhaust system surface temperatures of several different vehicles under typical drive cycles were documented in research conducted by Engle, Olson, and Sharma and reflect significantly lower temperatures than those documented in this testing [14].

A/C BENCH SYSTEM

A system bench stand was constructed that included the major components in an automotive air conditioning system. These components include the compressor, condenser, evaporator, and the A/C lines (see Figure F). This stand enabled the refrigerant to be released into the engine compartment of the buck in a volume and state that would simulate a release of the onboard refrigerant. Figure F reflects the A/C system components constructed for this test.

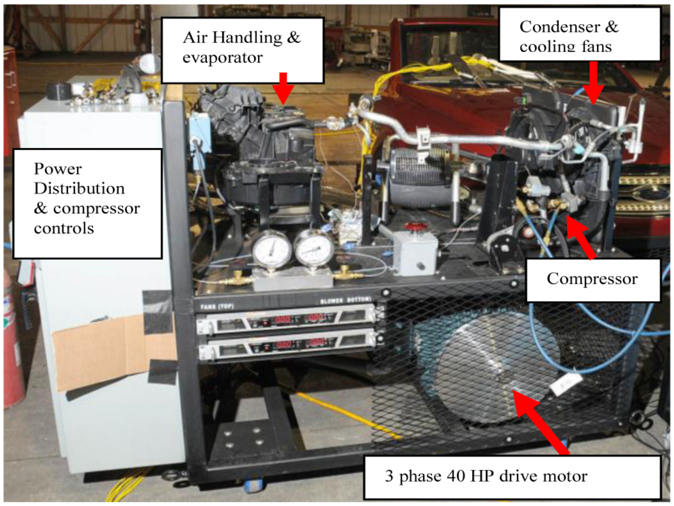

Figure F. Identification of A/C Test Stand Components

The A/C lines can be broken down into 3 categories that transport refrigerant. The discharge line connects the compressor and condenser. It carries a high pressure and high temperature refrigerant mixture that is in a pure vapor form. This temperature is typically 257° F at 325 psi. The liquid line connects the condenser and evaporator. It carries a high pressure and high temperature pure liquid refrigerant. The third A/C line system is the suction line. It completes the loop back to the compressor from the evaporator. The suction line is a low pressure and low temperature refrigerant mixture in vapor form. For this experiment, the hottest temperature that could be released from an A/C system was selected to minimize the quenching of the refrigerant on the hot exhaust in order to create the highest probability of ignition. The "leak" location on the discharge line was chosen since this is typically the closest to the exhaust as seen in Figure B.

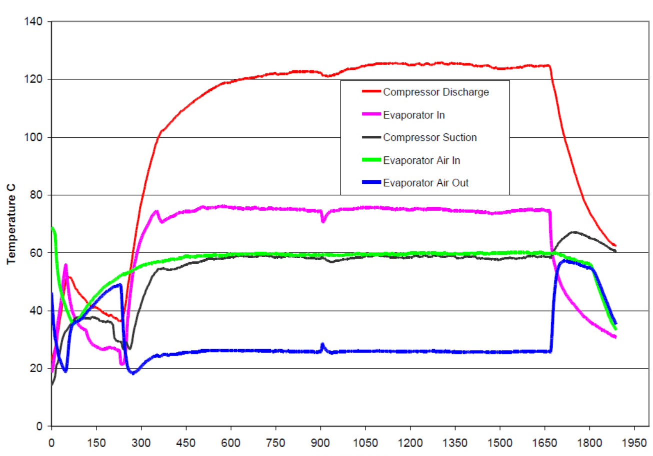

Figure G. A/C System Operation during Testing

Figure G is a graph depicting the temperatures of the AC refrigerant in different stages. The red line represents the A/C compressor discharge temperature of 124.7° C (256.5° F). The pink line represents the temperature at the inlet to the evaporator at the thermo expansion valve at 74.1° C (165.4° F). The heated air entering the evaporator was 60° C (140° F) and is shown in bright green and is intended to produce a high load on the A/C system. The compressor suction gas is shown in black and was 58.5° C (137.3° F), indicating a large thermal load on the A/C system. The blue line reflects the cooled air coming off the evaporator at 26° C (79° F). The following describes the operating cycle of the A/C stand for each test:

1. 0 - 250 seconds; system is off and being prepared to be turned on

2. 250 - 1700 seconds; system is engaged and running at maximum load, Time 250 to 1700 seconds

3. 1700 seconds; simulated leak of refrigerant occurs with sudden loss of pressure and the release of A/C refrigerant and PAG oil

The instrumentation used on the system stand during the testing for air temperatures was:

1. Ambient
2. Evaporator Inlet (heated air)
3. Evaporator Outlet (cooled air)
4. Compressor Discharge
5. TXV/Evaporator Inlet
6. Compressor Suction

There were three pressure ports on the system:

1. Compressor Suction
2. Compressor Discharge
3. Low Charge Protection System (set to 40 psi)

The compressor discharge pressure was adjusted by the bench stand cooling fans to maintain a maximum pressure of 375-385 psi in the system. The low charge protection system was very similar to one used in Ford vehicles to prevent the system from operating with low levels of refrigerant and causing catastrophic damage to the compressor.

REFRIGERANT IGNITION TEST PROCEDURE

The A/C test stand was charged with the appropriate amount and type of refrigerant and common PAG oil and was cycled per the description noted above. Multiple cameras were positioned at various locations within the engine compartment and at external locations. Data acquisition devices recorded data every 2 seconds. Heat was applied and when the desired test temperature was reached, the heat was very quickly turned off and the steel cap was placed on the heat tube. The refrigerant was released and the actual released temperature was recorded and documented.

There were 3 possible outcomes from each testing sequence; 1) No ignition, 2) PAG oil ignition only, 3) Refrigerant and PAG oil ignition. Cameras located within the engine compartment were utilized to document ignition characteristics and location. The PAG oil ignition was observed to be smaller, orange in flame color, and appeared to burn on the hot surface. The R1234yf refrigerant ignition was a larger flame pattern, wispy or weak in appearance, blue-green flame color, and dissipated quickly. In some cases where the R1234yf refrigerant did ignite it was theorized the burning PAG oil may have contributed to a secondary ignition source of the refrigerant. In either case the refrigerant did ignite and it was categorized as such.

Figure H. Completed Test Setup

Figure H shows the A/C bench stand and the vehicle buck. Heat was introduced into the engine's exhaust system and when the exhaust system surface reaches the intended test temperature the refrigerant and oil mixture was released. For each test, the A/C test stand system was charged with 150 grams of PAG 46 oil and 590 grams of refrigerant. These quantities represent typical refrigerant and PAG oil loads in automotive air conditioning systems. A simulated leak represented an A/C system failure that allowed the release of the refrigerant and oil mixture. The diameter of the simulated refrigerant leak point was the same as the discharge line in the A/C system. The released refrigerant will follow the path of least resistance with the vast majority existing at this simulated leak.

At the conclusion of each test sequence, the entire engine compartment of the buck was thoroughly cleaned and returned to its pre-test condition in order to eliminate the potential that any remaining PAG oil and/or fire suppressant from previous tests contaminating the exhaust system surfaces. The A/C system test stand was flushed to remove any remaining PAG oil from the system test stand. This flushing occurred overnight and completely removed any remaining oil. The compressor after each test run was removed, heated and drained overnight. The following day it was filled with the specified volume of oil. The process ensured the correct amount of PAG 46 oil in the system from test to test.

REFRIGERANT IGNITION TEST RESULTS

R134a

The criteria used to establish ignition or no ignition was to document the result at least 3 times at each test temperature. The results of this testing are shown graphically in Figure I.

No ignition occurred at the following surface temperatures:

- 810° C (1490° F)
- 833° C (1531° F)
- 840° C (1544° F)

PAG oil mixed with R134a refrigerant ignition occurred at the following surface temperatures:

- 837° C (1539° F)
- 874° C (1605° F)
- 884° C (1623° F)
- 892° C (1638° F)
- 915° C (1679° F)
- 932° C (1710° F)

When ignition occurred, the area of ignition was observed to be the exhaust system containing the heat shield shown in Figure C. The refrigerant ignition never occurred during any of the R134a testing. Data from this testing indicates that the transition from no ignition to PAG oil ignition mixed with the R134a refrigerant occurred between 837°C and 840° C (1539°- 1544° F).

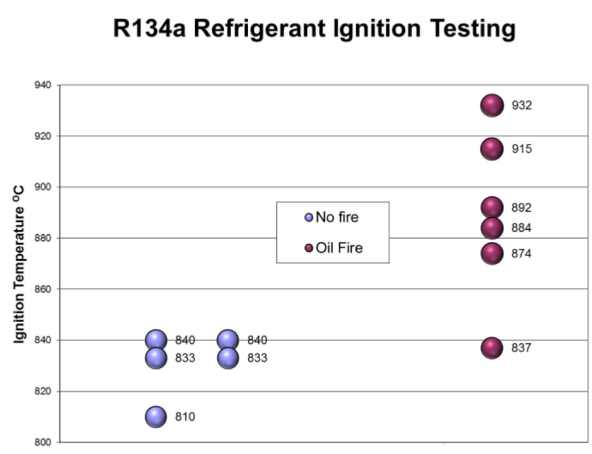

Figure I. R134a Testing Results

R1234yf

Similar to the R134a testing, each classification of fire or no fire was documented 3 times at each temperature. The R1234yf results are shown graphically in Figure J.

There was no ignition of PAG oil or refrigerant at the following surface temperatures:

- 813° C (1495° F)
- 815° C (1499° F)
- 840° C (1544° F)
- 886° C (1627° F)

PAG oil ignition (without refrigerant ignition) occurred at the following surface temperatures:

- 845° C (1553° F)
- 853° C (1567° F)
- 890° C (1634° F)
- 913° C (1675° F)

The PAG oil and R1234yf refrigerant mixture ignition occurred at the following surface temperatures:

- 847° C (1557° F)
- 863° C (1585° F)
- 881° C (1618° F)
- 891° C (1636° F)
- 906° C (1663° F)
- 913° C (1675° F)
- 925° C (1697° F)
- 930° C (1706° F)

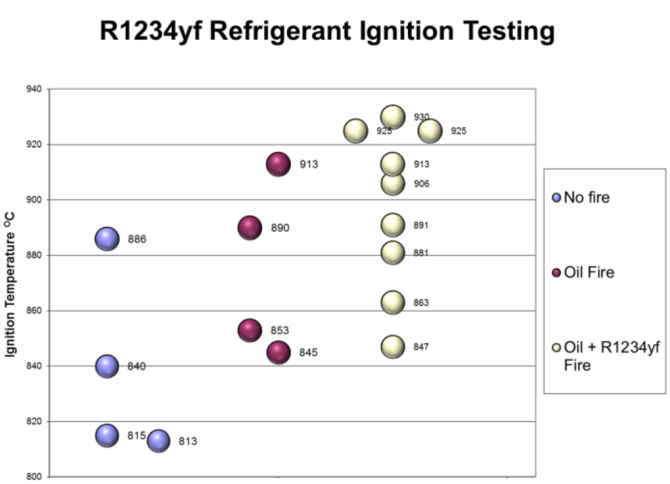

Figure J. R1234yf Testing Results

The results from the R1234yf testing show a large overlap between the 3 possible outcomes (no ignition, PAG oil ignition only, PAG oil and refrigerant ignition). This occurred from approximately 840° C (1544° F) up to approximately 890° C (1634° F). Ignition of the PAG oil, regardless of the refrigerant, occurred at approximately 840° C (1544° F) indicating that the type of refrigerant appears to not influence the likelihood of ignition of the PAG oil during this test. The hot surface ignition data collected in the testing described above represents a limited number of tests and describes the outcome at the temperatures noted. Additional tests at fixed temperatures would be required in order to establish a statistical probability of ignition at each temperature and would likely be the topic of future publications.

The results of auto-ignition testing conducted by Spatz/Minor study showed hot plate ignition of R1234yf was not achieved until temperatures exceeded 900° C (1652° F) but only with the presence of PAG oil. The research described by Spatz/Minor also indicated that they could not ignite the R1234yf refrigerant without the presence of PAG oil [14].

VEHICLE FIRE PROPAGATION TESTING

After documenting hot surface ignition properties and characteristics of both the R134a and R1234yf refrigerant/PAG oil mixtures, the next step in the analysis was to consider the impact, if any, the added fuel load associated with the R1234yf would have on the rate of fire propagation in the Ford Fiesta. The Ford Fiesta was selected because of its size, providing what is felt to be a worst-case ratio of potential fuel load to vehicle mass and geometry.

For this demonstration, two virtually identical 2011 Ford Fiestas were used. The test vehicles consisted of the same body style, powertrain, and option content. The vehicles were placed at the same orientation and were tested within hours on the same day to minimize the effects that changing wind and weather would have on the burn testing. The fluid levels for each vehicle were equalized so that potentially available fuel loads were common between the two vehicles. The one dissimilarity was the refrigerant for the HVAC system. Vehicle #1 contained the R134a refrigerant while vehicle #2 was purged of the R134a and was replaced by R1234yf refrigerant.

Figure K. Vehicle #1, 2011 Ford Fiesta w/R134a Refrigerant

Figure L. Vehicle #2, 2011 Ford Fiesta w/R1234yf Refrigerant

Prior to the tests, each vehicle was similarly equipped with nine thermocouples throughout the engine and passenger compartments of each vehicle. The purpose of these thermocouples was to document the temperature as a function of elapsed time in order to assess the rate at which heat and fire propagates from the vehicle's engine compartment to the passenger compartment. The temperature vs. time data was recorded and plotted at specific areas of the vehicle and was obtained with the use of a Yokagawa MV200 data logger. The sampling rate was set at one sample every 2 seconds. Video cameras captured views of each vehicle from the left front and the left rear. After the test, data was downloaded to an Excel spreadsheet and where it was converted into graphical plots depicting temperature (°F - vertical axis) and time (seconds - horizontal axis). Each vehicle was also equipped with a pressure sensor for the HVAC system so that a drop in pressure would be detected once the system was compromised by fire.

The nine thermocouple locations per vehicle are described in Table B:

Table B. Thermocouple Locations

Location Description	T/C #
Steering Wheel	1
Centered, Near Dome Light	2
Right Front Passenger Foot Well	3
Left Rear Engine Compartment	4
Left Front Engine Compartment	5
Right Front Engine Compartment	6
Right Midpoint Engine Compartment	7
Right Rear Engine Compartment	8
Center Rear Engine Compartment	9

Overall photos depicting these locations are shown in Figures M, N, O, P (similar for both vehicles).

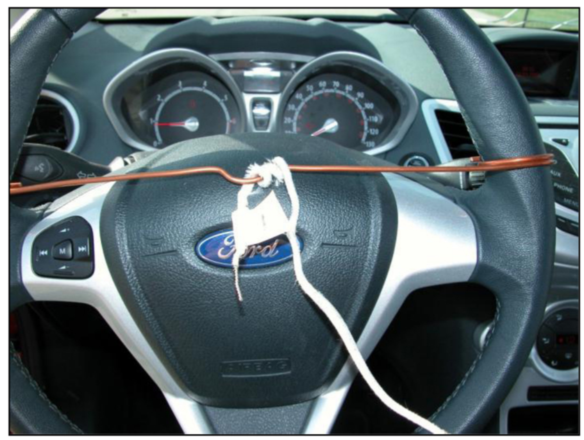

Figure M. Thermocouple 1 at Steering Wheel

Figure N. Thermocouple 2 Centered, Near Dome Light

Figure O. Thermocouple 3 in Passenger Foot Well

Figure P. Thermocouples 4 - 9 at Various Engine Compartment Locations

Prior to the initiation of the fire, the vehicle was started and allowed to idle for one minute with the manual transmission in neutral and the parking brake applied. The HVAC fan was turned to its highest setting while the temperature setting, with the air conditioning system in the “On” position, was turned to its lowest setting. All side glass windows were up and all doors were closed. Leaking fuel was created for the purpose of this test by drilling a 1/8th inch diameter hole in the fuel delivery line which resulted in a steady spillage of gasoline. The continuous flow of leaking gasoline created for this test is not representative of a vehicle that has been turned off or has been in a collision severe enough to deactivate fuel delivery. The intent was to provide a steady source fuel to ensure fire propagation would occur as well as to establish whether or not a competent ignition source existed within the engine compartment while the vehicle was running to ignite the gasoline vapors. If ignition did not occur after one minute, the initiation of the fire in each vehicle was achieved via a remotely activated pyrotechnic device located within the engine compartment. Both vehicles were aligned in a northerly direction with winds out of the southwest at approximately 7 - 12 mph. The ambient temperature at the time of the testing was approximately 72° F.

After one minute of engine idle and with fuel leaking in sufficient quantity to begin pooling beneath the vehicle, no ignition of gasoline occurred in either vehicle. At this point in the test the remote pyrotechnic device was activated which resulted in the immediate ignition of the spilled gasoline. Secondary combustibles within the engine compartment also became involved soon after the start of the fire. The engine, which had been running when the fire began, stalled shortly thereafter. The fires were allowed to propagate through the vehicles' architectures until they fully breached the passenger compartments of each vehicle while temperature and pressure data were being recorded. The fires in both vehicles were extinguished by fire service personnel. Still photos and video captured the event during both vehicle burns.

Figure Q is a photo of the Fiesta equipped with R134a refrigerant approximately 6 minutes after the initiation of the fire within the engine compartment.

Figure Q. 2011 Fiesta with R134a Refrigerant

Figure R is a photo of the Fiesta equipped with R1234YF refrigerant also taken approximately 6 minutes after the initiation of the fire in the same location.

Figure R. Fiesta with R1234yf Refrigerant

R134A VEHICLE FIRE PROPAGATION OBSERVATIONS

Temperature measurements within the engine compartment of both vehicles immediately show an increase in temperatures once the fire started while the temperatures within the passenger compartment remained at ambient temperatures during the early stages of the fire. Temperature measurements near the area of the fire's origin (left rear of engine compartment) reached 1000° F in approximately 20 seconds. A maximum temperature of 1737° F was recorded within the engine compartment and occurred at thermocouple #6 (right front engine compartment) after approximately 9 minutes of fire propagation. Temperature measurements within the passenger compartment remained below 100° F at all three interior thermocouple locations through the first 2½ minutes of the fire. Temperature measurements at the dome light (thermocouple #2) were the first within the passenger compartment to exceed 100° F. The highest temperature recorded within the passenger compartment was 702° F and occurred approximately 5½ minutes after the initiation of the fire.

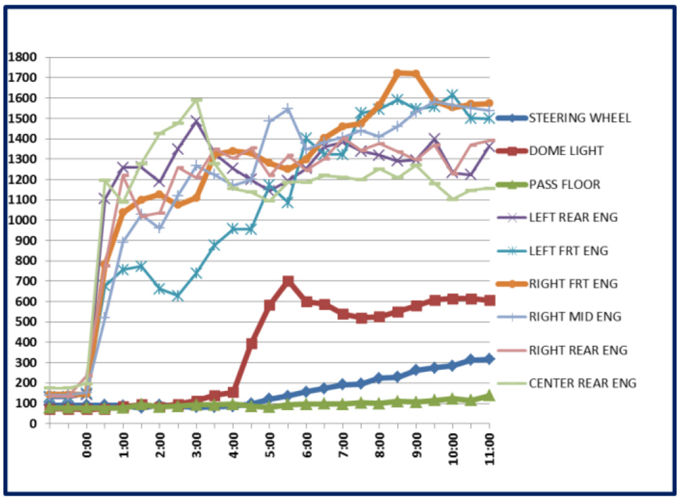

Figure S. R134a Temperature v. Time Plot (F° on the vertical axis; Time in minutes on the horizontal axis)

R1234YF VEHICLE FIRE PROPAGATION OBSERVATIONS

There were variations in the temperature measurements versus time of the vehicle containing the R1234yf refrigerant compared to the R134a vehicle. It took approximately 56 seconds for the fire's area of origin (left rear of engine compartment) to reach 1000° F. compared to the R134a vehicle taking 20 seconds. A maximum temperature of 1562° F was recorded within the engine compartment and occurred at thermocouple #6 (right front engine compartment) after approximately 6 minutes of fire propagation. This was 175° F less than the R134a vehicle but at the same location. Temperature measurements within the passenger compartment remained below 100° F through the first 3 minutes of the fire which was approximately 30 seconds longer than the R134a vehicle. Similar to the R134a test, the temperature measured at the dome light (thermocouple #2) was the first within the passenger compartment to exceed 100° F. The highest temperature recorded within the passenger compartment was 1016° F and occurred approximately 6 minutes after the initiation of the fire. This measurement was nearly 400° F higher than the maximum interior temperature recorded for the R134a vehicle.

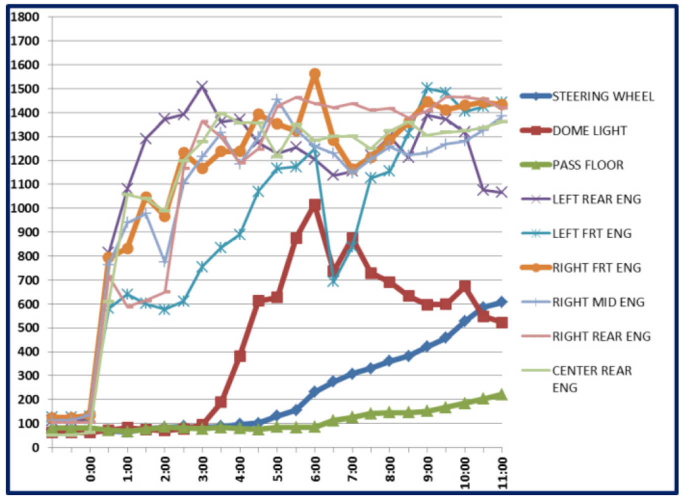

Figure T. R1234yf Temperature v. Time Plot (F° on the vertical axis; Time in minutes on the horizontal axis)

Pressure transducers installed on the high side pressure line of the HVAC systems were monitored during the fire for the purpose of measuring a drop in pressure that would coincide with a compromise in the polymer hoses of the HVAC system. The R134a transducer detected a pressure drop approximately one minute into the fire while the R1234yf detected a pressure drop approximately 1 minute, 40 seconds into the fire. Although it is not reflected in the thermocouple temperature data, the drop in AC system pressure and the rapid release of the R1234yf refrigerant coincided with a noticeably significantly increase in the amount of visible flame in and around the engine compartment of the Ford Fiesta. This increase lasted only a few seconds and the observable flame and smoke returned to the levels observed prior to the release of the R1234yf refrigerant.

CONCLUSIONS

Automotive engineers are tasked with balancing a variety of vehicle design and performance attributes that span a broad spectrum of needs and wants. These attributes are defined by the customers who purchase their products as well as industry, corporate, and regulatory standards. When considering the change in refrigerant for the vehicle's air conditioning system from R134a to R1234yf, an automotive engineer considers the intended design function of the new refrigerant as well as the effects that the unintended release of the refrigerant may create. This paper focused on the potential effects that a breach in the vehicle's air conditioning system containing R134a and R1234yf refrigerants may have from a fire perspective. The underlying test methodology for this research was to develop test conditions that are more representative of a real world automotive environment when compared to a laboratory environment. The test conditions defined throughout this paper were not intended to represent every possible scenario involving the release of A/C refrigerant, however considerations that included the highest probability of ignition and fire propagation within the scope of this research were incorporated.

The authors of this paper studied two different scenarios; 1) the ignition characteristics of R1234yf refrigerant on hot surfaces of an engine compartment; 2) the effects that R1234yf refrigerant may have on the rate at which a fire will propagate through a vehicle. In both test scenarios, the ignition and fire characteristics of the proposed R1234yf refrigerant was compared to the current R134a refrigerant. As anticipated, the observed hot surface ignition temperature of R1234yf in this testing was higher than the published laboratory auto ignition temperature. The published AIT of R1234yf at 405° C (761° F) is less than half of the lowest ignition temperature of 837° C (1539° F) observed during this test. The collaborative research conducted by Honeywell/ DuPont with R1234yf reflected similar hot surface ignition temperatures of approximately 900° C (1652° F) observed within this research but only with the presence of PAG oil. As discussed earlier, the methodology in this paper varied from the Honeywell/DuPont study which may account for the relatively small observed variation in ignition temperatures of R1234yf.

The temperatures necessary to ignite the R1234yf as well as the PAG oil present in both refrigerants during this test are not typically present during a vast majority of driving conditions. Given the relatively high temperatures necessary to ignite the R1234yf refrigerant and PAG oil, the likelihood of hot surface ignition under the vast majority of driving conditions is less than other existing under hood automotive fluids.

Although R134a is classified as nonflammable, the PAG oil present in the current R134a refrigerant mixture did ignite on the surface of the exhaust system at certain temperatures. The PAG oil in the R1234yf refrigerant exhibited similar ignition temperatures indicating that the two refrigerants tested did not influence the ignition characteristics of the PAG oil. Portions of the Honeywell/DuPont testing described in this paper included testing without PAG oil and would not represent real world usage conditions since the lubrication oil is required for automotive applications.

The exhaust system shield shown in Figure C appeared to trap the PAG oil vapors and increased the likelihood of ignition at this location. This is likely due to the fact that heat shields are generally not designed to prevent spilled fluids from contacting the exhaust system surface. As a result, vapors may remain in closer contact to the exhaust system surfaces thus increasing the likelihood of ignition. Furthermore, surface temperatures beneath the shield tend to be more insulated from convective cooling and tend to remain elevated for a longer period of time once the heat source is removed and convective cooling begins on the exhaust system surfaces.

Fire propagation through a vehicle that contains a very complex set of combustible fluids and materials is highly variable, even when attempts to minimize these variables are considered. Environmental and/or the condition of the vehicle at the time of the fire can have a significant impact on fire propagation. While it has been established that R1234yf refrigerant will ignite and rapidly burn under certain circumstances, the fuel load that this refrigerant adds to a vehicle is relatively small in comparison to the existing fuel load of a modern automobile. This was clearly observed at 1 minute and 40 seconds into the burn of the R1234yf vehicle when there was a visible increase in the amount of flames that lasted only a very short duration. The vehicle containing the R134a did not exhibit that same behavior when its A/C system was compromised from the fire.

Temperature data that shows passenger compartment temperatures began to elevate approximately 2 ½ minutes after the initiation of the fire in the vehicle containing non-flammable R134a. The same temperature increase was observed at approximately the 3 minute mark of the vehicle containing the flammable R1234yf refrigerant. Based on the results from the fire propagation testing, it appears the addition of the flammable R1234yf refrigerant has a negligible effect to the propagation of a fire within a vehicle when compared to other variables that affect fire propagation.

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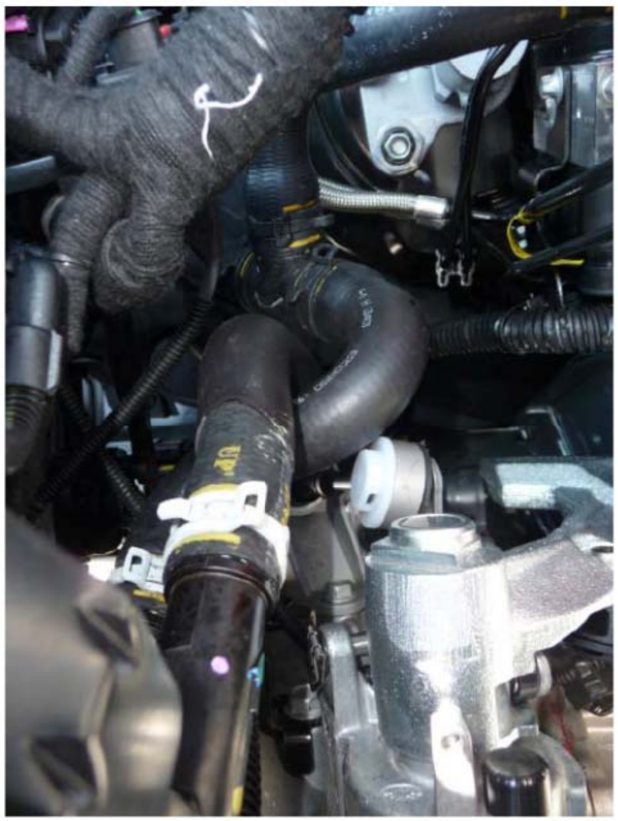

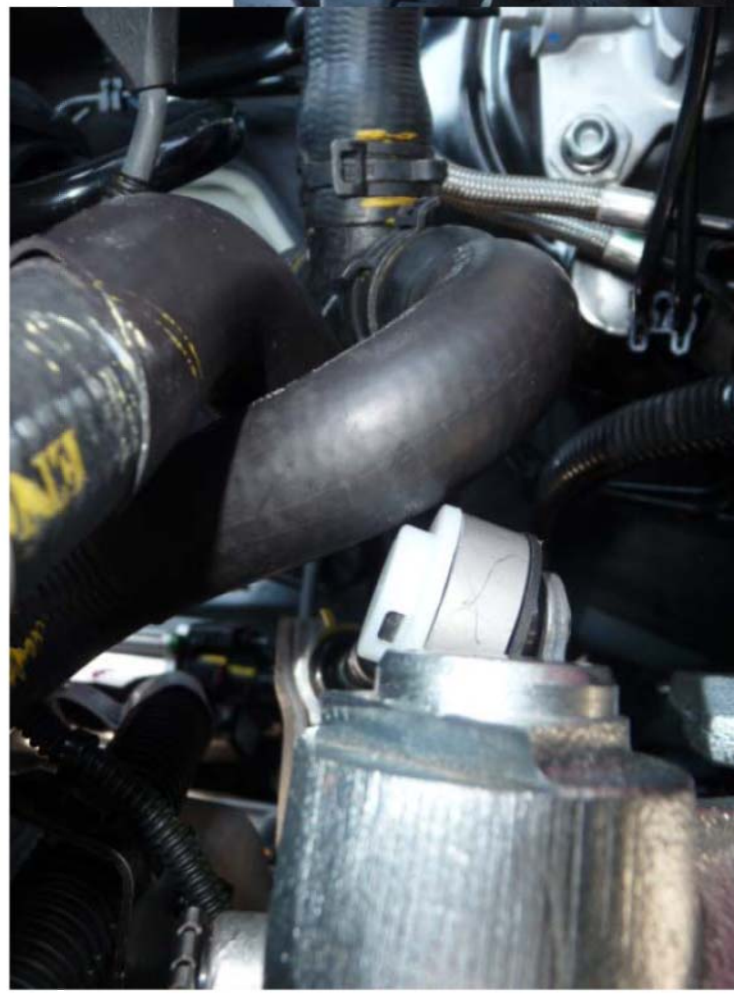

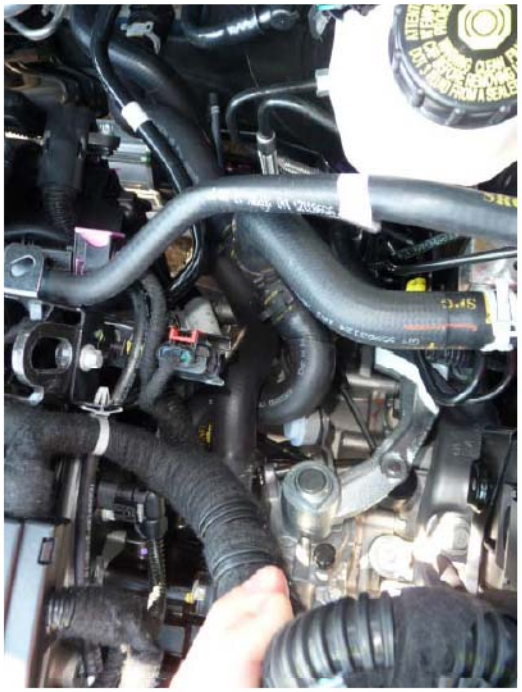


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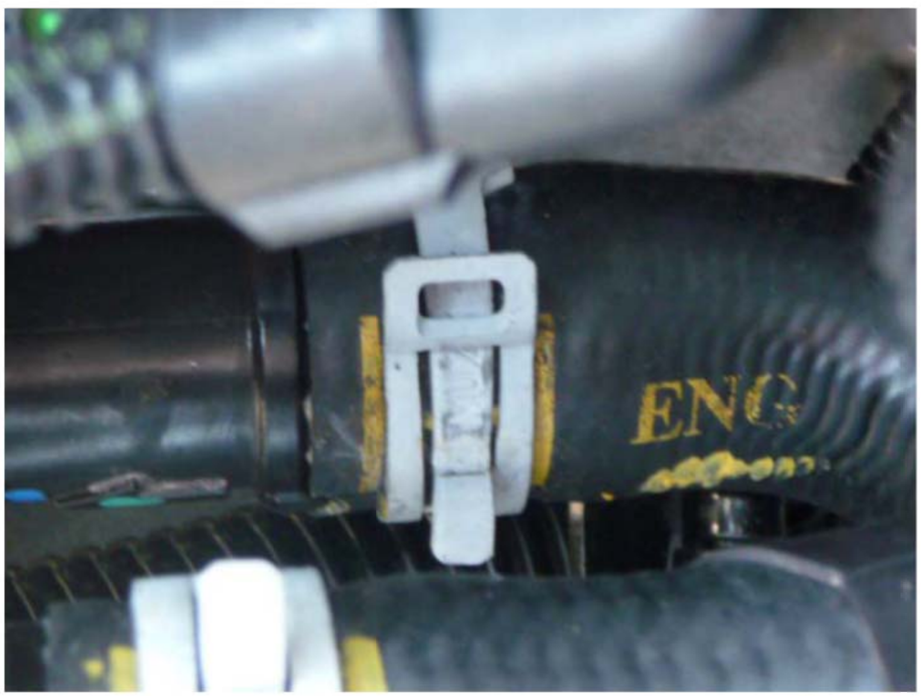
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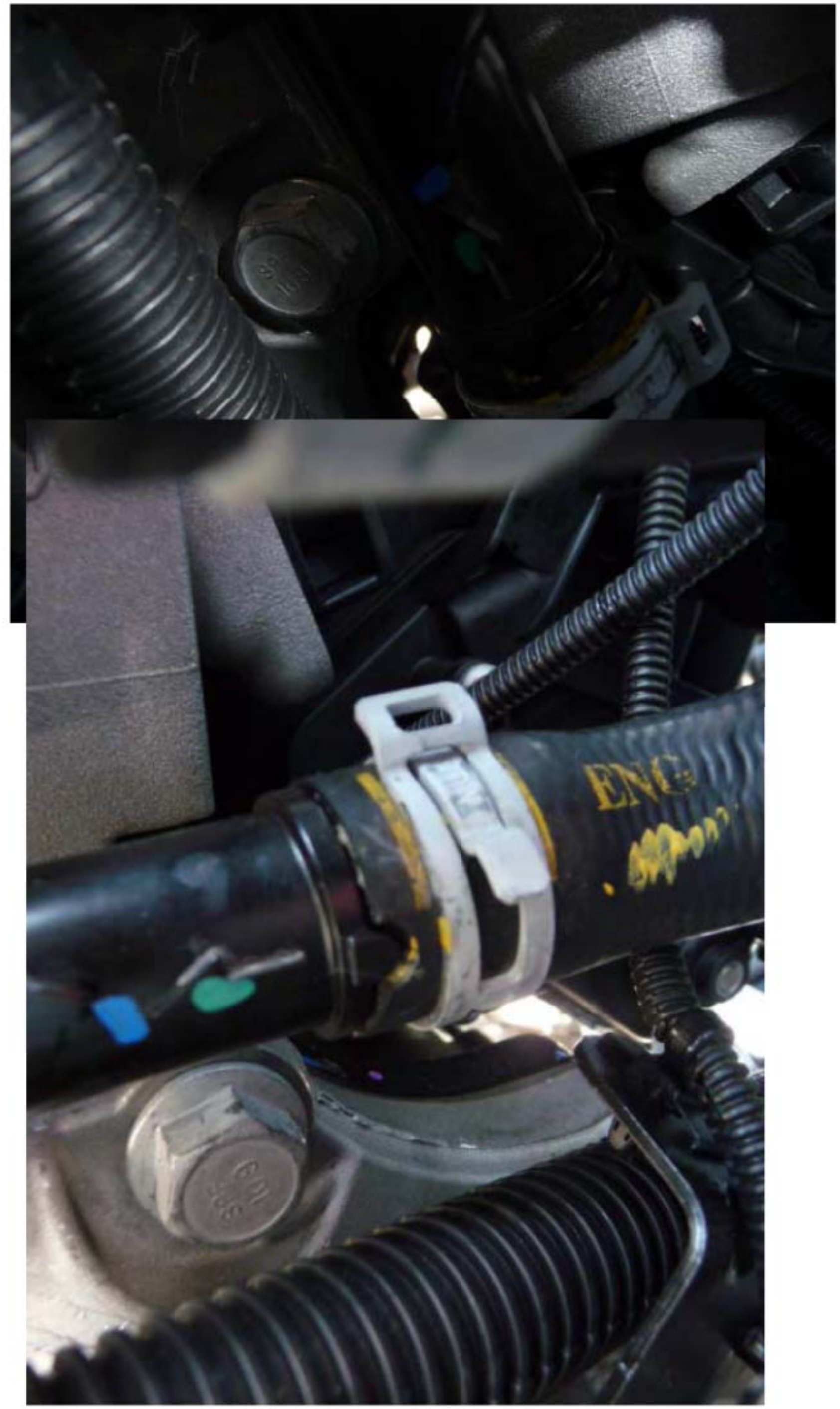
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cooling fan connector environment

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Q_07_9 HVAC

HVAC Cruze sharepoint summary 4-20-2012-p

SMT (30 – HVAC/PT Cooling)

		Total Open	Total Closed
TOTAL NUMBER OF Verbatims	58	27	31
Number of IR related Verbatims	**40**	**14**	**26**
Condenser Leak	10	0	10
Pressure Switch / Sensor	6	6	0
Unknown Smoke or Burn Smell	7	0	7
Cooling Fan	6	6	0
A/C System Restriction	4	0	4
Radiator Hose Routing	2	0	2
Transmission Oil Cooler Line	2	2	0
Aftermarket Parts	1	0	1
Coolant Cap Not Fully Secure	1	0	1
Coolant Leak at Reservoir	1	0	1

SMT (30 – HVAC/PT Cooling)

		Total Open	Total Closed
Number of Non-IR related Verbatims	18	13	5
Blower Motor Control Module	13	13	0
Heater Core Leak	3	0	3
Blower Motor	1	0	1
Drain Hose Plugged	1	0	1

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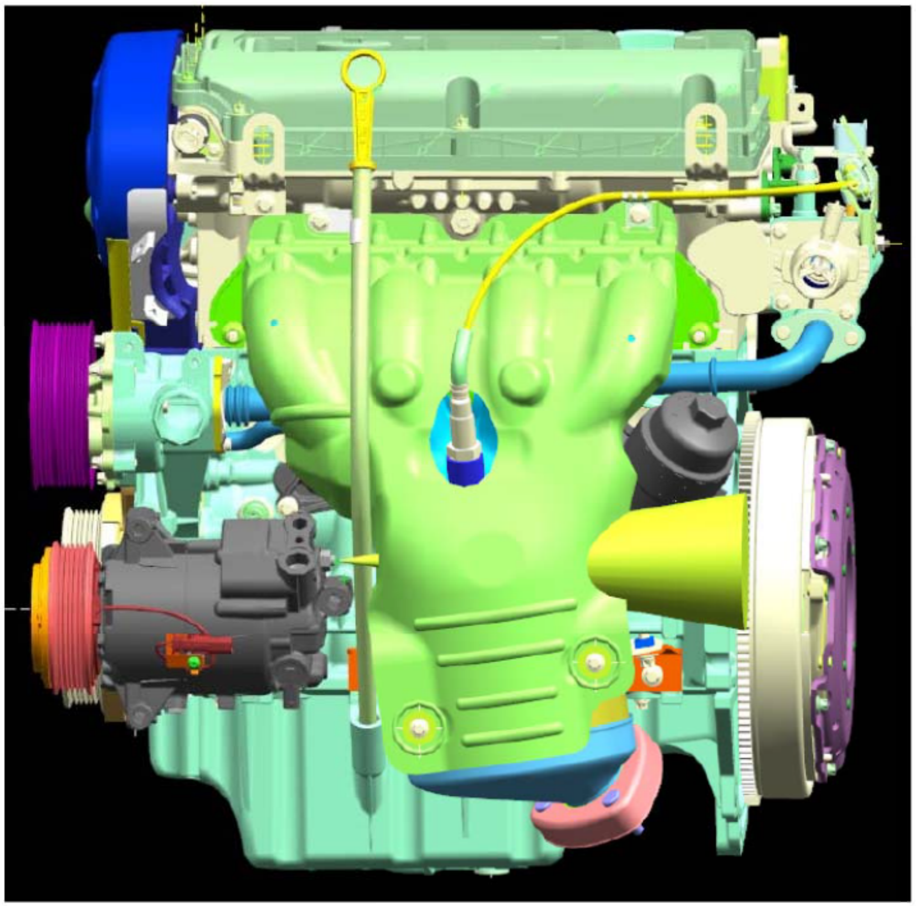
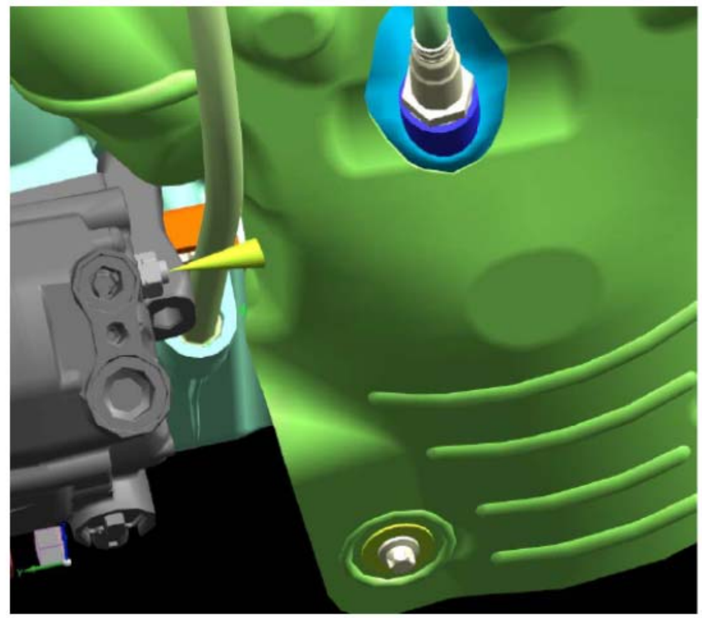
Backup

CRUZE -13335254 on LUW/LWE ENVIRONMENT-



HPRV DISCHARGE OVER CATALYTIC CONVERTER HEAT SHIELD (HOT SURFACE)



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Follow up questions

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HVAC Cruze sharepoint summary 4-25-2012-p

SMT (30 – HVAC/PT Cooling)

		Total Open	Total Closed
TOTAL NUMBER OF Verbatims	56	0	56
Number of IR related Verbatims	**38**	**0**	**38**
Condenser Leak	10	0	10
Pressure Switch / Sensor	6	0	6
Unknown Smoke or Burn Smell	7	0	7
Cooling Fan	6	0	6
A/C System Restriction	4	0	4
Radiator Hose Routing	2	0	2
Aftermarket Parts	1	0	1
Coolant Cap Not Fully Secure	1	0	1
Coolant Leak at Reservoir	1	0	1

SMT (30 – HVAC/PT Cooling)

		Total Open	Total Closed
Number of Non-IR related Verbatims	18	0	18
Blower Motor Control Module	13	0	13
Heater Core Leak	3	0	3
Blower Motor	1	0	1
Drain Hose Plugged	1	0	1

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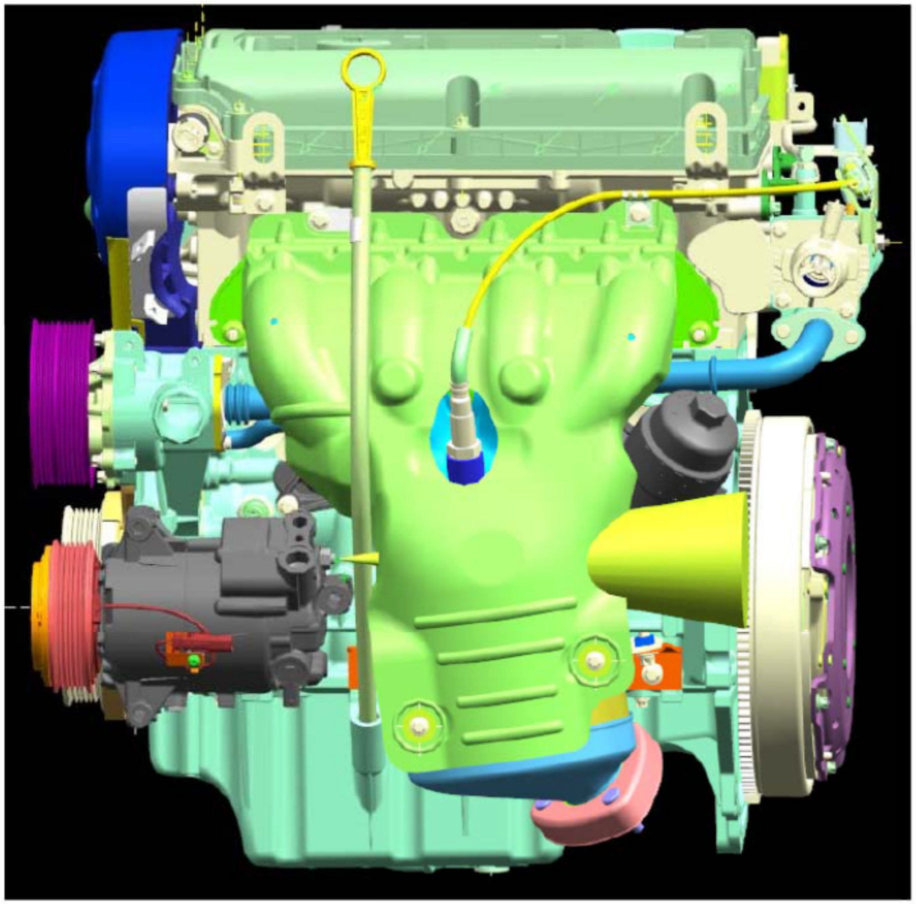
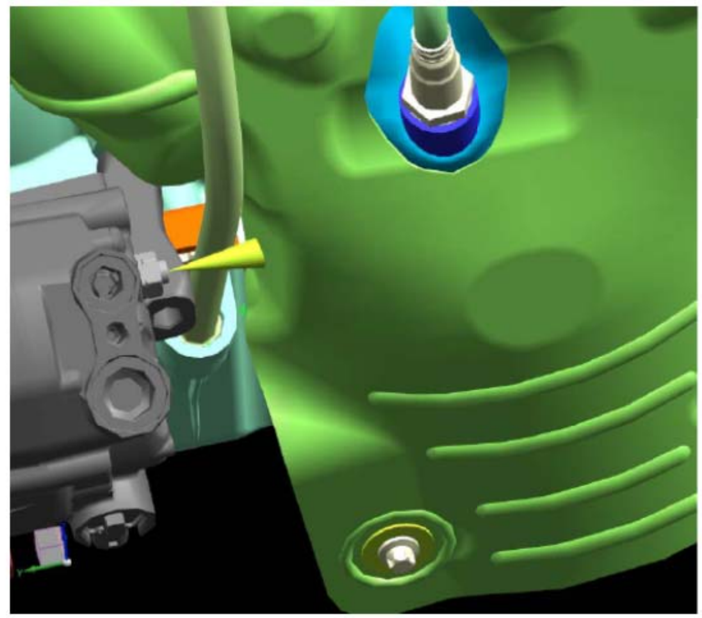
Backup

CRUZE -13335254 on LUW/LWE ENVIRONMENT-



HPRV DISCHARGE OVER CATALYTIC
CONVERTER HEAT SHIELD (HOT SURFACE)



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Hot Surface Ignition and Fire Propagation Characteristics of R134a and R1234yf Refrigerants

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Ford Motor Company

ABSTRACT

This paper summarizes hot surface ignition characteristics of R134a and R1234yf automotive air conditioning fluids on typical under-hood automotive surfaces that possess sufficient heat to ignite flammable or combustible fluids. It further investigates the effect, if any, that these two different fluids may have on the propagation of a fire in two identically equipped vehicles under similar test conditions. This testing, in part, is in response to the United States Environmental Protection Agency's proposal which seeks comments concerning the proposed replacement of the current R134a air conditioning refrigerant with R1234yf

R134a is currently regarded as the global choice for automotive air conditioning systems however the EPA classifies it as an ozone depleting substance (ODS) and is tasked with proposing and reviewing alternatives that do not contribute to stratospheric ozone depletion. R1234yf refrigerant is classified as a non-ozone depleting gas by the EPA and has been proposed as an acceptable alternative to R134a through the authority of the Clean Air Act and the Significant New Alternatives Policy (SNAP) program. The SNAP program sets forth criteria for the implementation of R1234yf refrigerant and has indicated that the proposed alternative refrigerant does not have to be risk free to be found acceptable for use. European Union (EU) countries have developed Directive 2006/40/EC that mandates a 100-year CO_2 Global Warming Potential (GWP) of less than 150. R134a is nearly 10 times this level with a rating of 1430 GWP. R1234yf has a GWP rating of 4.0 or approximately 0.3% of the current R134a refrigerant [1].

Hot surface ignition testing of R134a and R1234yf mixtures with PAG 46 oil were evaluated in the first part of this paper. Typical under-hood automotive surfaces at maximum operating temperatures were established, along with a functional AC system to evaluate the ignition characteristics of the refrigerant and lubricant mixtures. Tightly controlled test parameters and conditions were utilized to minimize test to test variation. The results obtained in this testing were compared to the published auto ignition properties of the refrigerants and other automotive fluids. The second part of this paper assesses the potential effects that the changing from R134a to R1234yf may have on fire propagation in a motor vehicle.

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INTRODUCTION

Modern vehicle designs consist of a variety of different fluids and materials located throughout the vehicle, some of which are classified as flammable or combustible as defined by National Fire Protection Association Standard (NFPA) 921. Many of these fluids or materials are chosen because of the benefits they provide relative to safety, environmental, weight, and durability performance characteristics. In the unlikely event of a vehicle fire, some of these materials or fluids may contribute to the initiation and/or the propagation of fire within a vehicle. R134a and R1234yf refrigerants do not provide adequate lubrication for moving parts within the AC system and require PAG oil to be dispersed within the refrigerant. Pure R134a is classified as non-flammable [2] however when it is mixed with the compressor oil, the mixture may ignite in the presence of a competent ignition source. R1234yf has been classified by Honeywell as a flammable gas [3] and also requires the same type of compressor oil as R134a for automotive use. Modern vehicles that include R134a refrigerant and compressor oil have been deemed safe and do not represent an unreasonable risk to automotive safety.

Automotive manufacturers as well as the National Highway Traffic Safety Administration have promulgated standards that are intended to apply objective measures of vehicle safety as it relates to fires in motor vehicles. Federal Motor Vehicle Safety Standard (FMVSS) 301 specifies fuel spillage rates after a vehicle is subjected to impacts from the front, side, and rear as well as a post-test static roll procedure [4]. This standard does not apply to other fluids typically contained within motor vehicles. Additionally, burn rates of combustible materials within the passenger compartment of motor vehicles are regulated by FMVSS 302, Flammability of Interior Materials [5]. These standards state that their purpose is to reduce the death and injuries to motor vehicle occupants caused by vehicle fires.

Applying a burn rate standard similar to the FMVSS 302 standard at a vehicle level may prove impractical due to a number of considerations which include significant variations in overall vehicle design, mass, and architecture as well as variations of potential fuel loads from vehicle to vehicle. Any or all of these variables would most likely change the way a fire progresses through a vehicle. Other real world considerations such as the area of the fire's origin, wind and weather, or even vehicle orientation or condition at the time of the fire will also alter the rate of fire progression in a vehicle. This paper does not attempt to develop or specify an acceptable or reasonably safe rate of fire progression in a vehicle (similar to FMVSS 302). The intent is to compare the ignition and fire propagation characteristics of the two refrigerants in an identically equipped vehicle in order to provide an objective comparison in the rate of fire propagation between the two.

HOT SURFACE IGNITION TEST INTRODUCTION

The published auto ignition temperature (AIT) values for typical automotive fluids under various test conditions are widely discussed and reviewed with a number of technical papers and industry standards, including; LaPointe, Adams, Washington [6], Arndt, Stevens, Arndt [7], Santrock, Kononen [8], Colwell [9]. Research conducted in these papers reflects a wide variation of published auto ignition temperatures of these fluids based on test conditions. The AIT is defined by NFPA 921 as, “The lowest temperature at which a combustible material ignites in air without a spark or flame”. The upper and lower flammability limits (UFL and LFL respectively) are defined by NFPA 921 as, “The upper or lower concentration limit at a specified temperature and pressure of a flammable gas or vapor of an ignitable liquid and air, expressed as a percentage of fuel by volume that can be ignited [10]. Above the UFL, the mixture is too rich and below the LFL the mixture is too lean to support combustion. At a standard temperature of 21 ° C (70° F), the LFL is 6.2% and UFL is 12.3% for the R1234yf refrigerant [3]. Higher and lower temperatures can alter these percentages. Since R134a is nonflammable, these limits for ULF and LFL do not exist (see Table A for a comparison of other common under hood fluids).

Table A. Typical Under Hood Fluids Properties, Honeywell MSDS [2, 3, 11, 12], NFPA 921, 2008 Edition [10]

FLUID	LFL (%)	UFL%	Auto Ignition Temperature (°F)
$R134a_{2}$	NA	NA	>1369
$R1234yf_{3}$	6.2	12.3	761
$R152a_{11}$	3.7	18.0	851
$R32_{12}$	12.7	33.4	>1369
$Gasoline_{10}$	1.4	7.6	495 - 536
Washer $Fluid_{10}$	6.0	36.0	867 - 903
Diesel $Fuel_{10}$	0.4	7.0	489 - 500
Trans $Fluid_{10}$	1.0	7.0	626 - 716
$P/Steering_{10}$	0.9	7.0	680 - 720
Brake $Fluid_{10}$	NA	NA	210 - 550
Motor Oil_{10}	1.0	7.0	644 - 680

HOT SURFACE IGNITION TEST METHODOLGY OVERVIEW

The next section of this paper focuses on hot surface ignition properties of R134a and R1234yf refrigerants on typical exhaust system surfaces and includes a description of the testing methodology for the vehicle buck and the A/C system bench stand. This testing methodology varies from joint research previously conducted by Marc Spatz (Honeywell) and Barbara Minor (DuPont) which studied the auto-ignition properties of various refrigerants, including R1234yf, and was presented the SAE World Congress in 2008 [13]. The research described in that study documented auto-ignition properties of R1234yf both with and without PAG oil in a laboratory environment. The test methodology described in this paper reflects conditions that are more representative of the refrigerant/oil mixtures and under hood environments in a typical automobile.

There were two main test apparatus for this testing. The first was the vehicle buck that the refrigerant mixture was released onto (shown in Figure A). The second was the operational A/C system bench stand that released the refrigerant, (shown in Figure F) with the appropriate volume, orientation, and condition of AC refrigerant/PAG 46 oil mixture in a typical automobile.

The control variables for this testing were the R134a and R1234yf refrigerants and the under hood exhaust system surface temperatures. Prior to the start of the testing, a number of safety precautions were developed and incorporated during the testing process. These precautions were incorporated to provide the maximum level of safety for on-site personnel as well as the test facility and equipment. They did not influence the results of the testing.

VEHICLE TEST BUCK

For the purpose of this testing, a 2011 Ford Taurus SHO with a 3.5L, 24V, V6 EcoBoost™ engine was used. Prior to this test, this fully functional vehicle had accumulated approximately 14,000 miles. All under hood fluids were drained and removed prior to the test. The under hood appearance and arrangement of components were kept intact with the exception of a 25 mm by 35 mm nozzle that was added for fire suppression capabilities. A heat input manifold was installed to the exhaust manifold that facilitated the introduction of heat to the vehicle's exhaust system. Finally, thermocouples were added at various under hood locations to record test temperatures. A photo of this test buck is shown in Figure A.

Figure A. Exterior of 2011 Ford Taurus SHO Vehicle Buck

Twelve thermocouples were welded to various locations in the immediate area from the exhaust manifold to the start of the exhaust down tube pipe of the Taurus SHO. The locations of these thermocouples were selected due to their relative proximity to the A/C system and because they represent some of the highest temperatures observed during Ford's thermal testing of the Taurus SHO. The thermocouple locations are described as follows:

1. Exhaust manifold flange
2. Heat tube near torch rosebud at collector
3. Manifold tube
4. Bottom of light off catalytic
5. Top of light off catalytic
6. Exhaust manifold
7. Exhaust turbo body
8. Turbo left front
9. Turbo outlet
10. Turbo inlet flange
11. Turbo bottom
12. Turbo piping connector

Figure B depicts a number of thermocouple locations with the heat shield removed for clarity. Figure C depicts the test condition with the heat shield reattached. The large red arrows shown in Figures B and C indicate the direction of the refrigerant mixture being discharged on the hot exhaust system. The A/C line and portions of the exhaust system can be seen near the engine oil filter. The direction and location of the simulated leak near the exhaust system was selected because it represented the highest potential of ignition of the released refrigerant/PAG oil mixture.

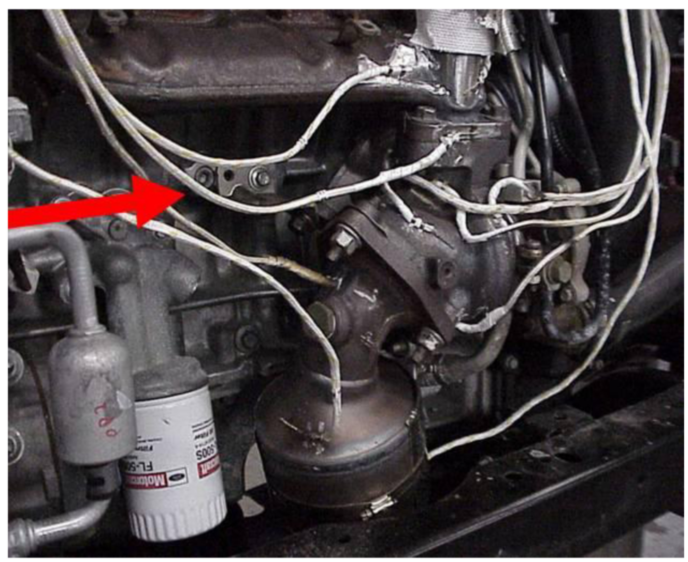

Figure B. Thermocouples (Heat Shield Removed)

Once the thermocouples were installed, the production heat shield was reinstalled over the exhaust system. The thermocouple wires were routed in a manner so that they did not block the surface of the exhaust system from the refrigerant being dispersed. Figure C shows the production exhaust manifold shield reinstalled.

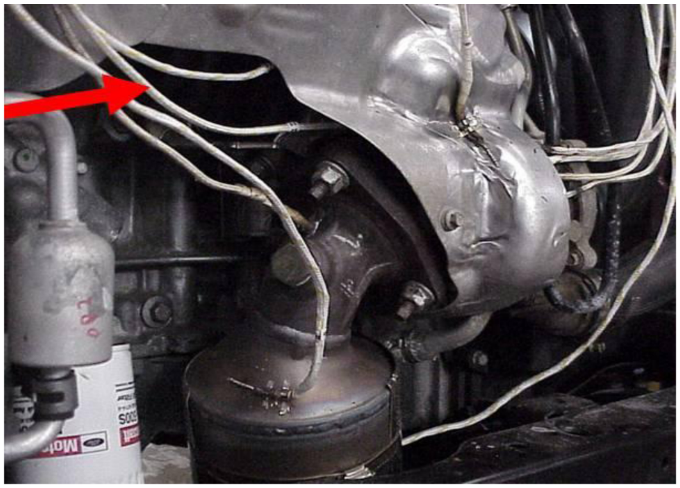

Figure C. Test Condition (Heat Shield Reinstalled)

Because the engine in the test buck was not capable of running, an alternative method of introducing heat into the engine's exhaust system was developed. This method allowed precise control of the exhaust system surface temperatures while maintaining the integrity of the exhaust system surfaces. The gas chosen to heat the vehicle's exhaust system was HGX mixed with oxygen. The gas was delivered through a torch that was inserted into the front exhaust system manifold (see Figure D). The flame was not exposed to the outside of the exhaust system and the cap prevented refrigerant from entering into the exhaust system.

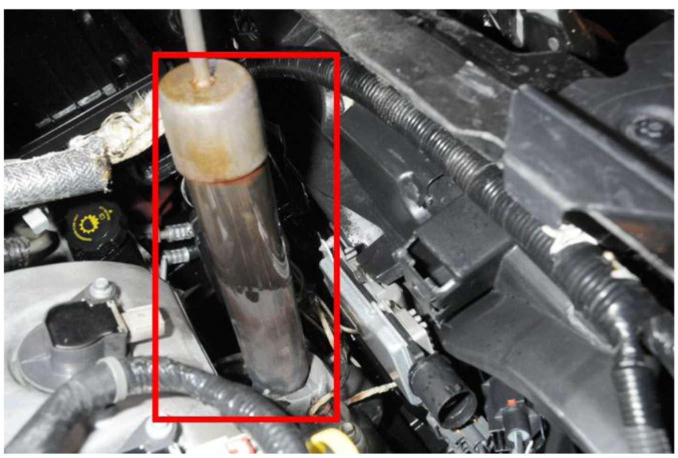

Figure D. Heat Tube and Top Cap.

The heat that was introduced into test buck's exhaust system was allowed to move through the system. Figure E reflects the routing of the exhaust system underneath the front passenger compartment of the buck and illustrates the point at which heat exited the system.

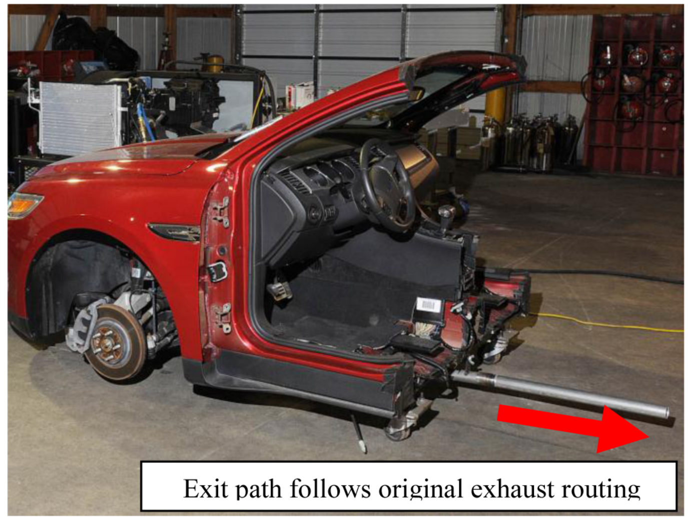

Figure E. Exit Path for Heated Exhaust

The maximum temperatures selected for this test were determined from internal heat management data from Ford. The intent of the heat management test is to verify that under severe operating conditions, the level of heat generated will not exceed the capabilities of materials in and around the exhaust system. The highest surface temperatures reflected in this test represent the maximum temperatures recorded during heat management testing at Ford Motor Company and do not represent typical operating surface temperatures of exhaust systems. Actual exhaust system surface temperatures can vary depending on a number of factors including, engine size, drive cycle, condition of the vehicle, ambient temperatures, etc. Lower exhaust system surface temperatures of several different vehicles under typical drive cycles were documented in research conducted by Engle, Olson, and Sharma and reflect significantly lower temperatures than those documented in this testing [14].

A/C BENCH SYSTEM

A system bench stand was constructed that included the major components in an automotive air conditioning system. These components include the compressor, condenser, evaporator, and the A/C lines (see Figure F). This stand enabled the refrigerant to be released into the engine compartment of the buck in a volume and state that would simulate a release of the onboard refrigerant. Figure F reflects the A/C system components constructed for this test.

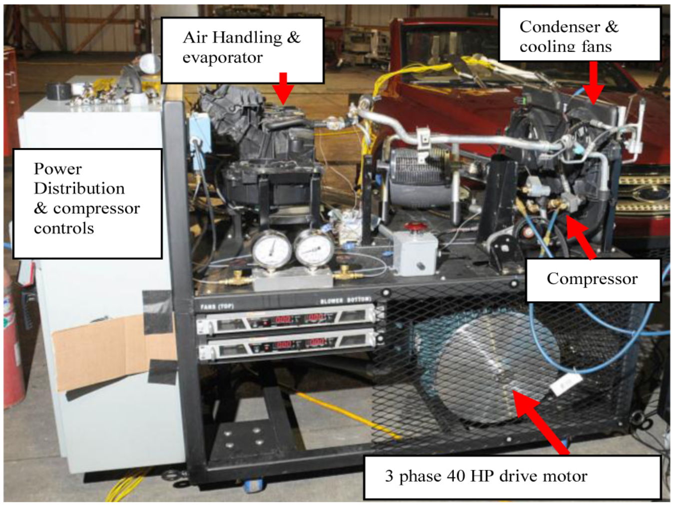

Figure F. Identification of A/C Test Stand Components

The A/C lines can be broken down into 3 categories that transport refrigerant. The discharge line connects the compressor and condenser. It carries a high pressure and high temperature refrigerant mixture that is in a pure vapor form. This temperature is typically 257° F at 325 psi. The liquid line connects the condenser and evaporator. It carries a high pressure and high temperature pure liquid refrigerant. The third A/C line system is the suction line. It completes the loop back to the compressor from the evaporator. The suction line is a low pressure and low temperature refrigerant mixture in vapor form. For this experiment, the hottest temperature that could be released from an A/C system was selected to minimize the quenching of the refrigerant on the hot exhaust in order to create the highest probability of ignition. The "leak" location on the discharge line was chosen since this is typically the closest to the exhaust as seen in Figure B.

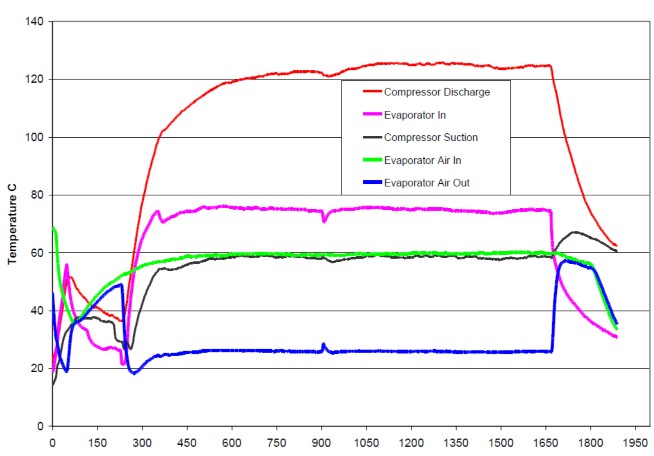

Figure G. A/C System Operation during Testing

Figure G is a graph depicting the temperatures of the AC refrigerant in different stages. The red line represents the A/C compressor discharge temperature of 124.7° C (256.5° F). The pink line represents the temperature at the inlet to the evaporator at the thermo expansion valve at 74.1° C (165.4° F). The heated air entering the evaporator was 60° C (140° F) and is shown in bright green and is intended to produce a high load on the A/C system. The compressor suction gas is shown in black and was 58.5° C (137.3° F), indicating a large thermal load on the A/C system. The blue line reflects the cooled air coming off the evaporator at 26° C (79° F). The following describes the operating cycle of the A/C stand for each test:

1. 0 - 250 seconds; system is off and being prepared to be turned on

2. 250 - 1700 seconds; system is engaged and running at maximum load, Time 250 to 1700 seconds

3. 1700 seconds; simulated leak of refrigerant occurs with sudden loss of pressure and the release of A/C refrigerant and PAG oil

The instrumentation used on the system stand during the testing for air temperatures was:

1. Ambient

2. Evaporator Inlet (heated air)

3. Evaporator Outlet (cooled air)

4. Compressor Discharge

5. TXV/Evaporator Inlet

6. Compressor Suction

There were three pressure ports on the system:

1. Compressor Suction

2. Compressor Discharge

3. Low Charge Protection System (set to 40 psi)

The compressor discharge pressure was adjusted by the bench stand cooling fans to maintain a maximum pressure of 375-385 psi in the system. The low charge protection system was very similar to one used in Ford vehicles to prevent the system from operating with low levels of refrigerant and causing catastrophic damage to the compressor.

REFRIGERANT IGNITION TEST PROCEDURE

The A/C test stand was charged with the appropriate amount and type of refrigerant and common PAG oil and was cycled per the description noted above. Multiple cameras were positioned at various locations within the engine compartment and at external locations. Data acquisition devices recorded data every 2 seconds. Heat was applied and when the desired test temperature was reached, the heat was very quickly turned off and the steel cap was placed on the heat tube. The refrigerant was released and the actual released temperature was recorded and documented.

There were 3 possible outcomes from each testing sequence; 1) No ignition, 2) PAG oil ignition only, 3) Refrigerant and PAG oil ignition. Cameras located within the engine compartment were utilized to document ignition characteristics and location. The PAG oil ignition was observed to be smaller, orange in flame color, and appeared to burn on the hot surface. The R1234yf refrigerant ignition was a larger flame pattern, wispy or weak in appearance, blue-green flame color, and dissipated quickly. In some cases where the R1234yf refrigerant did ignite it was theorized the burning PAG oil may have contributed to a secondary ignition source of the refrigerant. In either case the refrigerant did ignite and it was categorized as such.

Figure H. Completed Test Setup

Figure H shows the A/C bench stand and the vehicle buck. Heat was introduced into the engine's exhaust system and when the exhaust system surface reaches the intended test temperature the refrigerant and oil mixture was released. For each test, the A/C test stand system was charged with 150 grams of PAG 46 oil and 590 grams of refrigerant. These quantities represent typical refrigerant and PAG oil loads in automotive air conditioning systems. A simulated leak represented an A/C system failure that allowed the release of the refrigerant and oil mixture. The diameter of the simulated refrigerant leak point was the same as the discharge line in the A/C system. The released refrigerant will follow the path of least resistance with the vast majority existing at this simulated leak.

At the conclusion of each test sequence, the entire engine compartment of the buck was thoroughly cleaned and returned to its pre-test condition in order to eliminate the potential that any remaining PAG oil and/or fire suppressant from previous tests contaminating the exhaust system surfaces. The A/C system test stand was flushed to remove any remaining PAG oil from the system test stand. This flushing occurred overnight and completely removed any remaining oil. The compressor after each test run was removed, heated and drained overnight. The following day it was filled with the specified volume of oil. The process ensured the correct amount of PAG 46 oil in the system from test to test.

REFRIGERANT IGNITION TEST RESULTS

R134a

The criteria used to establish ignition or no ignition was to document the result at least 3 times at each test temperature. The results of this testing are shown graphically in Figure I.

No ignition occurred at the following surface temperatures:

- 810° C (1490° F)
- 833° C (1531° F)
- 840° C (1544° F)

PAG oil mixed with R134a refrigerant ignition occurred at the following surface temperatures:

- 837° C (1539° F)
- 874° C (1605° F)
- 884° C (1623° F)
- 892° C (1638° F)
- 915° C (1679° F)
- 932° C (1710° F)

When ignition occurred, the area of ignition was observed to be the exhaust system containing the heat shield shown in Figure C. The refrigerant ignition never occurred during any of the R134a testing. Data from this testing indicates that the transition from no ignition to PAG oil ignition mixed with the R134a refrigerant occurred between 837°C and 840° C (1539°- 1544° F).

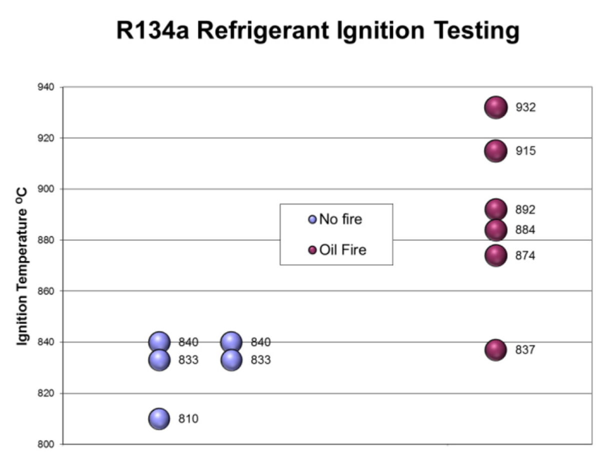

Figure I. R134a Testing Results

R1234yf

Similar to the R134a testing, each classification of fire or no fire was documented 3 times at each temperature. The R1234yf results are shown graphically in Figure J.

There was no ignition of PAG oil or refrigerant at the following surface temperatures:

- 813° C (1495° F)
- 815° C (1499° F)
- 840° C (1544° F)
- 886° C (1627° F)

PAG oil ignition (without refrigerant ignition) occurred at the following surface temperatures:

- 845° C (1553° F)
- 853° C (1567° F)
- 890° C (1634° F)
- 913° C (1675° F)

The PAG oil and R1234yf refrigerant mixture ignition occurred at the following surface temperatures:

- 847° C (1557° F)
- 863° C (1585° F)
- 881° C (1618° F)
- 891° C (1636° F)
- 906° C (1663° F)
- 913° C (1675° F)
- 925° C (1697° F)
- 930° C (1706° F)

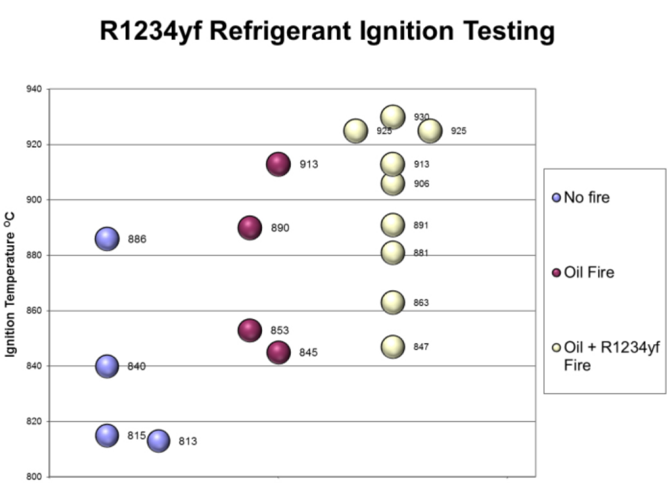

Figure J. R1234yf Testing Results

The results from the R1234yf testing show a large overlap between the 3 possible outcomes (no ignition, PAG oil ignition only, PAG oil and refrigerant ignition). This occurred from approximately 840° C (1544° F) up to approximately 890° C (1634° F). Ignition of the PAG oil, regardless of the refrigerant, occurred at approximately 840° C (1544° F) indicating that the type of refrigerant appears to not influence the likelihood of ignition of the PAG oil during this test. The hot surface ignition data collected in the testing described above represents a limited number of tests and describes the outcome at the temperatures noted. Additional tests at fixed temperatures would be required in order to establish a statistical probability of ignition at each temperature and would likely be the topic of future publications.

The results of auto-ignition testing conducted by Spatz/Minor study showed hot plate ignition of R1234yf was not achieved until temperatures exceeded 900° C (1652° F) but only with the presence of PAG oil. The research described by Spatz/Minor also indicated that they could not ignite the R1234yf refrigerant without the presence of PAG oil [14].

VEHICLE FIRE PROPAGATION TESTING

After documenting hot surface ignition properties and characteristics of both the R134a and R1234yf refrigerant/PAG oil mixtures, the next step in the analysis was to consider the impact, if any, the added fuel load associated with the R1234yf would have on the rate of fire propagation in the Ford Fiesta. The Ford Fiesta was selected because of its size, providing what is felt to be a worst-case ratio of potential fuel load to vehicle mass and geometry.

For this demonstration, two virtually identical 2011 Ford Fiestas were used. The test vehicles consisted of the same body style, powertrain, and option content. The vehicles were placed at the same orientation and were tested within hours on the same day to minimize the effects that changing wind and weather would have on the burn testing. The fluid levels for each vehicle were equalized so that potentially available fuel loads were common between the two vehicles. The one dissimilarity was the refrigerant for the HVAC system. Vehicle #1 contained the R134a refrigerant while vehicle #2 was purged of the R134a and was replaced by R1234yf refrigerant.

Figure K. Vehicle #1, 2011 Ford Fiesta w/R134a Refrigerant

Figure L. Vehicle #2, 2011 Ford Fiesta w/R1234yf Refrigerant

Prior to the tests, each vehicle was similarly equipped with nine thermocouples throughout the engine and passenger compartments of each vehicle. The purpose of these thermocouples was to document the temperature as a function of elapsed time in order to assess the rate at which heat and fire propagates from the vehicle's engine compartment to the passenger compartment. The temperature vs. time data was recorded and plotted at specific areas of the vehicle and was obtained with the use of a Yokagawa MV200 data logger. The sampling rate was set at one sample every 2 seconds. Video cameras captured views of each vehicle from the left front and the left rear. After the test, data was downloaded to an Excel spreadsheet and where it was converted into graphical plots depicting temperature (°F - vertical axis) and time (seconds - horizontal axis). Each vehicle was also equipped with a pressure sensor for the HVAC system so that a drop in pressure would be detected once the system was compromised by fire.

The nine thermocouple locations per vehicle are described in Table B:

Table B. Thermocouple Locations

Location Description	T/C #
Steering Wheel	1
Centered, Near Dome Light	2
Right Front Passenger Foot Well	3
Left Rear Engine Compartment	4
Left Front Engine Compartment	5
Right Front Engine Compartment	6
Right Midpoint Engine Compartment	7
Right Rear Engine Compartment	8
Center Rear Engine Compartment	9

Overall photos depicting these locations are shown in Figures M, N, O, P (similar for both vehicles).

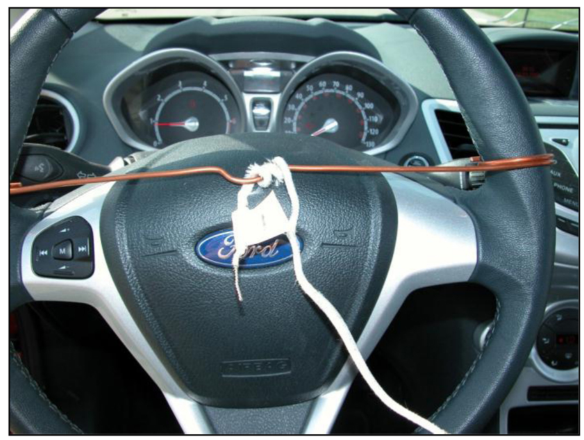

Figure M. Thermocouple 1 at Steering Wheel

Figure N. Thermocouple 2 Centered, Near Dome Light

Figure O. Thermocouple 3 in Passenger Foot Well

Figure P. Thermocouples 4 - 9 at Various Engine Compartment Locations

Prior to the initiation of the fire, the vehicle was started and allowed to idle for one minute with the manual transmission in neutral and the parking brake applied. The HVAC fan was turned to its highest setting while the temperature setting, with the air conditioning system in the "On" position, was turned to its lowest setting. All side glass windows were up and all doors were closed. Leaking fuel was created for the purpose of this test by drilling a 1/8th inch diameter hole in the fuel delivery line which resulted in a steady spillage of gasoline. The continuous flow of leaking gasoline created for this test is not representative of a vehicle that has been turned off or has been in a collision severe enough to deactivate fuel delivery. The intent was to provide a steady source fuel to ensure fire propagation would occur as well as to establish whether or not a competent ignition source existed within the engine compartment while the vehicle was running to ignite the gasoline vapors. If ignition did not occur after one minute, the initiation of the fire in each vehicle was achieved via a remotely activated pyrotechnic device located within the engine compartment. Both vehicles were aligned in a northerly direction with winds out of the southwest at approximately 7 - 12 mph. The ambient temperature at the time of the testing was approximately 72° F.

After one minute of engine idle and with fuel leaking in sufficient quantity to begin pooling beneath the vehicle, no ignition of gasoline occurred in either vehicle. At this point in the test the remote pyrotechnic device was activated which resulted in the immediate ignition of the spilled gasoline. Secondary combustibles within the engine compartment also became involved soon after the start of the fire. The engine, which had been running when the fire began, stalled shortly thereafter. The fires were allowed to propagate through the vehicles' architectures until they fully breached the passenger compartments of each vehicle while temperature and pressure data were being recorded. The fires in both vehicles were extinguished by fire service personnel. Still photos and video captured the event during both vehicle burns.

Figure Q is a photo of the Fiesta equipped with R134a refrigerant approximately 6 minutes after the initiation of the fire within the engine compartment.

Figure Q. 2011 Fiesta with R134a Refrigerant

Figure R is a photo of the Fiesta equipped with R1234YF refrigerant also taken approximately 6 minutes after the initiation of the fire in the same location.

Figure R. Fiesta with R1234yf Refrigerant

R134A VEHICLE FIRE PROPAGATION OBSERVATIONS

Temperature measurements within the engine compartment of both vehicles immediately show an increase in temperatures once the fire started while the temperatures within the passenger compartment remained at ambient temperatures during the early stages of the fire. Temperature measurements near the area of the fire's origin (left rear of engine compartment) reached 1000° F in approximately 20 seconds. A maximum temperature of 1737° F was recorded within the engine compartment and occurred at thermocouple #6 (right front engine compartment) after approximately 9 minutes of fire propagation. Temperature measurements within the passenger compartment remained below 100° F at all three interior thermocouple locations through the first 2½ minutes of the fire. Temperature measurements at the dome light (thermocouple #2) were the first within the passenger compartment to exceed 100° F. The highest temperature recorded within the passenger compartment was 702° F and occurred approximately 5½ minutes after the initiation of the fire.

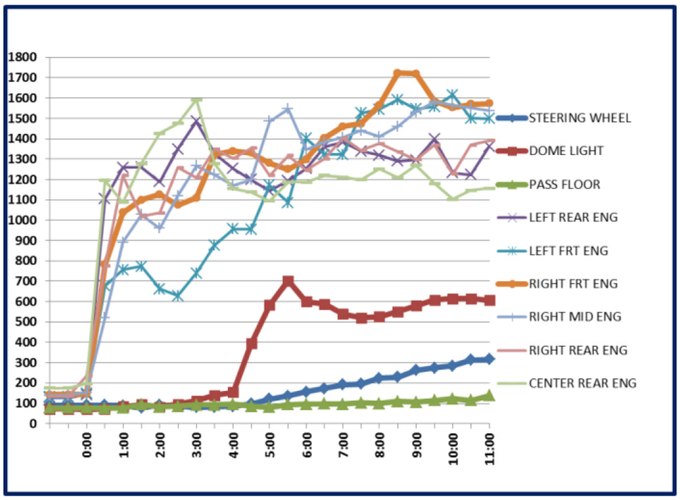

Figure S. R134a Temperature v. Time Plot (F° on the vertical axis; Time in minutes on the horizontal axis)

R1234YF VEHICLE FIRE PROPAGATION OBSERVATIONS

There were variations in the temperature measurements versus time of the vehicle containing the R1234yf refrigerant compared to the R134a vehicle. It took approximately 56 seconds for the fire's area of origin (left rear of engine compartment) to reach 1000° F. compared to the R134a vehicle taking 20 seconds. A maximum temperature of 1562° F was recorded within the engine compartment and occurred at thermocouple #6 (right front engine compartment) after approximately 6 minutes of fire propagation. This was 175° F less than the R134a vehicle but at the same location. Temperature measurements within the passenger compartment remained below 100° F through the first 3 minutes of the fire which was approximately 30 seconds longer than the R134a vehicle. Similar to the R134a test, the temperature measured at the dome light (thermocouple #2) was the first within the passenger compartment to exceed 100° F. The highest temperature recorded within the passenger compartment was 1016° F and occurred approximately 6 minutes after the initiation of the fire. This measurement was nearly 400° F higher than the maximum interior temperature recorded for the R134a vehicle.

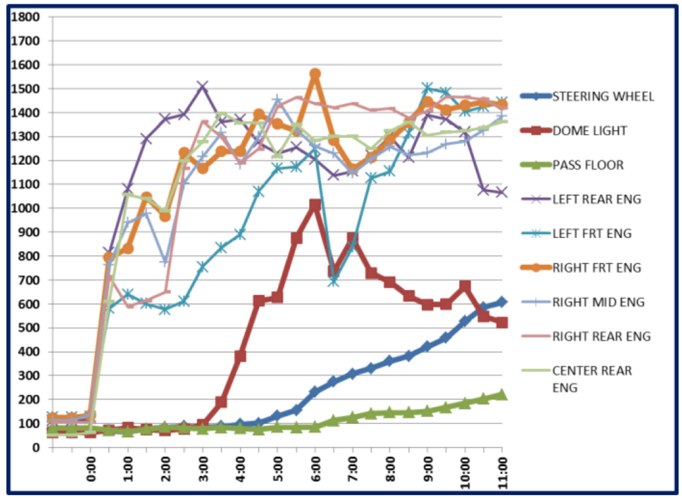

Figure T. R1234yf Temperature v. Time Plot (F° on the vertical axis; Time in minutes on the horizontal axis)

Pressure transducers installed on the high side pressure line of the HVAC systems were monitored during the fire for the purpose of measuring a drop in pressure that would coincide with a compromise in the polymer hoses of the HVAC system. The R134a transducer detected a pressure drop approximately one minute into the fire while the R1234yf detected a pressure drop approximately 1 minute, 40 seconds into the fire. Although it is not reflected in the thermocouple temperature data, the drop in AC system pressure and the rapid release of the R1234yf refrigerant coincided with a noticeably significantly increase in the amount of visible flame in and around the engine compartment of the Ford Fiesta. This increase lasted only a few seconds and the observable flame and smoke returned to the levels observed prior to the release of the R1234yf refrigerant.

CONCLUSIONS

Automotive engineers are tasked with balancing a variety of vehicle design and performance attributes that span a broad spectrum of needs and wants. These attributes are defined by the customers who purchase their products as well as industry, corporate, and regulatory standards. When considering the change in refrigerant for the vehicle's air conditioning system from R134a to R1234yf, an automotive engineer considers the intended design function of the new refrigerant as well as the effects that the unintended release of the refrigerant may create. This paper focused on the potential effects that a breach in the vehicle's air conditioning system containing R134a and R1234yf refrigerants may have from a fire perspective. The underlying test methodology for this research was to develop test conditions that are more representative of a real world automotive environment when compared to a laboratory environment. The test conditions defined throughout this paper were not intended to represent every possible scenario involving the release of A/C refrigerant, however considerations that included the highest probability of ignition and fire propagation within the scope of this research were incorporated.

The authors of this paper studied two different scenarios; 1) the ignition characteristics of R1234yf refrigerant on hot surfaces of an engine compartment; 2) the effects that R1234yf refrigerant may have on the rate at which a fire will propagate through a vehicle. In both test scenarios, the ignition and fire characteristics of the proposed R1234yf refrigerant was compared to the current R134a refrigerant. As anticipated, the observed hot surface ignition temperature of R1234yf in this testing was higher than the published laboratory auto ignition temperature. The published AIT of R1234yf at 405° C (761° F) is less than half of the lowest ignition temperature of 837° C (1539° F) observed during this test. The collaborative research conducted by Honeywell/ DuPont with R1234yf reflected similar hot surface ignition temperatures of approximately 900° C (1652° F) observed within this research but only with the presence of PAG oil. As discussed earlier, the methodology in this paper varied from the Honeywell/DuPont study which may account for the relatively small observed variation in ignition temperatures of R1234yf.

The temperatures necessary to ignite the R1234yf as well as the PAG oil present in both refrigerants during this test are not typically present during a vast majority of driving conditions. Given the relatively high temperatures necessary to ignite the R1234yf refrigerant and PAG oil, the likelihood of hot surface ignition under the vast majority of driving conditions is less than other existing under hood automotive fluids.

Although R134a is classified as nonflammable, the PAG oil present in the current R134a refrigerant mixture did ignite on the surface of the exhaust system at certain temperatures. The PAG oil in the R1234yf refrigerant exhibited similar ignition temperatures indicating that the two refrigerants tested did not influence the ignition characteristics of the PAG oil. Portions of the Honeywell/DuPont testing described in this paper included testing without PAG oil and would not represent real world usage conditions since the lubrication oil is required for automotive applications.

The exhaust system shield shown in Figure C appeared to trap the PAG oil vapors and increased the likelihood of ignition at this location. This is likely due to the fact that heat shields are generally not designed to prevent spilled fluids from contacting the exhaust system surface. As a result, vapors may remain in closer contact to the exhaust system surfaces thus increasing the likelihood of ignition. Furthermore, surface temperatures beneath the shield tend to be more insulated from convective cooling and tend to remain elevated for a longer period of time once the heat source is removed and convective cooling begins on the exhaust system surfaces.

Fire propagation through a vehicle that contains a very complex set of combustible fluids and materials is highly variable, even when attempts to minimize these variables are considered. Environmental and/or the condition of the vehicle at the time of the fire can have a significant impact on fire propagation. While it has been established that R1234yf refrigerant will ignite and rapidly burn under certain circumstances, the fuel load that this refrigerant adds to a vehicle is relatively small in comparison to the existing fuel load of a modern automobile. This was clearly observed at 1 minute and 40 seconds into the burn of the R1234yf vehicle when there was a visible increase in the amount of flames that lasted only a very short duration. The vehicle containing the R134a did not exhibit that same behavior when its A/C system was compromised from the fire.

Temperature data that shows passenger compartment temperatures began to elevate approximately 2 ½ minutes after the initiation of the fire in the vehicle containing non-flammable R134a. The same temperature increase was observed at approximately the 3 minute mark of the vehicle containing the flammable R1234yf refrigerant. Based on the results from the fire propagation testing, it appears the addition of the flammable R1234yf refrigerant has a negligible effect to the propagation of a fire within a vehicle when compared to other variables that affect fire propagation.

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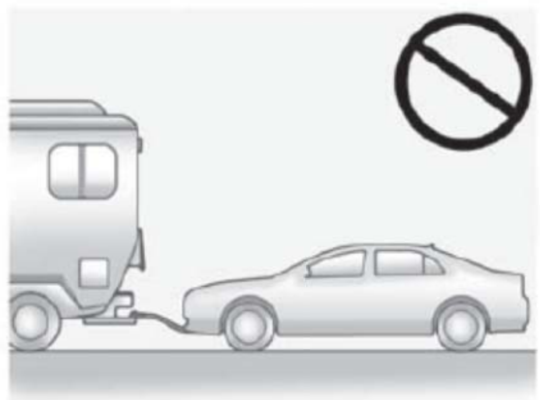
This information replaces the information located under "Recreational Vehicle Towing, Dinghy Towing" found in Section 10 of your owner manual.

Dinghy Towing (With Automatic Transmission)



Notice: **If the vehicle is towed with all four wheels on the ground, the drivetrain components could be damaged. The repairs would not be covered by the vehicle warranty. Do not tow the vehicle with all four wheels on the ground.**

Vehicles with an automatic transmission should not be towed with all four wheels on the ground. If the vehicle must be towed, a dolly should be used. See "Dolly Towing" that follows for more information.

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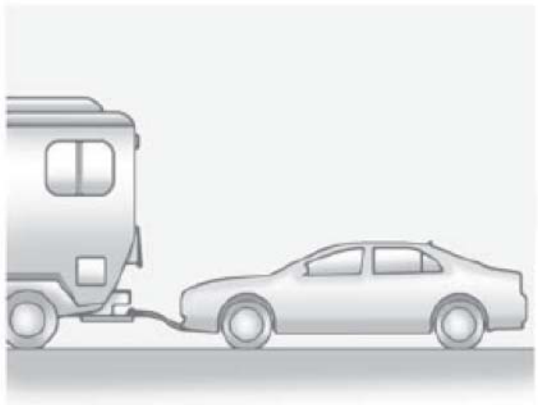
Dinghy Towing (With Manual Transmission)



To dinghy tow the vehicle from the front with all four wheels on the ground:

1. Position the vehicle to tow and then secure it to the towing vehicle.
2. Shift the transmission to Neutral.
3. Turn the ignition to ACC/ ACCESSORY.
4. To prevent the battery from draining while the vehicle is being towed, remove fuse 22, 23, 24, and 25 from the instrument panel fuse block. See *Instrument Panel Fuse Block* for more information.

Remember to reinstall the fuses once the destination has been reached.

Notice: **If 105 km/h (65 mph) is exceeded while towing the vehicle, it could be damaged. Never exceed 105 km/h (65 mph) while towing the vehicle.**

2012 Supplement for Section on Dinghy Towing

Example mailings

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Backup Slides

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Towing

Towing the Vehicle

Notice: **To avoid damage, the disabled vehicle should be towed with all four wheels off the ground. Care must be taken with vehicles that have low ground clearance and/or special equipment. Always flatbed on a car carrier.**

Consult your dealer or a professional towing service if the disabled vehicle must be towed. See *Roadside Assistance Program on page 13-6*.

To tow the vehicle behind another vehicle for recreational purposes, such as behind a motorhome, see "Recreational Vehicle Towing" in this section.

Recreational Vehicle Towing

Recreational vehicle towing refers to towing the vehicle behind another vehicle – such as behind a motor home. The two most common types of recreational vehicle towing are known as dinghy towing and dolly towing. Dinghy towing is towing the vehicle with all four wheels on the ground. Dolly towing is towing the vehicle with two wheels on the ground and two wheels up on a device known as a dolly.

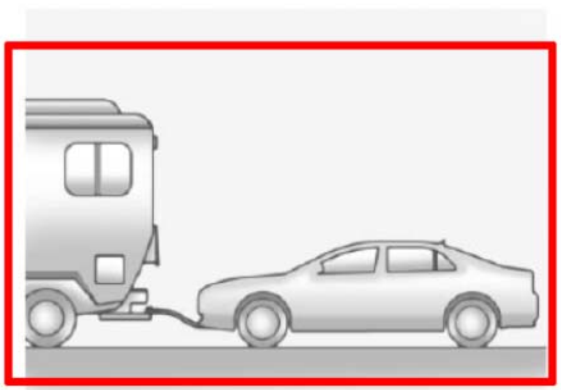
Here are some important things to consider before recreational vehicle towing:

- The towing capacity of the towing vehicle. Be sure to read the tow vehicle manufacturer's recommendations.
- How far will the vehicle be towed. Some vehicles have restrictions on how far and how long they can tow.
- Does the vehicle have the proper towing equipment. See your dealer or trailering professional for additional advice and equipment recommendations.
- Is the vehicle ready to be towed. Just as preparing the vehicle for a long trip, make sure the vehicle is prepared to be towed.

Dinghy Towing

When dinghy towing a vehicle with an automatic transmission, the vehicle should be run at the beginning of each day and at each RV fuel stop for about five minutes. This will ensure proper lubrication of transmission components.

GMNA Owner's Manual

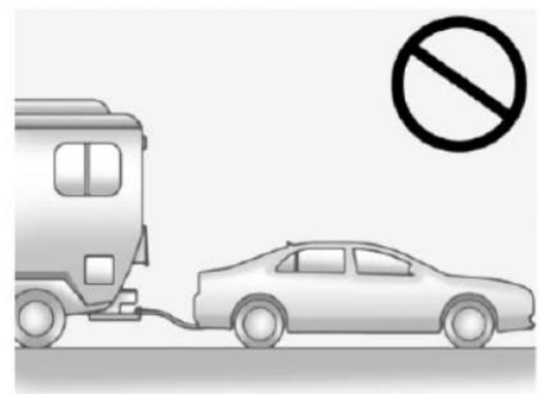


To dinghy tow the vehicle from the front with all four wheels on the ground:

1. Position the vehicle to tow and then secure it to the towing vehicle.
2. Shift the automatic transmission to P (Park) or a manual transmission into first gear and turn the ignition to LOCK/OFF.
3. Set the parking brake.
4. To prevent the battery from draining while the vehicle is being towed, remove fuse 22 from the instrument panel fuse block. See *Instrument Panel Fuse Block on page 10-38* for more information.
5. Turn the ignition to ON/RUN.
6. Shift the automatic transmission to N (Neutral) or a manual transmission to neutral.
7. Turn the ignition to ACC/ ACCESSORY.
8. Release the parking brake.

Remember to reinstall the fuse once the destination has been reached.

Notice: **If 105 km/h (65 mph) is exceeded while towing the vehicle, it could be damaged. Never exceed 105 km/h (65 mph) while towing the vehicle.**



Notice: **Towing the vehicle from the rear could damage it. Also, repairs would not be covered by the vehicle warranty. Never have the vehicle towed from the rear.**

2011MY Cruze - MH8 6 speed Automatic Transmission Overheat while Dinghy Towing

Screw in the towing eye as far as it will go until it stops in a horizontal position.

Attach a tow rope to the towing eye.

The towing eye must only be used for towing and not for recovering the vehicle.

Switch on ignition to release steering column lock and to permit operation of brake lights, horn and windscreen wipers.

Transmission in neutral.

Caution

Drive slowly. Excessive force can damage the vehicle.

When the engine is not running, considerably more force is needed to brake and steer.

To prevent the entry of exhaust fumes from the towing vehicle, switch on the air recirculation and close the windows.

Vehicles with automatic transmission: The vehicle must be towed facing forwards, not faster than 80 km/h nor further than 100 km. In all other cases and when the transmission is defective, the front axle must be raised off the ground.

Seek the assistance of your Holden Dealer.

After towing, unscrew the towing eye and replace cap.

The best method is to have the vehicle transported using a recovery vehicle.

Appearance care

Exterior care

Washing

The paintwork of your vehicle is exposed to environmental influences. Wash and wax your vehicle regularly. When using automatic vehicle washes, select a programme that includes waxing.

Bird droppings, dead insects, resin, pollen and the like should be cleaned off immediately, as they contain aggressive constituents which can cause paint damage. Failure to do so may result in permanent damage, particularly in hot weather conditions.

Road bloom is a gradual build up of road and environmental grime. This should be removed with a paint cleaner product, in addition to normal washing, on an annual basis.

If using a vehicle wash, comply with the vehicle wash manufacturer's instructions. Never use an automatic wash that requires anything touching

Global read-across - GM Holden Owner's Manual

2011MY Cruze - MH8 6 speed Automatic Transmission Overheat while Dinghy Towing

Row Labels	Count of VEH_IDENT_NBR
CANADA	28455
PUERTORICO	78
THAILAND	2
UNITEDSTATES	163393
VIRGINISLANDS(U.S.)	17
#N/A	
(blank)	
Grand Total	**191945**

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PE12-010

GM

6/22/2012

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Automatic Transmission
sharepoint summary 4-24-2012

Automatic Transmission 39

25 TREAD hits on 9 VINs — Dinghy Towing (Smoke Only) — FPE action 8/2011 (Do not dinghy tow)

- IR related = Yes
- Closing statement written and approved – Issue Closed

11 TREAD hits on 8 VINs — Seized Pumps – starter cannot turn engine (Fuse Melted/Burned – proper function)

- Recommend changing to IR related = No
- Customer experienced no "smoke / melt / smell / flame / burnt"
- Closing statement written and approved – Issue Closed

3 TREAD hits on 3 VINs — Dealer teardown comments of melted/burned internal components

- Customer experienced no "smoke / melt / smell / flame / burnt"
- Closing statement written and approved – Issue Closed

PE12-010

GM

6/22/2012

Q_07_10 PT AT

Automatic Transmission sharepoint summary 4-19-2012

Automatic Transmission 39

25 TREAD hits on 9 VINs — Dinghy Towing (Smoke Only) — FPE action 8/2011 (Do not dinghy tow)

- IR related = Yes

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PE12-010

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6/22/2012

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GF6 Dinghy Tow Summary_26MR12-p

GF6 Dinghy Tow Testing Summary

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