

NATIONAL TRANSPORTATION SAFETY BOARD

Office of Research and Engineering
Materials Laboratory Division
Washington, D.C. 20594



August 16, 2018

MATERIALS LABORATORY FACTUAL REPORT

Report No. 18-064

A. ACCIDENT INFORMATION

Place : Reno, Nevada
Date : May 1, 2018
Vehicle : Thunder Mustang
NTSB No. : WPR18FA131
Investigator : Elliott Simpson, AS-WPR

B. COMPONENTS EXAMINED

Water pump assembly with separated pulley, fractured attachment cap screw piece, 2 washers, serpentine belt, and exemplar pulley, attachment cap screw, and washer from a Falconer V12 engine.

C. DETAILS OF THE EXAMINATION

An overall view of the submitted components is shown in figure 1. Four attachment cap screws for attaching the water pump pulley to the flange on the water pump assembly were fractured. Fractured shank pieces of the four attachment screws remained within the flange shown in figure 2. An attachment screw head piece and 2 washers were received as shown, and a second screw head piece with its washer was embedded within one of the pulley attachment holes. The serpentine belt was partially fractured and deformed, and a portion of the belt was trapped between the pulley flange and the water pump housing. An exemplar water pump pulley, attachment cap screw, and washer were also submitted as shown in figure 1. The engine had reportedly been overhauled 6 hours before the accident.

The pulley attachment flange surface shown in figure 2 was rough consistent with heavy fretting contact damage. The mating face of the pulley also similar heavy fretting contact features. The pulley had been attached with four attachment screws, and the screws were arbitrarily numbered clockwise as viewed looking at the attachment flange as shown in figure 2.

Closer views of the fracture surfaces of the attachment screws are shown in figure 3. Greasy deposits had covered some of the fracture features on screws 1, 2, and 4, so those screws were cleaned with a soft bristle brush using a solution of Alconox detergent and warm water, and the cleaned surfaces are shown in figure 3. The fracture surface of screw 1 mated to the fracture surface of the fractured screw head piece shown in figure 1. The fracture surface of screw 3 appeared to mate with the screw piece

embedded in the pulley. Portions of the screw fracture faces had relatively smooth features oriented perpendicular to the fracture surface with curving crack arrest lines, features consistent with fatigue fracture. Unlabeled brackets in figure 3 indicate fatigue origin areas on each of the screws. Screw 1 had multiple fatigue origins located around its circumference with fracture on multiple planes, a feature consistent with the first screw to fracture in the attachment assembly. Screw 2 had relatively prominent crack arrest lines with a fracture origin area located at one side of the screw, features consistent with fatigue fracture under relatively higher cyclic stresses. Screw 3 had small fatigue regions with multiple origins around the circumference, and the remainder of the fracture surface had matte gray features consistent with ductile overstress fracture. Screw 4 had relatively smooth fracture features with crack arrest marks extending across most of the fracture and origins located around much of the circumference.

Next, attempts were made to extract the pulley attachment flange from the shaft using a puller, but the attachment flange did not move with the available pulling device. Alternatively, the attachment flange was cut along the dotted lines shown in figure 2 to facilitate an examination of the screw 3 threads. After the first cut was made to remove an arc portion of the flange, a Dremel tool was used to cut a slot in the back side of the attachment screw shank. Then a screwdriver was inserted in the slot to turn the screw. The screw turned about $\frac{1}{2}$ of a turn before the screwdriver slipped out of the slot, and no additional turns were possible without the screwdriver slipping out of the cut slot.

Next, cuts were made along the radial dashed lines in figure 2 toward the screw to separate the flange piece into 2 pieces. A view of the resulting exposed threads for screw 3 are shown in figure 4. A powdery orange deposit consistent with iron oxide was observed on the threads. Upon closer inspection as shown in figure 4, black deposits were observed in the space between the screw threads and the flange threads. The black deposits were probed while viewed under a stereomicroscope using a scalpel, and the material flaked into small pieces with little effort as it was probed.

A sample of the black deposit removed from the screw 3 threads was examined using a Fourier Transform Infrared (FTIR) spectrometer with a diamond attenuated total reflectance (ATR) accessory in accordance to ASTM E1252-98.¹ The spectrometer was used to collect and process infrared wavelength absorbance spectra of the unknown material(s).

The spectrum for the unknown contained the following combination of spectral peaks corresponding to particular functional groups found within molecular structure of the material. The presence of a low, broad peak at $\sim 3200\text{ cm}^{-1}$ is indicative of an oxygen-hydrogen bond (O-H). The presence of a strong doublet peak between $\sim 2910\text{ cm}^{-1}$ and $\sim 2850\text{ cm}^{-1}$ is indicative of a carbon-hydrogen (C-H) single stretching bond. The presence of a single peak at $\sim 1670\text{ cm}^{-1}$ is indicative of a carbon-oxygen (C=O) double bond. The presence of a single peak at $\sim 1450\text{ cm}^{-1}$ is indicative of a carbon-hydrogen₂ (C-H₂) bending bond. A peak at $\sim 1130\text{ cm}^{-1}$ is indicative of a carbon-oxygen (C-O)

¹ American Society for Testing Materials E1252-98: *Standard Practice for General Techniques for Obtaining Infrared Spectra for Qualitative Analysis*, ASTM International, West Conshohocken, Pennsylvania (1998).

stretching bond. The presence of a single peak $\sim 700\text{ cm}^{-1}$ is indicative of multiple carbon-hydrogen₂ (C-H₂) bending bonds. Based on peak heights and peak resolution, the sample was present in a very small amount and/or was degraded. The spectrum was consistent with a methacrylate. A spectral library search was performed on the unknown material spectrum. There were no strong matches. However, there were some similarities to the spectra of oleic acid and Loctite® 242.

According to the engine manufacturer, blue Loctite is applied to the threads of the pulley attachment screws at installation. According to the Henkel website,² multiple kinds of Loctite® medium strength blue threadlocker are available including Loctite® Threadlocker 242 and Loctite® Threadlocker 243. The website further states that Loctite 243 is an “upgraded version of Loctite 242” and is needed for applications including pulley assemblies.

A view of the aft face of the pulley with embedded attachment screw is shown in figure 5. The areas around the attachment holes were worn away consistent with heavy contact wear with the washers. Thread impressions were also observed in the holes consistent with heavy contact with the threads of the attachment screws.

Hardness tests were conducted on the head piece from screw 1 and the exemplar screw. To facilitate testing, transverse cuts were made through the threaded shanks adjacent to the head, and the cut surface was polished to a 4000-grit finish. Hardness tests were conducted on the polished surfaces using a Rockwell superficial hardness tester. The average hardness was 41.7 HRC (61.1 HR30N) and 41.5 HRC (60.8 HR30N) for the screw 1 and the exemplar screw, respectively. According to ASTM Standard A370-12a,³ the measured average hardness values for screw 1 and the exemplar screw correspond to tensile strengths of approximately 191,000 psi and 192,000 psi, respectively.

According to the engine manufacturer, Grade 8 socket head cap screws torqued to 18 pound feet are used to attach the pulley. Grade 8 socket head cap screws have a minimum tensile strength of 180,000 psi.

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² <http://henkeladhesivesna.com/blog/blue-threadlocker-basics/> dated February 20, 2014, and accessed August 16, 2018.

³ ASTM International Standard A 370 – 12a, *Standard Test Methods and Definitions for Mechanical Testing of Steel Products*, Annual Book of ASTM Standards, ASTM International, West Conshohocken, Pennsylvania (2014)

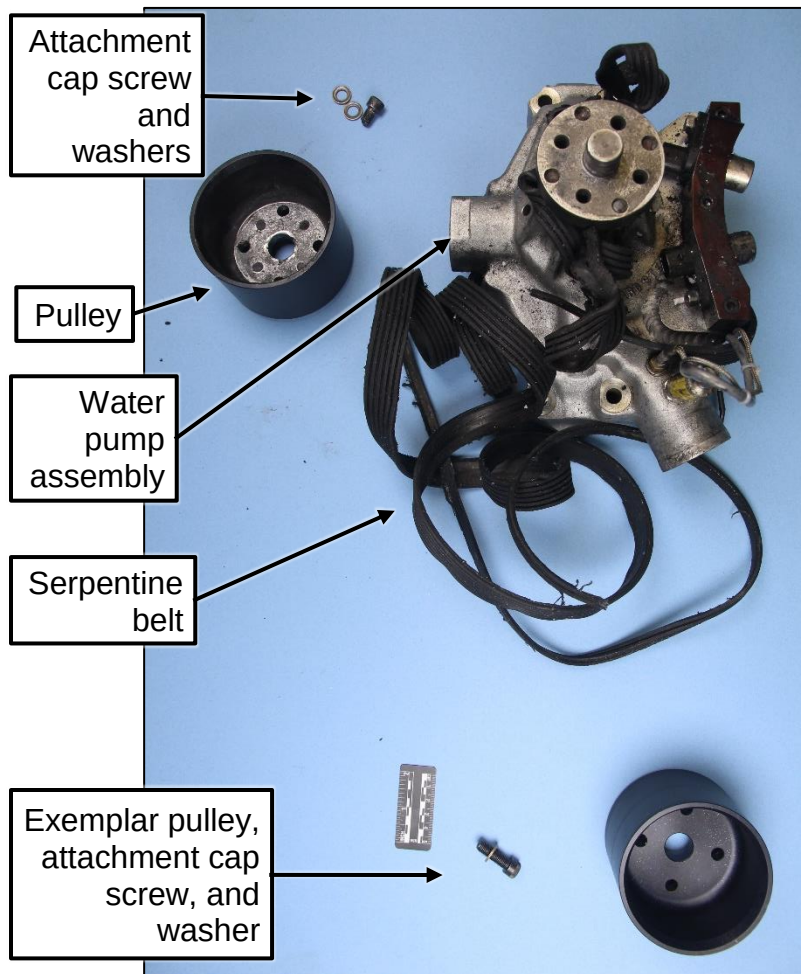


Figure 1. Overall view of the submitted components.

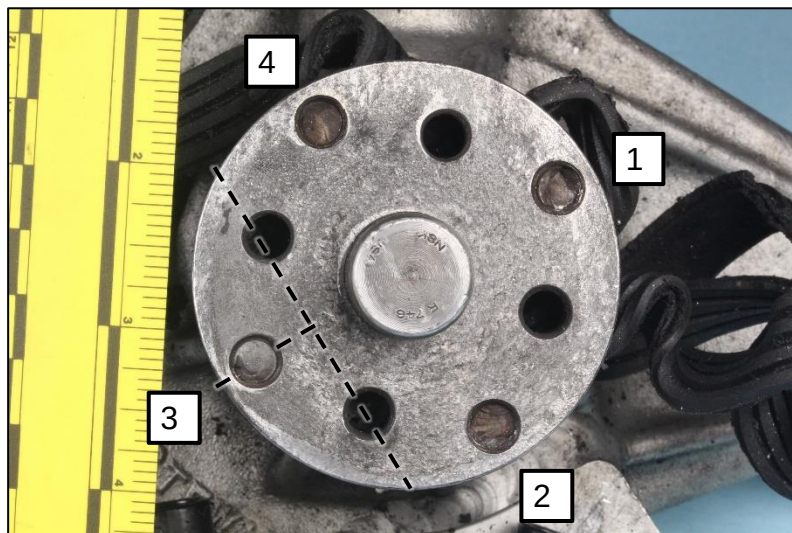


Figure 2. Close view of the pulley attachment flange on the water pump. Attachment cap screw locations were arbitrarily numbered as shown. Dashed lines indicate cut locations.

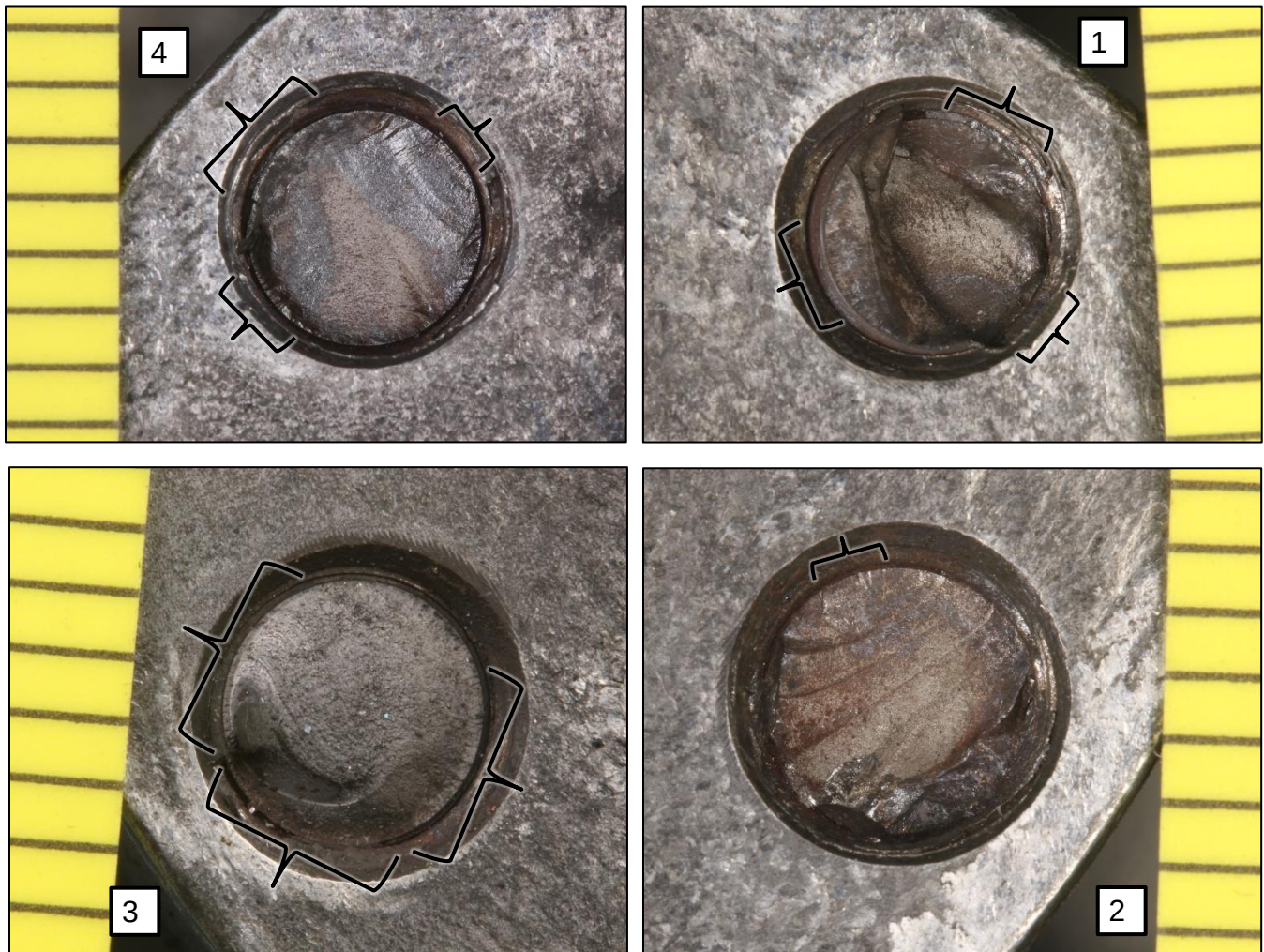


Figure 3. Closer view of the pulley attachment cap screw fractures after cleaning.

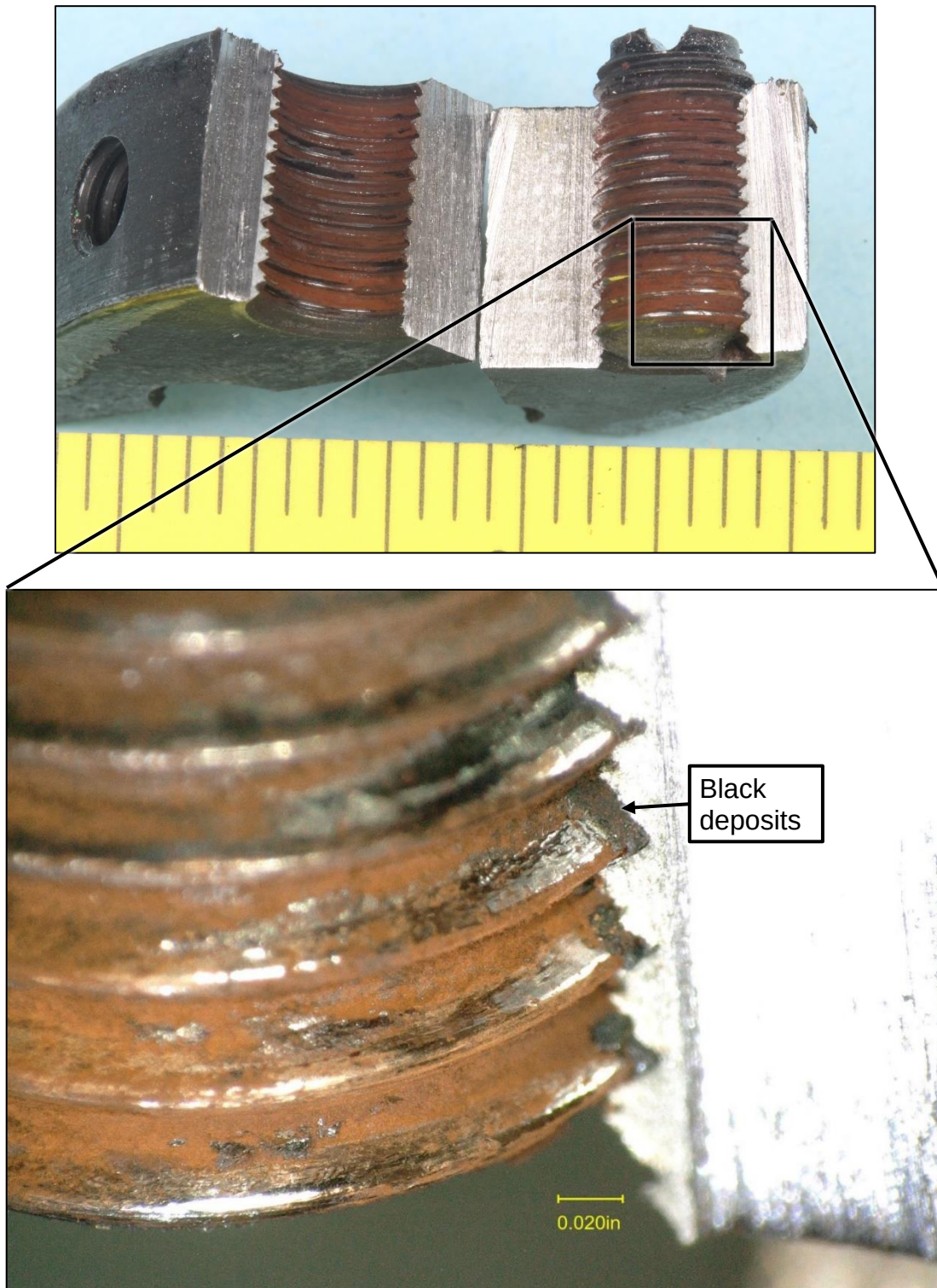


Figure 4. Views of the cap screw 3 threads after cutting along the dashed lines shown in figure 2.



Figure 5. View of the forward face of the pulley with a trapped attachment cap screw and washer.