U.S. Department of Transportation

National Highway Traffic Safety Administration

ODI RESUME

OFFICE OF DEFECTS INVESTIGATION

NHTSA

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Investigation: EA 15-005
Prompted by:
Date Opened: 09/28/2015 **Date Closed:** 11/02/2018
Investigator: Chris Lash **Reviewer:** Jeff Quandt
Approver: Stephen Ridella
Subject: Front Brake Hose Failure

MANUFACTURER & PRODUCT INFORMATION

Manufacturer: Ford Motor Company
Products: 2013 - 2015 Ford Explorer Police Interceptor
Population: 49,732

Problem Description: The front brake hoses may fail at the caliper-end crimp fitting due to exposure to extreme temperatures and severe duty cycle conditions.

FAILURE REPORT SUMMARY

	ODI	Manufacturer	Total
Complaints:	7	7	7**
Crashes/Fires:	0	0	0
Injury Incidents:	0	0	0
Fatality Incidents:	0	0	0
Other*:	0	7	7

***Description of Other:** Other field reports potentially related to front brake caliper crimp failures.

** Total eliminates duplicates received by ODI and manufacturer.

ACTION / SUMMARY INFORMATION

Action: This Engineering Analysis is closed.

Summary:

On April 29, 2015, the Office of Defects Investigation (ODI) opened PE15-017 to investigate a report alleging incidents of front brake hose failure in model year (MY) 2015 Ford Explorer Police Interceptor vehicles used by the Sacramento Police Department in its pursuit driving training program (VOQ 10705832). On September 28, 2015, ODI upgraded the investigation to an Engineering Analysis (EA15-005) to assess maximum front caliper crimp temperatures under various test conditions, test hose assemblies removed from police interceptor service for any signs of thermal degradation, and further assess field data for evidence of a defect trend related to the alleged defect.

The alleged defect results from exposure to extremely high heat at the caliper-side hose crimp. NHTSA's vehicle testing suggests that the conditions necessary to produce the critical temperatures in the subject components result from drive-soak intervals that can occur during the Sacramento training program. NHTSA's testing of hose assemblies returned from police interceptor service did not identify any evidence of thermal degradation. NHTSA has not confirmed any incidents of caliper crimp failures due to overheating in vehicles not subjected to the Sacramento training course driving. The low number of hose assembly failure reports and the absence of any verified incidents of heat related front brake hose crimp failures since 2015 suggests that the Sacramento PD incidents resulted from conditions unique to the training program.

A safety related defect trend has not been identified at this time and further use of Agency resources does not appear to be warranted. Accordingly, this investigation is closed. The closing of this investigation does not constitute a finding by NHTSA that a safety-related defect does not exist. The Agency will take further action if warranted by the circumstances. For additional information, see the Closing Report in the document file for EA15-005 on www.nhtsa.gov.

Subject. Under certain operating conditions, the front brake hose may separate from the caliper side hose crimp joint, resulting in partial system failure (loss of primary or secondary hydraulic circuit). Partial system failure results in increased pedal travel and an approximately 50 percent reduction of maximum braking capability.

EA No.: EA15-005 **Date Opened:** 28-Sep-2015 **Date:** 02-Nov-2018

Subject vehicles. The subject vehicles are model year (MY) 2013 through 2015 Ford Explorer Police Interceptor vehicles. The subject hose assemblies are also used in MY 2013 through 2015 civilian Explorer vehicles.

Figure 1. 2015 Ford Explorer Police Interceptor (left) and Civilian (right) vehicles.

Basis. On April 29, 2015, the Office of Defects Investigation (ODI) opened PE15-017 to investigate a report alleging incidents of front brake hose failures in 2015 Ford Explorer Police Interceptor vehicles used by the Sacramento Police Department in its police pursuit training program (ODI VOQ No. 10705832). To date, the Sacramento police fleet has reported a total of 7 front hose failures to both ODI and Ford. The failures have occurred in 5 different Explorer Police Interceptor vehicles used in the Sacramento PD Emergency Vehicle Operation Course (EVOC) training program.

Most of the failures occurred within the first few miles of service on a closed course used for the EVOC program, which includes evasive accident avoidance and pursuit maneuver training. The hose assemblies either leaked at, or pulled completely free from, the caliper-end attachment where the hose is crimped to the steel end fitting (Figures 3 and 4). Most of the failures resulted in a sudden reduction of braking performance that caused the vehicle to run off the intended course. None of the failures resulted in any crashes, injuries or property damage.

On September 28, 2015, ODI upgraded the investigation to an Engineering Analysis (EA15-005) to conduct vehicle testing to assess maximum brake component temperatures under various test conditions, test hose assemblies removed from police interceptor service for any signs of thermal degradation, and further assess field experience for evidence of potential defect trends related to front brake hose caliper crimp joint failures in the subject vehicles.

System description. Ford first offered a Police Interceptor version of the Explorer in MY 2013. The subject vehicles are equipped with a 4-wheel heavy duty brake system that included larger mass rotors, larger brake calipers, and heavier duty pads. Ford expanded the application of the heavy duty brake system as standard equipment on MY 2013 and later Explorer XLT, Explorer Limited, and Explorer Sport trim versions. Base trim level and all MY 2011 through 2012 Explorer vehicles use the standard duty brake system.

The front and rear rotors and calipers in the heavy duty brake system are industry standard grey cast iron material. The front and rear calipers are the same between retail and police interceptor units with two

exceptions. The front caliper piston material (304 stainless steel) and piston boots (silicon rubber) are upgraded in the police interceptor units to handle higher operating temperatures. The original equipment friction material is industry standard semi-metallic material used in performance applications.

Partial system failure. The subject vehicle brake system is split diagonally ("X-split"). Front brake hose assembly failure on either side results in loss of brake pressure at the associated front wheel and at the opposite side rear wheel. Federal Motor Vehicle Safety Standard (FMVSS) No. 135, Light vehicle brake systems, testing conducted by Ford shows that maximum deceleration capability drops from approximately 1.0 g (22 mph/s) with full system performance to 0.5 g (11 mph/s) after a partial system failure (50 percent reduction). Brake pedal travel increases from about 3.0 to 3.4 inches with full system performance to about 4.2 to 4.6 inches after a partial system failure (30 to 40 percent increase).

Design history. The front brake hose assemblies used in the subject vehicles are distinct from earlier and later production Explorer vehicles by the absence of steel tubes ("banjo tubes") between the banjo block and caliper side crimp joint (Figures 5-7). Table 1 summarizes the changes that eliminated the banjo tubes near the beginning of MY 2013 Explorer vehicles in June 2012 and later added banjo tubes to accommodate the addition of a ride height sensor in late MY 2015 Explorer production.

Date Part Incorporated into Vehicle Production	Description of Change	Reasons for Change	Modified Service Part Numbers	New Component Availability Date for Service
25-Jun-2012 (Job #2, MY 2013)	Removed banjo tube and lengthened hose	Material Cost Reduction (MCR)	DB5Z-2078-B - Right DB5Z-2078-A - Left	May-2012
06-Apr-2015	New brake jounce hose including a banjo tube at the current crimp location and a slightly longer hose	Routing changes necessary to accommodate addition of a ride height sensor	DB5Z-2078-F - Right FB5Z-2078-A - Left	Nov-2015

Table 1. 2013-2015 Explorer Police/Civilian Front Jounce Hose Significant Part Changes.

Subject brake hose. The brake hose construction for both the subject hose assembly and the 2016 hose assembly consists of five layers (Figure 2): 1) Inner Tube – carries the brake fluid; 2) Inner Braid – provides structure to hold internal pressure; 3) Friction Layer – separates two braids; 4) Outer Braid – provides additional structure to hold internal pressure; and 5) Outer Cover – protects the Outer Braid from the elements. The maximum design operating temperature for the subject brake hose and subject caliper crimp joint is 120°C (248°F).

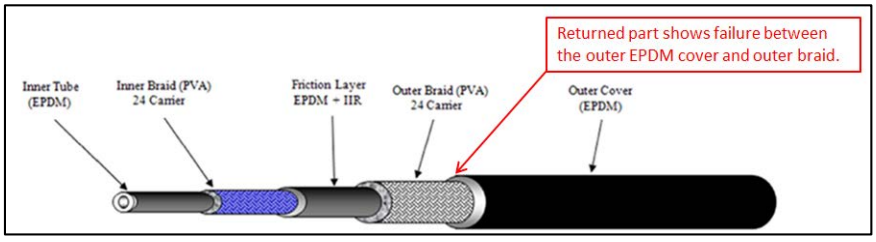

Figure 2. Subject Hose Construction.

Sacramento EVOC. The Sacramento Police Department EVOC training program consists of continuous intervals of short (5-10 minute) driving exercises separated by longer (8-15 minutes) periods in which the vehicle sits stationary so the trainers can review driver performance (hot soak intervals). The number of turns, speed, and driver skill are all factors in the times to complete each driving cycle. Sacramento strongly discourages two-foot driving in the EVOC course and does not use or teach such a method in the training.

The EVOC driving involves three different exercises: 1) Controlled Braking; 2) Collision Avoidance; and 3) City Street Hazard Complex Exercise (Pursuit Driving). The course is a multiple-option turn points course that could be zig-zagged at multiple intersections and run in any direction. During the EVOC driving cycle, vehicles are subjected to repeated and continual hard throttle and brake applications with virtually no operation at steady, cruising speeds (Figure 8). This results in substantial heat build-up in the brake rotors by the end of each training run (Figure 9), as heat is generated in rotors faster than it can be dissipated and there are no periods between the hard accelerations and braking during which the ventilated brake rotors would be able to dissipate heat most efficiently by forced convection.[1]

Ford assessment. Based on supplier (Hitachi) laboratory inspection of failed parts returned from Sacramento EVOC vehicles, testing of the subject crimp strength at elevated temperatures, and vehicle testing conducted to reproduce EVOC training course operating conditions, Ford concluded that the failures were caused by extreme use and duty cycle conditions unique to the Sacramento EVOC training course:

> ***Ford's analysis of the returned parts from the Sacramento Police Department identified the root cause of the failure as exposure to extreme heat at the jounce hose crimp joint on the caliper side, in combination with the added force of multiple electronic brake impulses resulting from their unique driver training course and procedures. In addition, all four reports related to the alleged defect from the Sacramento Police Department involved vehicles that were either currently or previously used for training purposes on this course. Ford is not aware of any other similar failures on any of the other subject or peer vehicles. Therefore, Ford believes this failure to be the result of an extreme usage and duty cycle unique to the Sacramento Police Department's pursuit training course and not a design or manufacturing defect.***

NHTSA testing. NHTSA's Vehicle Research and Test Center (VRTC) in East Liberty, Ohio, conducted testing to assess factors affecting front brake component temperatures, conditions necessary to exceed critical operating temperatures for the subject hose assembly, and service part testing to assess the strength of front hose assemblies removed from police interceptor vehicles in the Columbus, Ohio area. The vehicle testing involved duplication of the EVOC training course simulated pursuit driving and hot soak intervals with two test drivers. VRTC also conducted testing to monitor brake component temperatures while intentionally causing brake friction fade or brake fluid vaporization by repeated accelerations to 45 mph followed by hard (50 lb) brake applications to 15 mph (brake snubs) until brake fade occurs or the brake fluid boils as indicated by pedal drop. For each of the tests, the vehicles were equipped with a subject front hose assembly on one side and a 2016 front hose assembly on the opposite side to compare component temperatures under similar operating conditions. Temperature data was collected for the outer caliper housing adjacent to the banjo block, the banjo block, the caliper-side crimp and the outer hose cover adjacent to the crimp.

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[1] Heat is transferred from the rotors by radiation, convection and conduction. Heat transfer by convection decreases by an order of magnitude when the vehicle is stopped.

Table 2 summarizes the results of VRTC's vehicle testing, showing the maximum temperatures achieved in each test. The highest caliper crimp temperature was recorded with a subject hose assembly in the EVOC training cycle with the first driver (VRTC Test #1). The temperature was reached toward the end of the fourth hot-soak interval of the testing (Figure 10). Substantially lower temperatures were recorded for the opposite side 2016 hose assembly in the same test (Figure 11). EVOC simulation testing by the second driving produced much lower temperatures for both the subject and 2016 hose assemblies (VRTC Test #2). In the over-temperature/brake snub testing with subject and 2016 hose assemblies (VRTC Test #3, Figures 12 and 13), the caliper crimp temperatures were much lower than the peak testing observed in the simulated EVOC training.

CPD Ford Explorer on a Simulated EVOC Course at VRTC Maximum Temperatures at Each Location on Test							
VRTC Test #	**Course**	**Hose Location**	**Hose Design Level**	**Caliper Housing °C (°F)**	**Banjo Block °C (°F)**	**Metal Crimp °C (°F)**	**Rubber Hose °C (°F)**
1	EVOC Driver #1 (drive & soak intervals)	**Left Front**	**Subject Hose**	**179 (354)**	**165 (329)**	**134 (273)**	**112 (233)**
		Right Front	2016 Hose	167 (333)	154 (309)	101 (214)	85 (185)
2	EVOC Driver #2 (drive & soak intervals)	Left Front	2016 Hose	114 (237)	104 (220)	76 (168)	72 (162)
		Right Front	**Subject Hose**	**116 (241)**	**108 (227)**	**97 (207)**	**72 (162)**
4	Over Temp (driving brake snubs to fluid boil)	Left Front	2016 Hose	164 (327)	102 (215)	64 (148)	76 (168)
		Right Front	**Subject Hose**	**164 (328)**	**103 (218)**	**60 (140)**	**68 (155)**

Table 2. VRTC dynamic brake overheat test summary.

The VRTC testing demonstrated that most of the temperature increases observed in the subject caliper crimp joints occurred during the hot soak periods of the simulated EVOC training cycle, rising most rapidly at the beginning of each hot soak period and reaching progressively higher temperatures with each successive hot soak. Under the same test conditions, the same patterns were observed for the 2016 hose assemblies, but with significantly lower maximum crimp temperatures. When tested to intentionally overheat the brakes, with repeated 45 to 15 mph brake snubs until the brake fluid boiled, the crimp joint temperatures were marginally lower than the hose temperatures, indicating that the mechanism of heat transfer from this condition may have been from the inside-out through the brake fluid rather than by heat conducted from the banjo block to the crimp ferrule.

VRTC also conducted tensile tests on 21 subject hose assemblies from 10 police interceptor vehicles, including a hose assembly removed from the opposite side of a Sacramento EVOC incident vehicle and hoses used in the VRTC EVOC testing (Figure 14). This testing did not identify any concerns with thermal degradation or loss of strength of the subject crimp joints. All of the hoses met the tensile strength requirements of Federal Motor Vehicle Safety Standard (FMVSS) No. 106, Brake Hoses, with

failures occurring above 325 lb, although one hose failed at 326 lb[2]. Only two of the hoses failed in the alleged defect mode, crimp separation. One of these was the hose from the Sacramento EVOC incident vehicle (Hose #42, 4,400 miles, 510 lb) and the other was from the VRTC test vehicle (Hose #8, 42,138 miles, 578 lb).

Problem experience. Table 3 summarizes all additional field data related to failures at or near the caliper-side crimp joints of the front brake hose assemblies in the subject vehicles by vehicle application and model year (the Sacramento fleet is not included in this table). There are multiple potential causes of front brake hose failure, including damage from road hazards and mishandling during routine brake maintenance (e.g., brake pad replacement). The field experience does not indicate a defect trend. None of the reports or claims involved verified caliper-side crimp failures related to extreme heat (the Sacramento failure mechanism).

Vehicle Application	Model Year	Production	Reports		Warranty Claims	
			Count	Rate (R/100k)	Claims	Rate (%)
Explorer Police Interceptor	2013	10,259	0	0.0	10	0.10
	2014	19,199	4	20.8	17	0.09
	2015	20,275	3	14.8	6	0.03
	Total	**49,732**	**7**	**14.1**	**33**	**0.07**
Explorer Civilian	2013	162,804	0	0.0	10	0.01
	2014	188,716	0	0.0	19	0.01
	2015	167,291	0	0.0	6	0.00
	Total	**518,811**	**0**	**0.0**	**35**	**0.01**

Table 3. Subject Vehicle Field Data.

Reason for closing. The alleged defect results from exposure to extremely high heat at the caliper-side hose crimp. NHTSA's vehicle testing suggests that the conditions necessary to produce the critical temperatures in the subject components result from drive-soak intervals that occur during the Sacramento EVOC training program duty cycle. Testing of hose assemblies returned from police interceptor service did not identify any evidence of strength reduction, degraded crimp joint integrity or thermal degradation.

NHTSA has not confirmed any incidents of caliper crimp failures due to overheating in vehicles not subjected to the Sacramento EVOC training course driving. The subject components have been replaced by the redesigned 2016 hose assemblies in all of the Sacramento PD vehicles. The low number of hose assembly failure reports and the absence of any verified incidents of heat related front brake hose crimp failures since 2015 suggests that the EVOC incidents resulted from conditions unique to the training program.

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[2] Hose #20 failed from tearing of the outer braid near the caliper crimp. This is not the same failure mode as the alleged defect, complete or partial separation from the crimp ferrule.

FIGURES

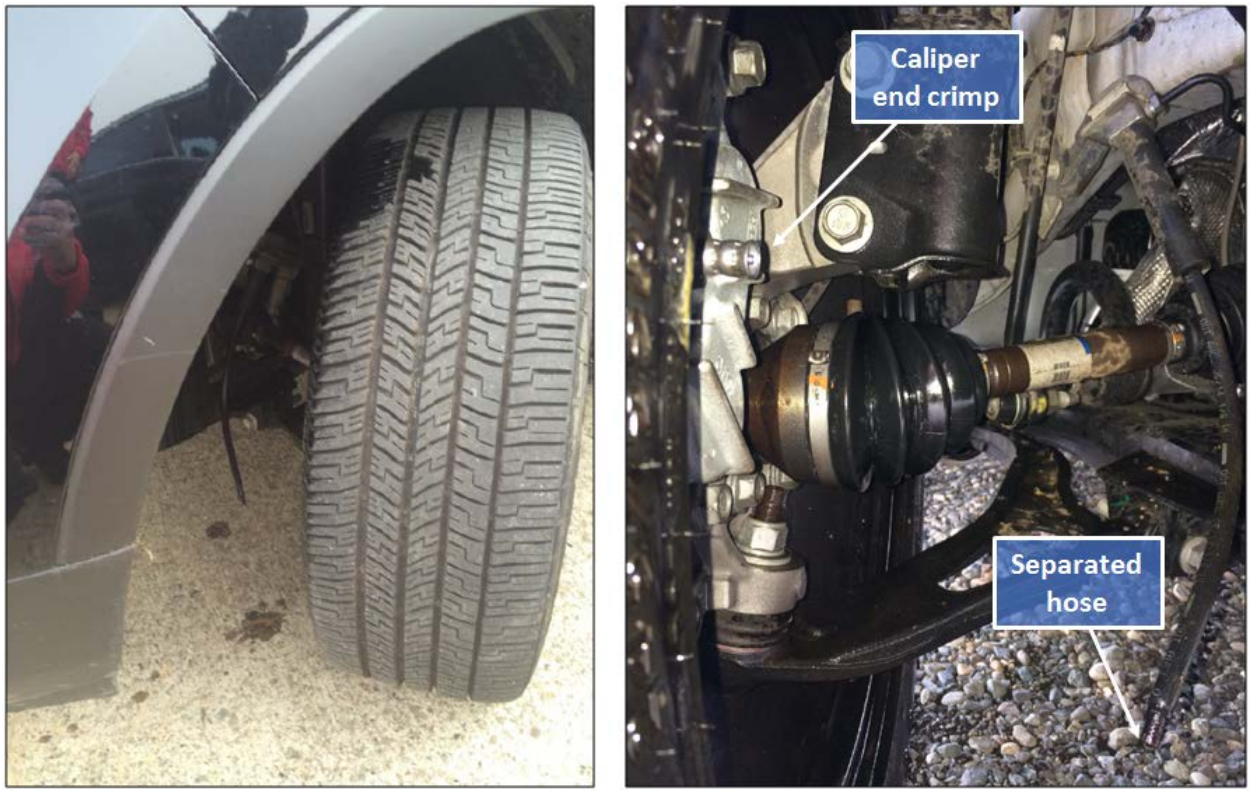

**Figure 3. Sacramento EVOC training hose failures,
left front brake hose (left) and right front brake hose (right).**

Figure 4. Sacramento EVOQ crimp failure mode.

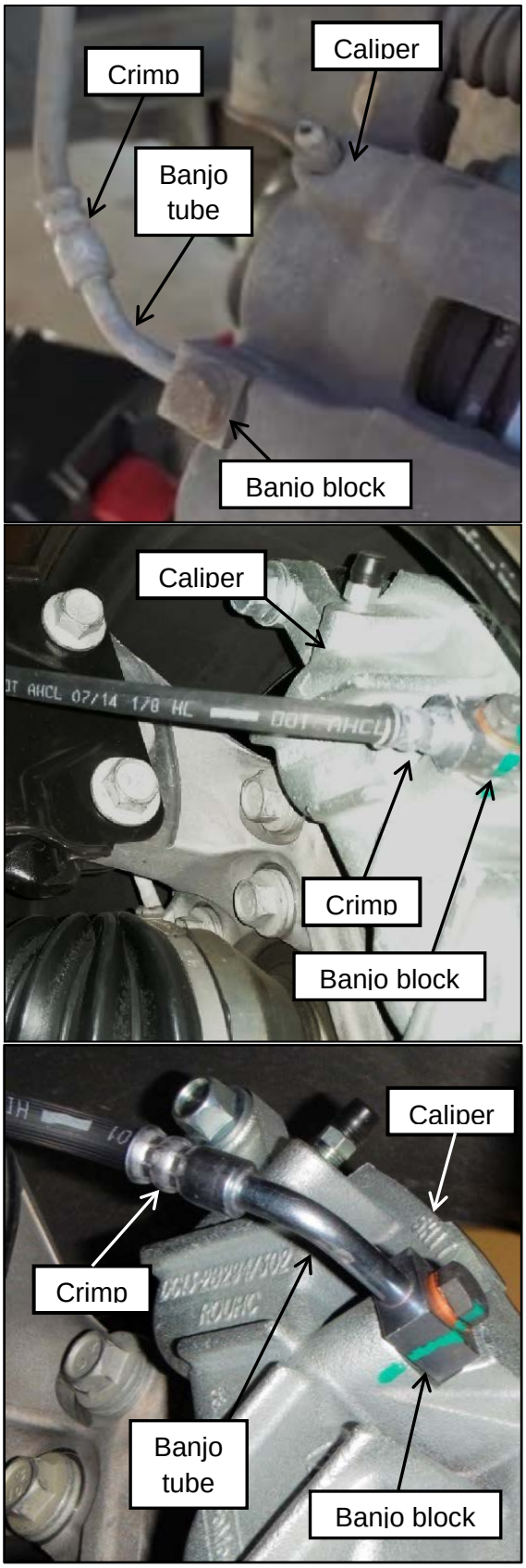

Figure 5. MY 2011-12 hose assembly, with banjo tube (top); Subject MY 2013-15 hose assembly, no banjo tube (middle); and MY 2016-18 hose assembly, with banjo tube (bottom).

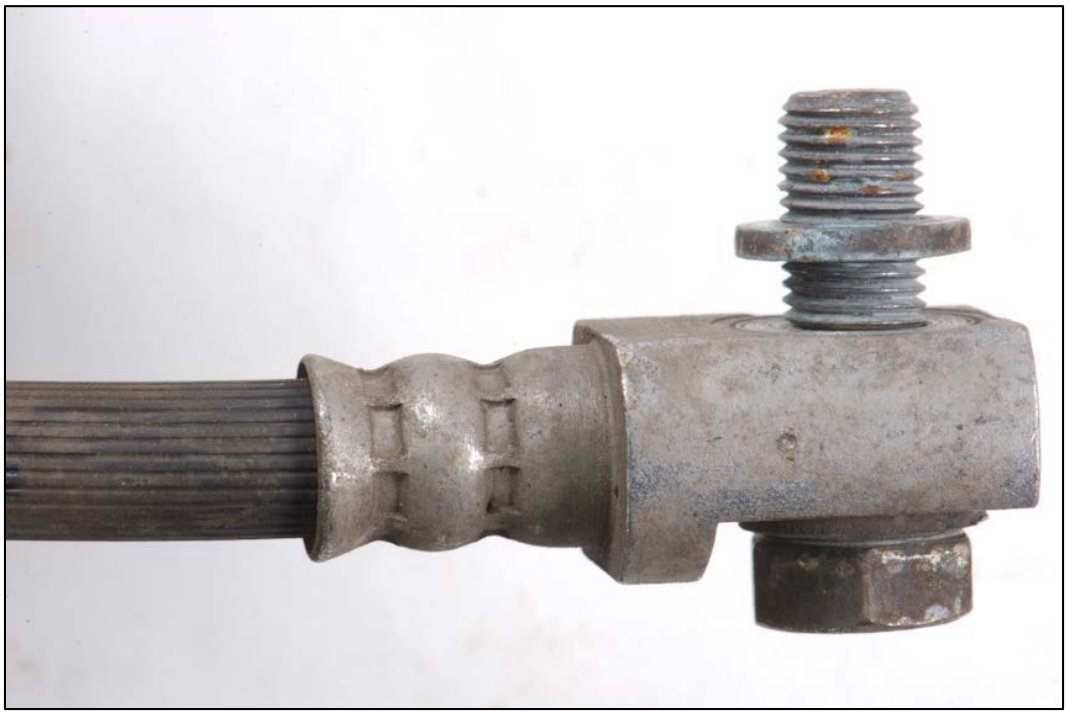

Figure 6. Caliper-side crimp, subject hose assembly (MY 2013-2015).

Figure 7. Caliper-side crimp, 2016 hose assembly.

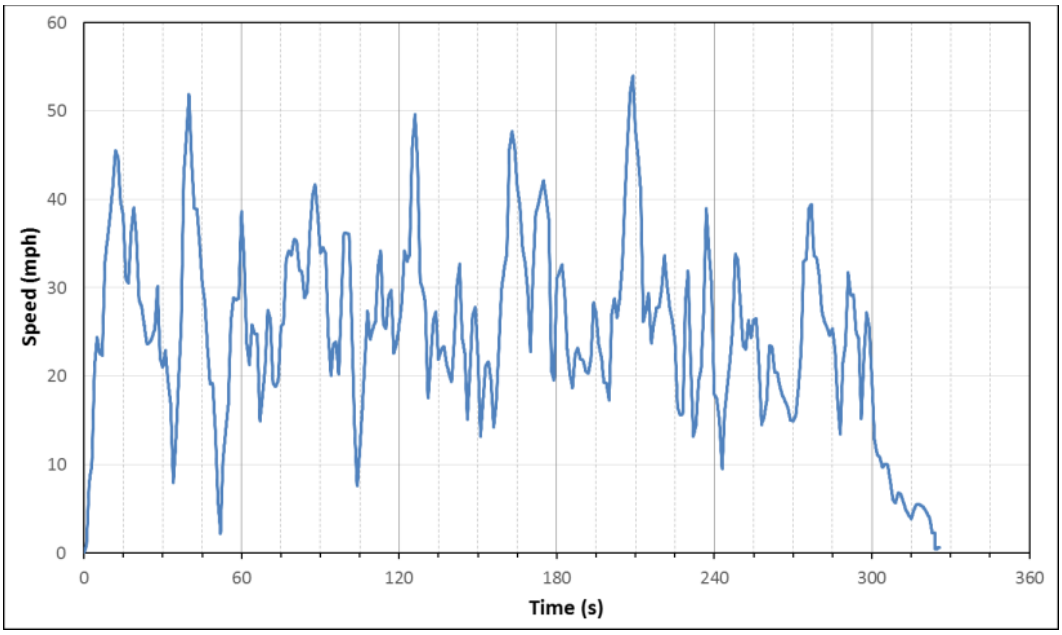

Figure 8. Typical Sacramento EVOC pursuit training speed profile.

Figure 9. Brake rotor heating during Ford EVOC reproduction testing.

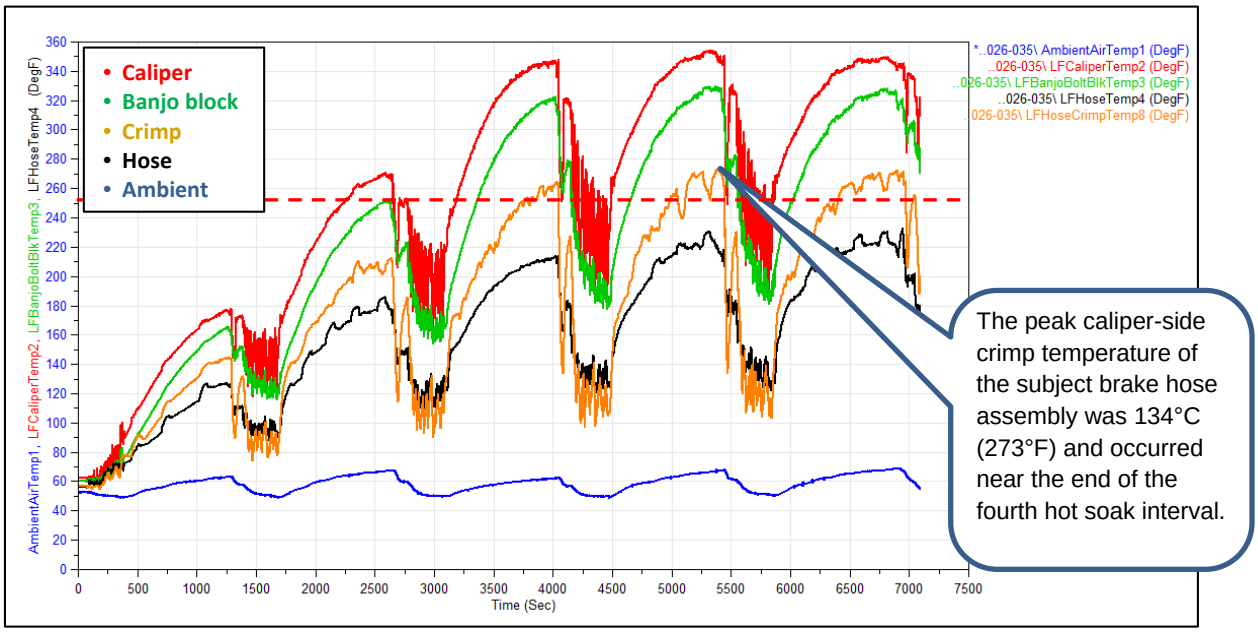

Figure 10. Subject brake hose assembly component temperatures in EVOC training with simulated pursuit driving and hot soak intervals, left front.

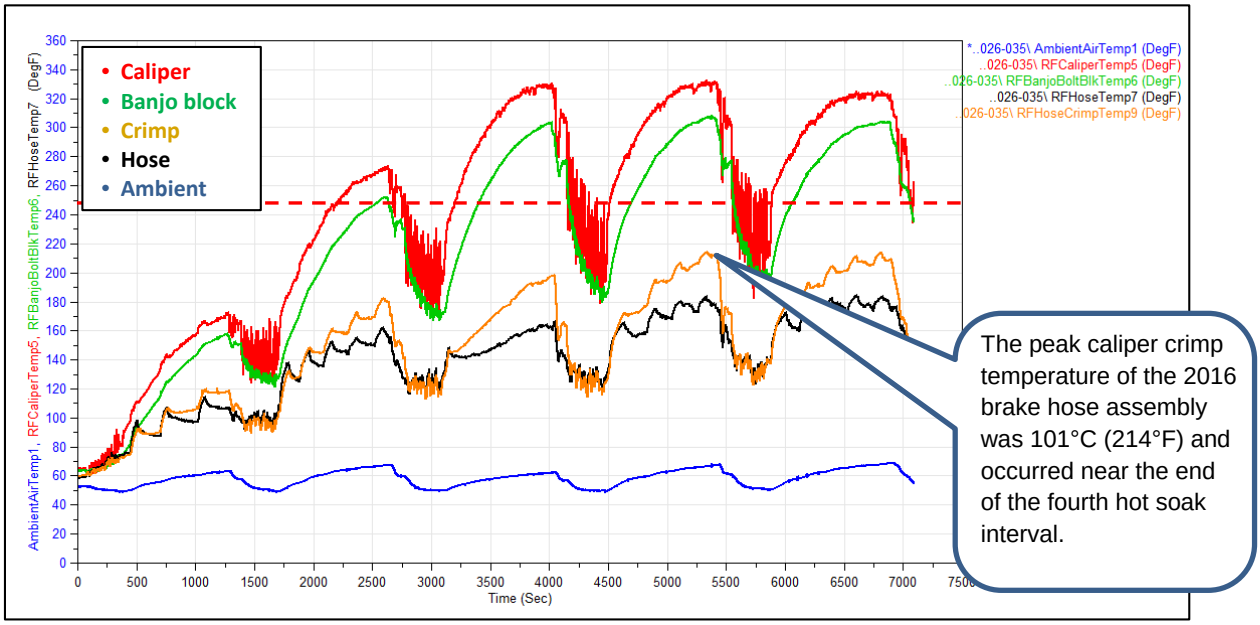

Figure 11. 2016 brake hose assembly component temperatures in EVOC training with simulated pursuit driving and hot soak intervals, right front.

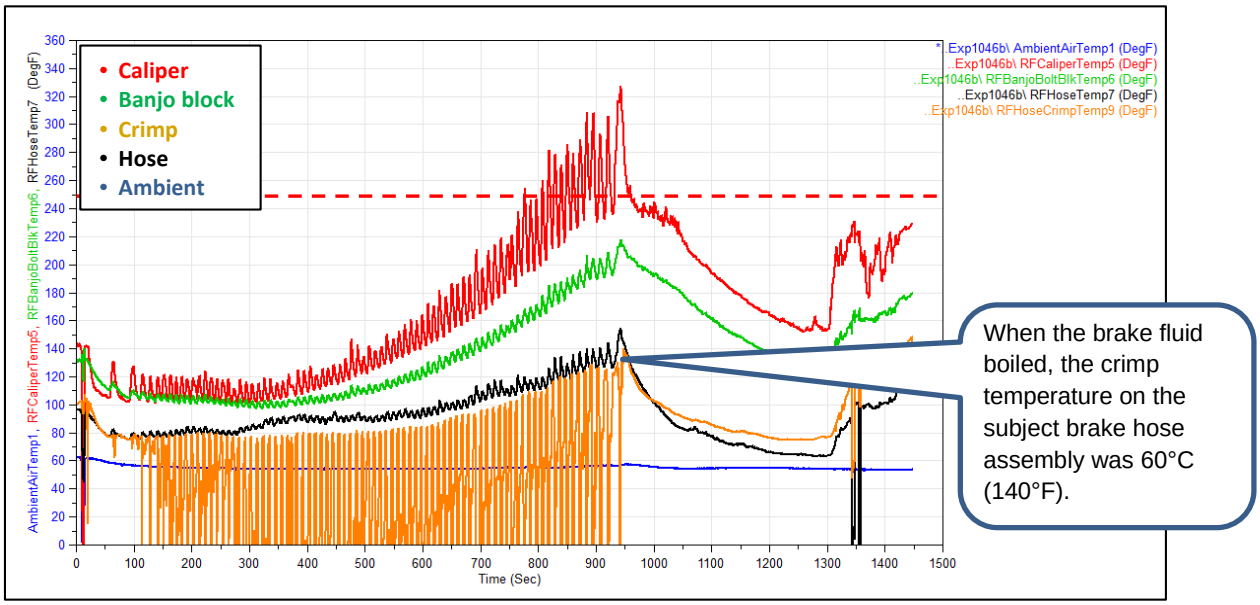

Figure 12. Subject brake hose assembly component temperatures in VRTC brake fade testing, right front wheel.

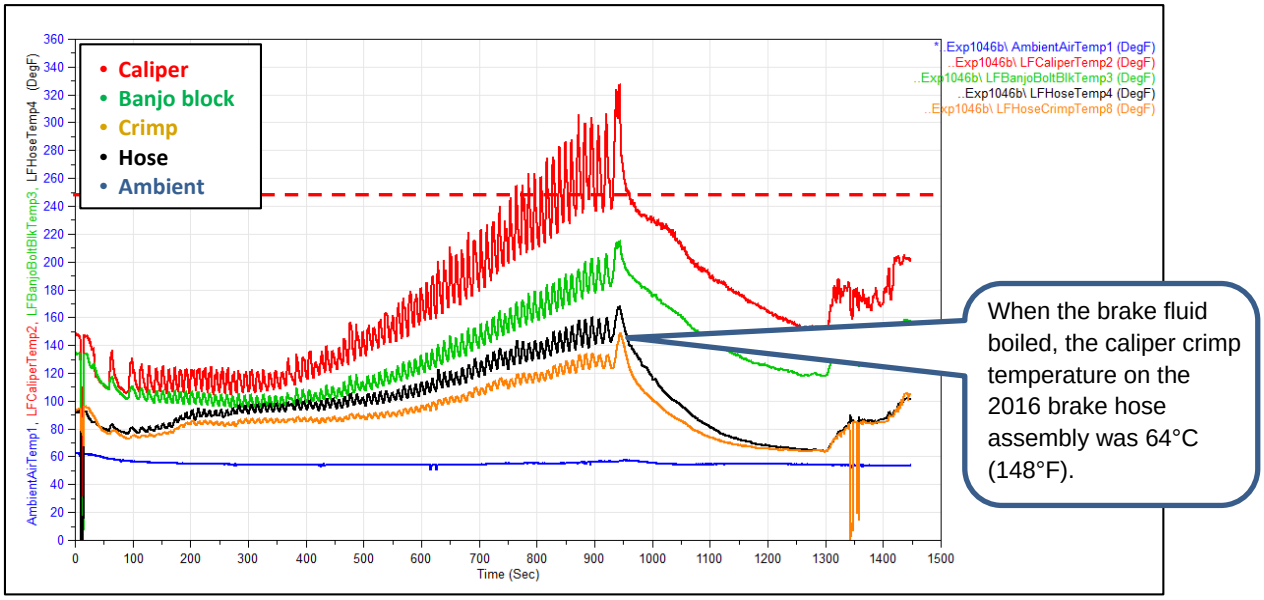

Figure 13. 2016 brake hose assembly component temperatures in VRTC brake fade testing, left front wheel.

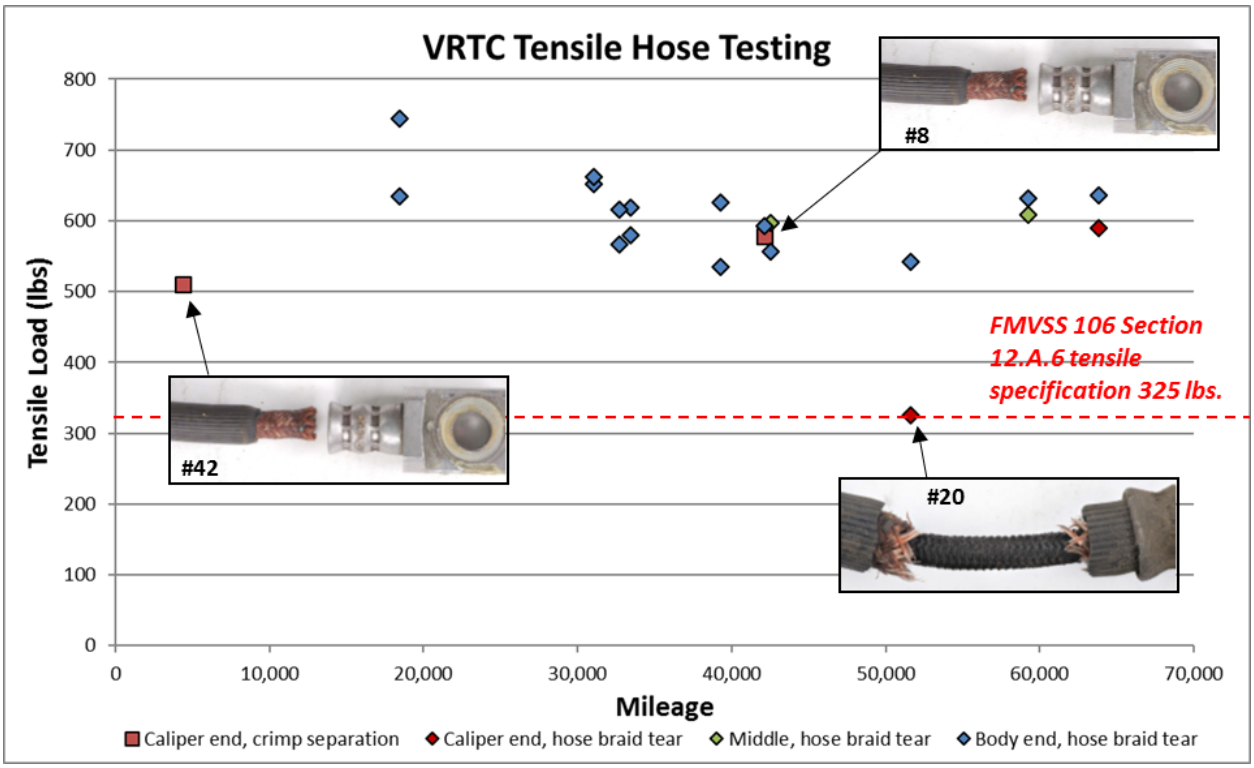

Figure 14. VRTC Tensile Hose Testing Results.