NATIONAL TRANSPORTATION SAFETY BOARD

Office of Aviation Safety
Aviation Engineering Division
Washington, DC 20594

December 16, 2009

AIRWORTHINESS FACTUAL ADDENDUM
LIGHTBULB RE-EXAMINATION AND STUDY

A. **ACCIDENT:** DCA08MA098

LOCATIONS: Columbia, South Carolina

DATE/TIME: September 19, 2008

AIRCRAFT: Learjet Model 60, N999LJ, S/N 60-314

B. GROUP MEMBERS:

Chairman: Robert L. Swaim
Washington, DC

C. SUMMARY:

On September 19, 2008, at about 11:53 p.m. EDT, a Learjet Model 60 (N999LJ) operated by Global Exec Aviation as an on-demand passenger flight under 14 CFR Part 135 overran runway 11 while departing Columbia, South Carolina, enroute to Van Nuys, California. The 2 crewmembers and 2 of the 4 passengers were fatally injured, the other 2 passengers suffered serious injuries. The aircraft was destroyed by extensive post-crash fire. Weather was reported as clear with light winds.

Some annunciator lights had been documented previously by the NTSB Materials Laboratory.[1] At the request of a party to the investigation, the annunciator panel lights were retrieved from the storage facility for re-examination. This addendum further documents the condition of each lightbulb.

This addendum also provides reference material related to impact-related filament characteristics. None of the filaments from the accident airplane exhibited the impact-types of stretching shown in the references. The reference material shows that filament distortion typically requires deceleration forces that would not be survivable for a human.

[1] See Materials Laboratory Factual Report 08-134, dated January 22, 2009.

EXAMINERS:

Robert L. Swaim
Washington, DC

Nancy B. McAtee
Washington, DC

D. DETAILS OF THE INVESTIGATION:

BACKGROUND:

The review used the following three references. Each discusses impacts involving lightbulbs, showing that filaments exhibit different characteristics when hot, versus when the filaments are cold.

> Guide to the Impact Behaviour of Aircraft Instrument Panel Lamp Filaments, Australian Department of Defense Report DSTO-TR-2217, October 2008, by B. Grigson
>
> A Guide to Light Bulb Analysis In Support of Aircraft Accident Investigation, Transportation Safety Board of Canada Report TP6255E, Rev 1991, M. R. Poole & M. Vermij
>
> Light Bulb Filament Impact Dynamics Study, Published in 16 ISASI 1985, By M.R. Poole, M. Vermij, T.W. Heaslip

As noted in these and other references from manufacturers of incandescent lightbulbs, tungsten achieves luminosity at about 3000-5000 degrees F and becomes ductile at about 480 F. Variables involved in the stretch of filaments are primarily temperature, impact load, and filament age (migration of heated tungsten over time).

With respect to loads required for filament deformation, hundreds of bulb test specimens had been intentionally damaged by impact at known loads to create the three references. These tests are the source for the chart of probabilistic damage boundaries that is shown in Figure 1. The Australian "Guide to Impact Behaviour" provided further definition to these boundaries.

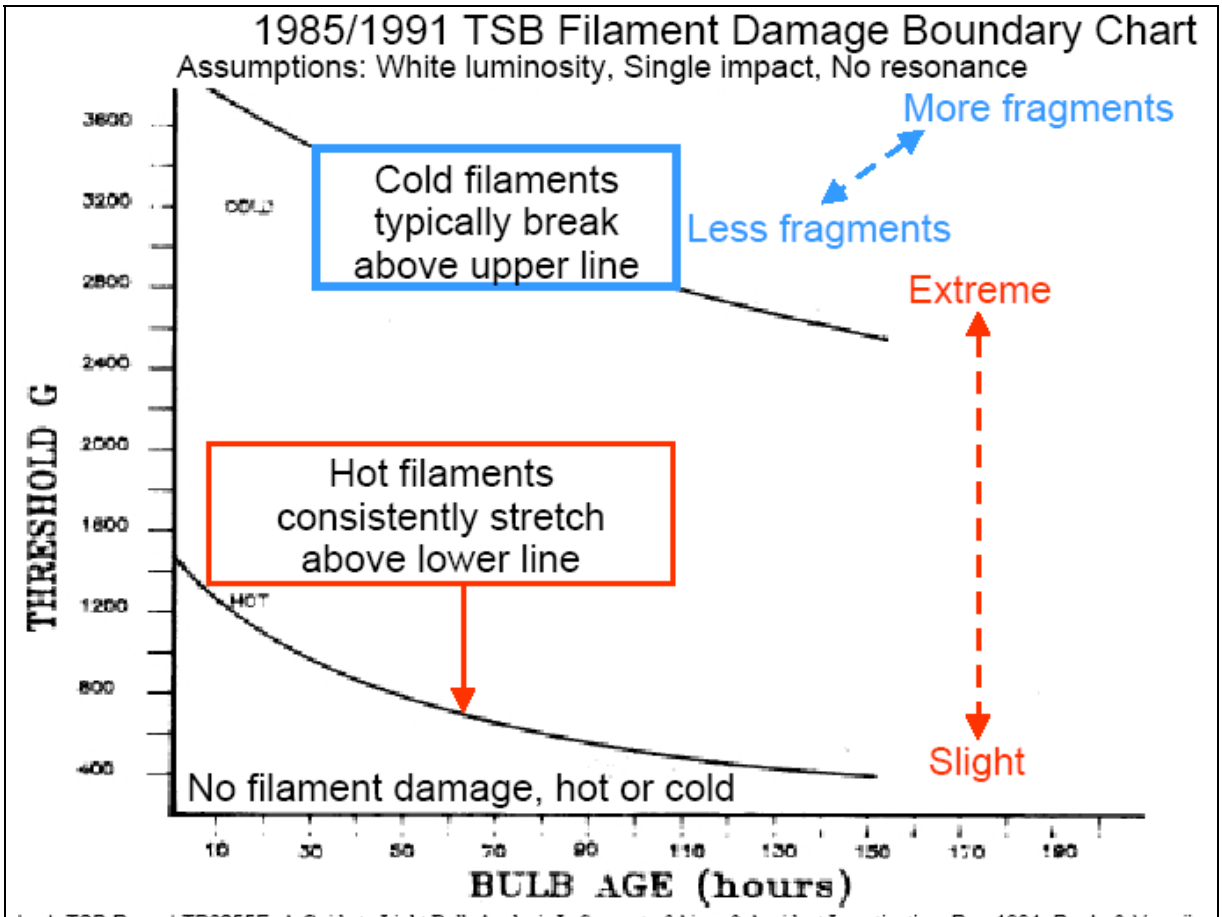


Figure 1. Transportation Safety Board of Canada chart with colored items added to illustrate text that accompanied the original chart. Note that the accident airplane had approximately 110 hours. (Reference value only, refer to Airworthiness Factual Report for airplane history.)

Military tests and research providing deceleration loads survivable for humans were consulted as reference values.[2] As long as the human and bulb were able to experience the same deceleration loads, the probability curves that describe the minimum boundaries for filament deformation (Figure 1) exceed the reference loads for human survival.

LIGHTBULBS FROM ACCIDENT AIRPLANE (N999LJ):

The lightbulbs were re-examined in the NTSB Materials Laboratory and each bulb was photographed for this document. The original Factual Report examined specific

[2] Paper presented at the RTO HFM Lecture Series on "Pathological Aspects and Associated Biodynamics in Aircraft Accident Investigation", held in Madrid, Spain, 28-29 October 2004; Königsbrück, Germany, 2-3 November 2004, and published in RTO-EN-HFM-113., titled Human Tolerance and Crash Survivability, by Dr. Dennis Shanahan. http://ftp.rta.nato.int/public/PubFullText/RTO/EN/RTO-EN-HFM-113/EN-HFM-113-06.pdf

lightbulbs that had been of interest at the time. The re-examination documented those lights and the rest of the forward cockpit annunciator panel.

The bulbs were encased in plastic that had melted and resolidified or charred. (See Figures 2A and 2B) Extraction of the bulbs required softening of the plastic with chemicals and physical probing that resulted in breaking the glass of some bulbs.

Figure 2A. Left portion of annunciator panel from accident airplane, showing melted and charred annunciators prior to excavation and removal.

Figure 2B. Left portion of annunciator panel in a similar airplane.

Two styles of bulb filaments were found that were of the type described in the laboratory reference tests described in the background section of this report. As in the original examination, this second examination found no bulbs with gross filament distortion.[3] Some filaments in bulbs with the glass broken did exhibit bends and other foreign

[3] The right main landing gear filaments were less defined in filament shape and regarded as uncertain.

damage. None exhibited the types or extent of distortion found in the reference test specimens that had experienced impact loads of 1000 G or more.

Damage to each of the accident filaments is shown in Appendix A. Five annunciator assemblies contained four bulbs in each. Each of these annunciator assemblies is documented on a single page of the Appendix. The five annunciators were for:

Captain's Master Caution/Warning,[4]
First Officer's Master Caution/Warning,
Left Main Landing Gear (UNSAFE/DOWN),
Nose Landing Gear (UNSAFE/DOWN),
Right Main Landing Gear (UNSAFE/DOWN)

The majority of the annunciators were of the 2-bulb design. The photographs are presented from the right side of the display to the left. Because each annunciator had 2 bulb receptacles, each bulb photograph begins with a unique descriptor for each bulb, as in the following example:

A1L Rt OIL PRESS

The "A" designates the top of four rows, labeled A, B, C, D.
The "1" designates the column, as counted from what the pilots would view as the right to left. This right to left numbering was used to maintain continuity with the original documentation for the annunciator panel.
The letter "L" or "R" designates whether the bulb came from the left or right receptacle, as viewed by the pilots.
Following the initial A1L is the caption found in a similar airplane for an annunciator in the noted position. For legibility , some captions in this report are less abbreviated than the actual captions found in the airplane.

NOTES:

1. The re-examination numbering convention maintained continuity with the original laboratory work and markings. This is not the same numbering system used by Learjet in Proprietary Specification Control Drawing (6608482), which defined the requirements for the annunciator panel as rows one to four, from top to bottom, and columns A through AE, from left to right.

2. The numbering sequence in this report has gaps because of skipping damaged or blank annunciator positions.

[4] Each of the five annunciator assemblies had an upper legend and lower legend. The master Caution/Warning annunciator assemblies had two bulbs in the upper half as the master warning (WARN) and two bulbs in the lower half as the master caution (CAUT). The halves of each landing gear annunciator were split to illuminate the captions UNSAFE and DOWN.

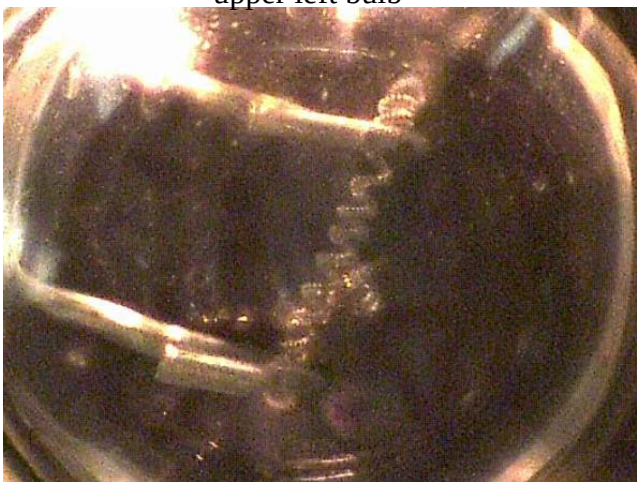
3. Annunciator captions were destroyed by fire. The captions shown are from manufacturer drawings and comparisons with other Model 60 Learjets.

4. The photos have been cropped to maximize the view of the filaments.

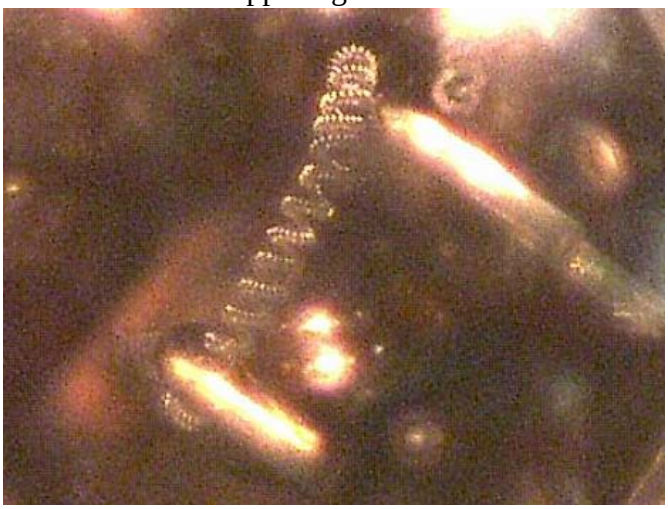
Attachment A
Bulb Photographs

First Officer's master WARNING,
upper left bulb

First Officer's master WARNING,
upper right bulb

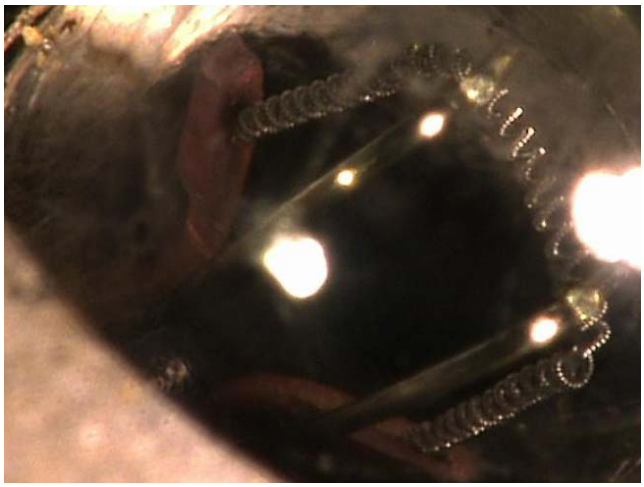


First Officer's master CAUTION,
lower left bulb

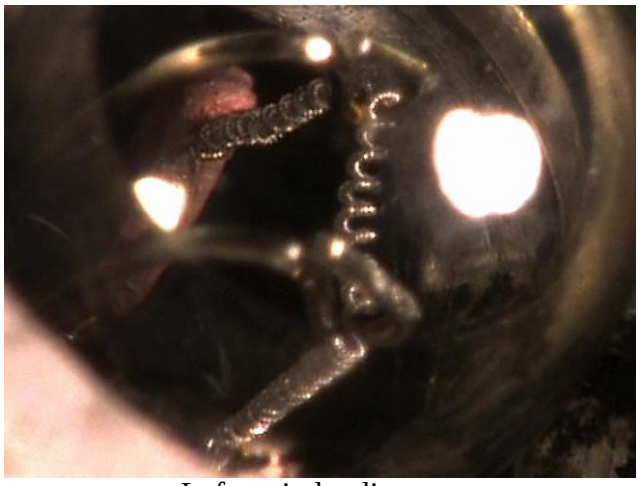


First Officer's master CAUTION,
lower right bulb

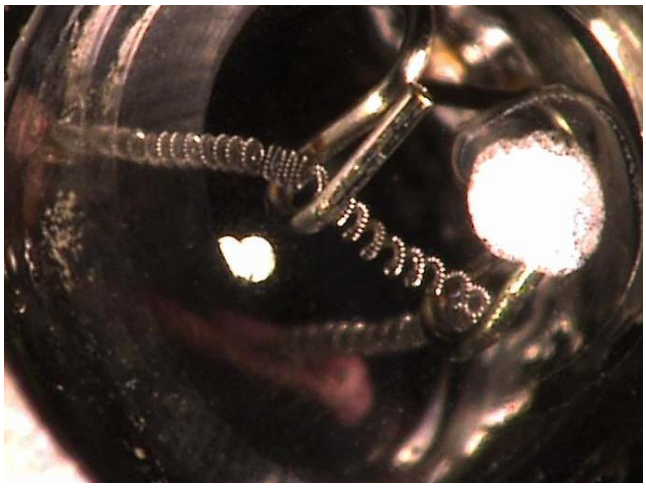
Left main landing gear,
first bulb examined



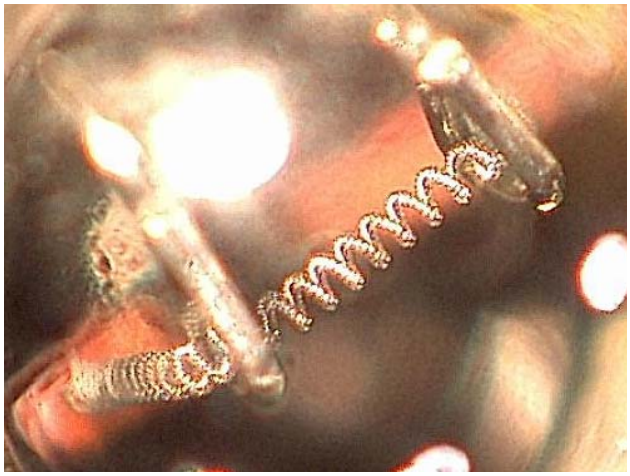
Left main landing gear,
second bulb examined



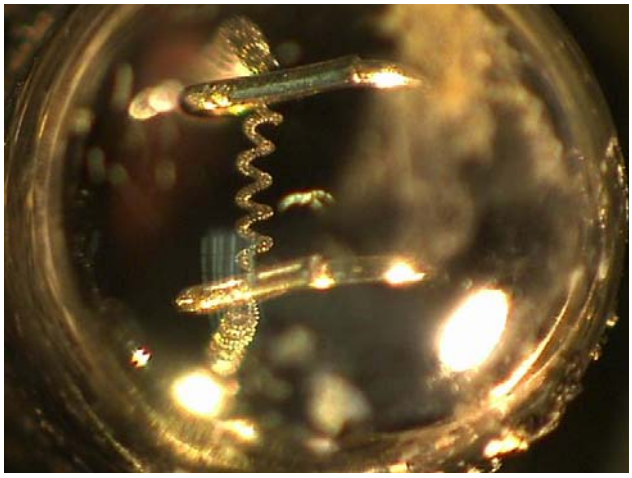
Left main landing gear,
third bulb examined



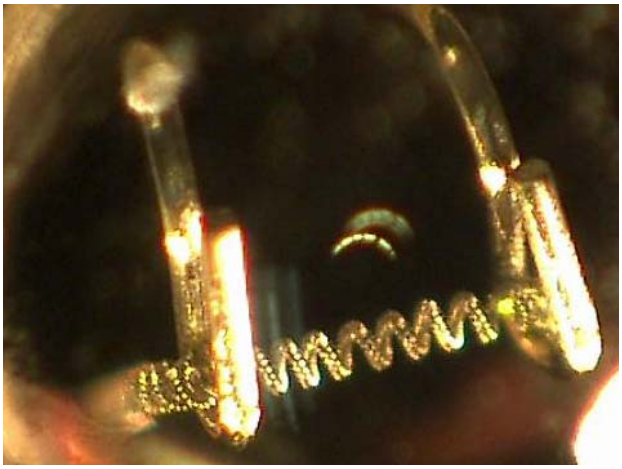
Left main landing gear,
fourth bulb examined



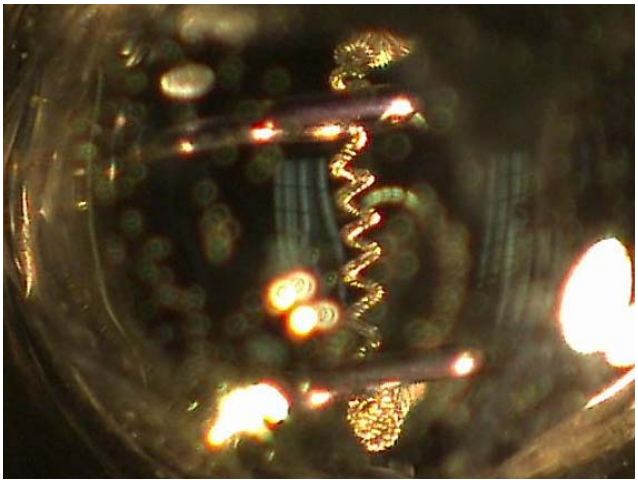
Nose landing gear,
first bulb examined



Nose landing gear,
second bulb examined

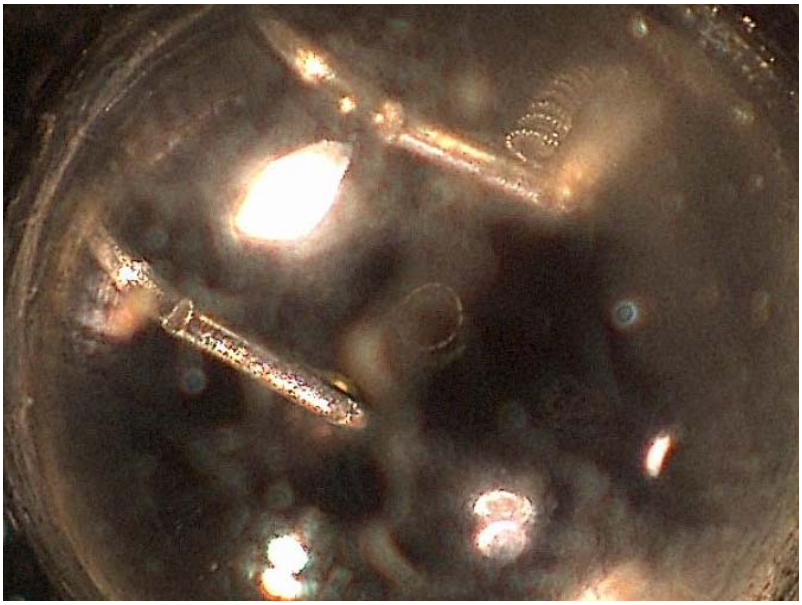


Nose landing gear,
third bulb examined

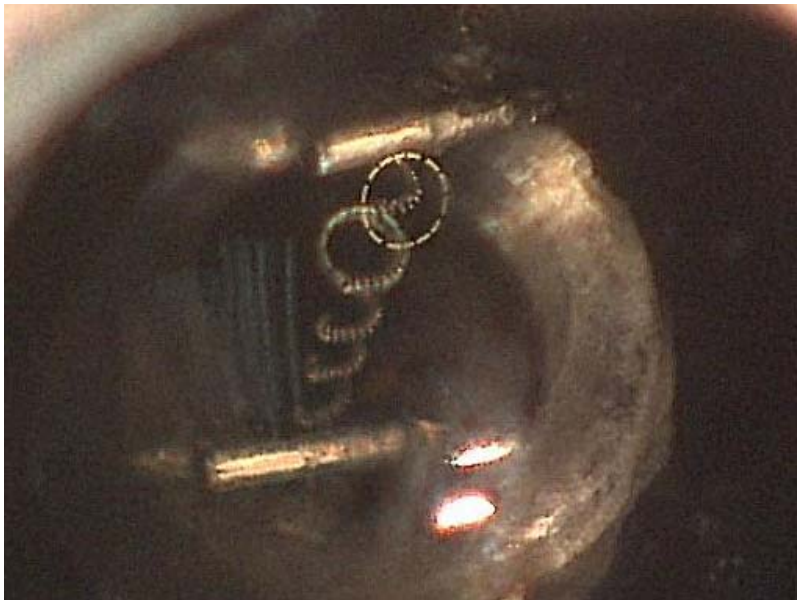


Nose landing gear,
fourth bulb examined

Right main landing gear,
first bulb examined

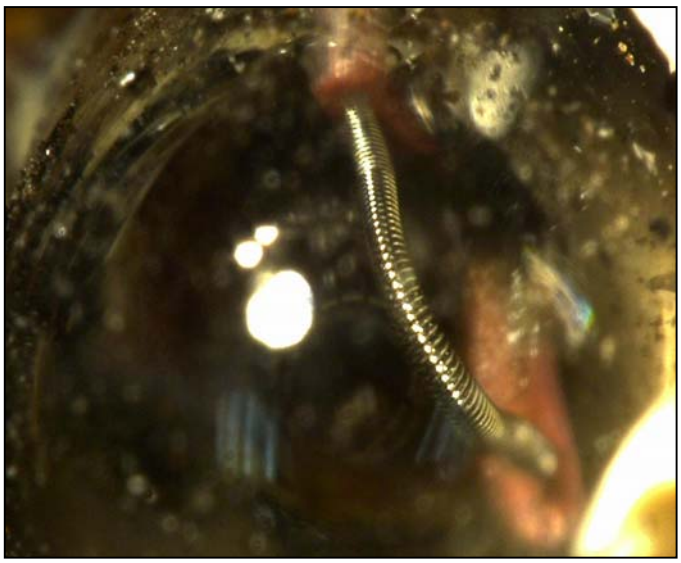


Right main landing gear,
second bulb examined

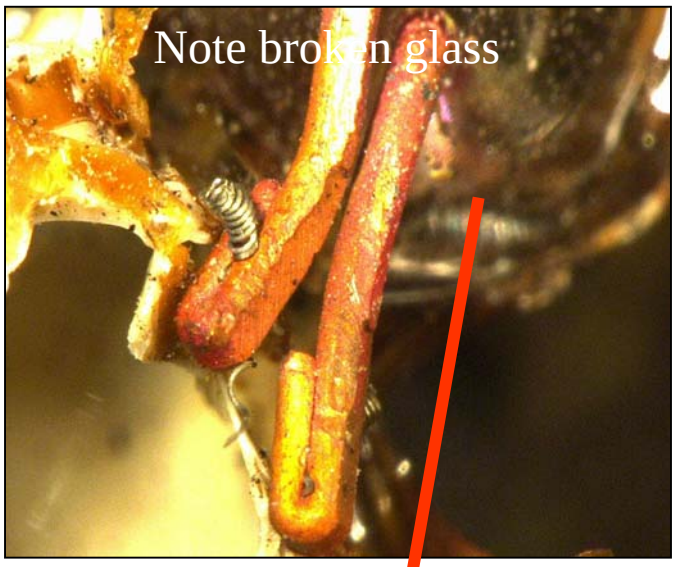


Right main landing gear,
third bulb examined

[No fourth right main landing gear bulb]

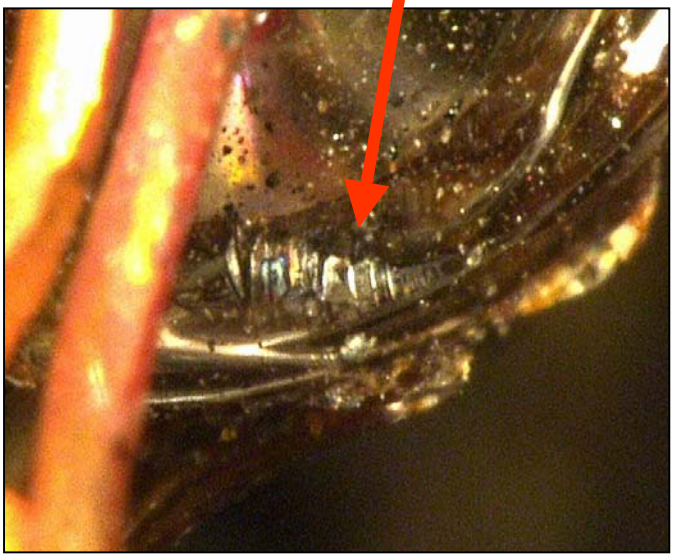


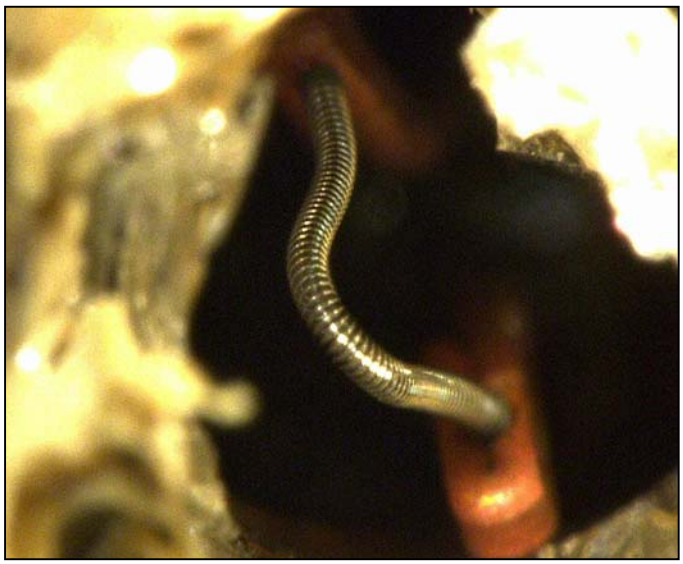
A1L, RIGHT OIL PRESS



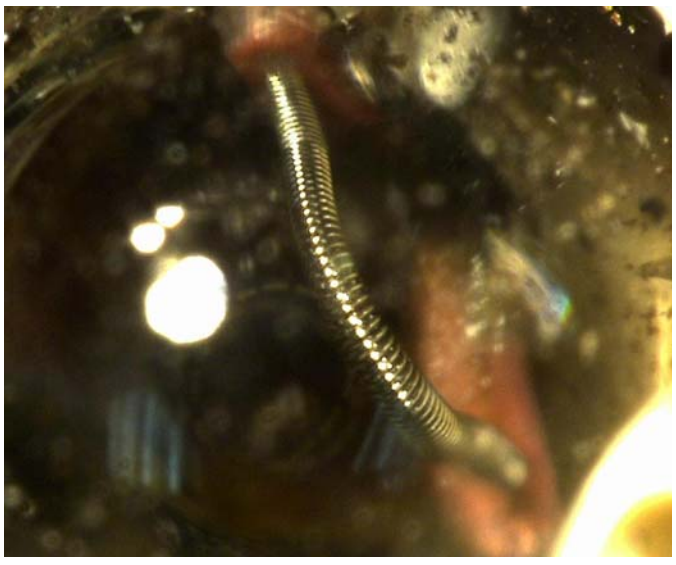
A1R, RIGHT OIL PRESS

To the right is detail of bulb A1R,
RIGHT OIL PRESS,
showing fragment of
filament within the broken glass.

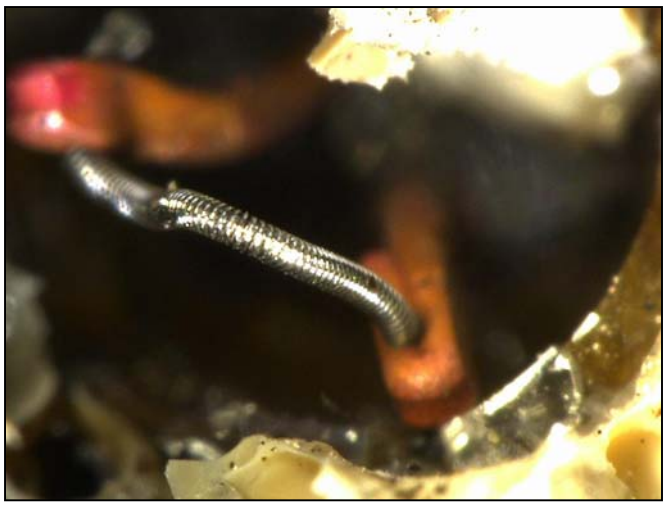




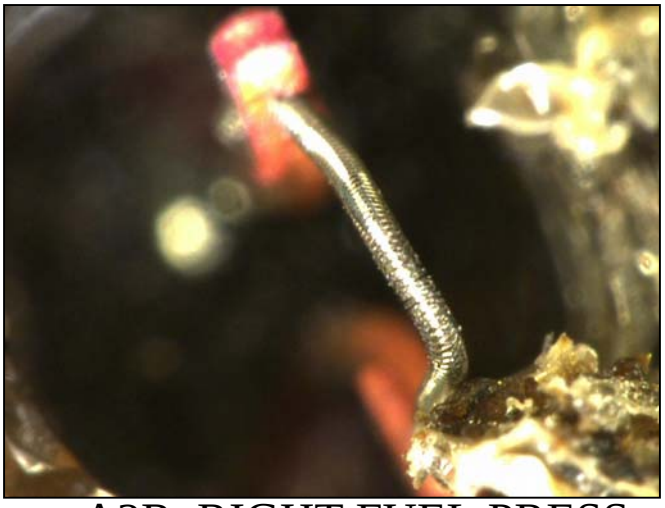
B1L, RIGHT ENG CMPTR



B1R, RIGHT ENG CMPTR

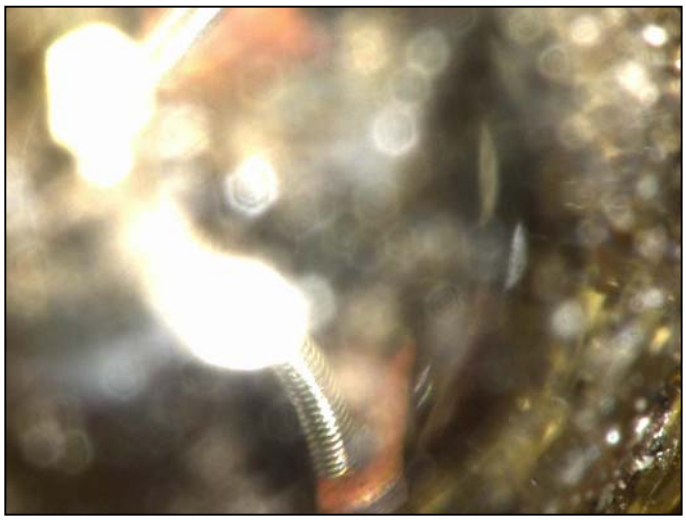


A2L, RIGHT FUEL PRESS

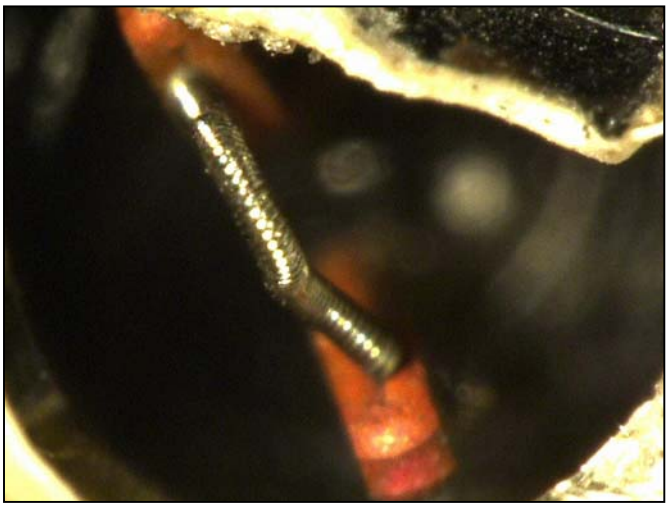


A2R, RIGHT FUEL PRESS

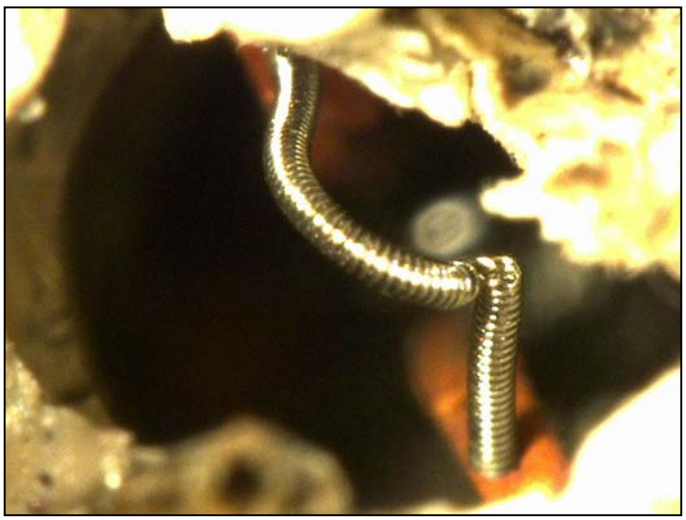
B2L, RIGHT ENG CMPTR



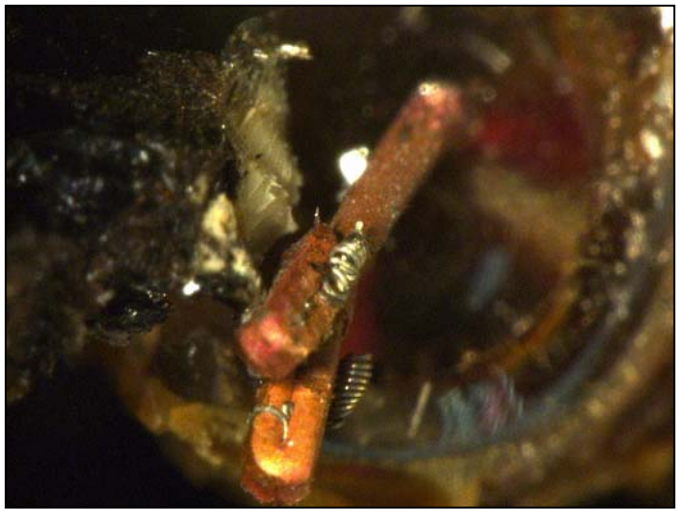
B2R, RIGHT ENG CMPTR



A3L, RIGHT ENG CHIP



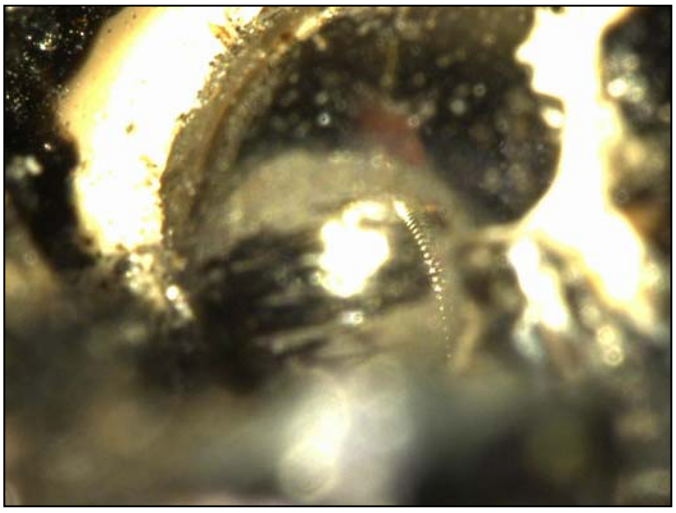
A3R, RIGHT ENG CHIP



B3L, RIGHT ENG FILTERS

B3R, RIGHT ENG FILTERS

A4L, RIGHT ENG VIB

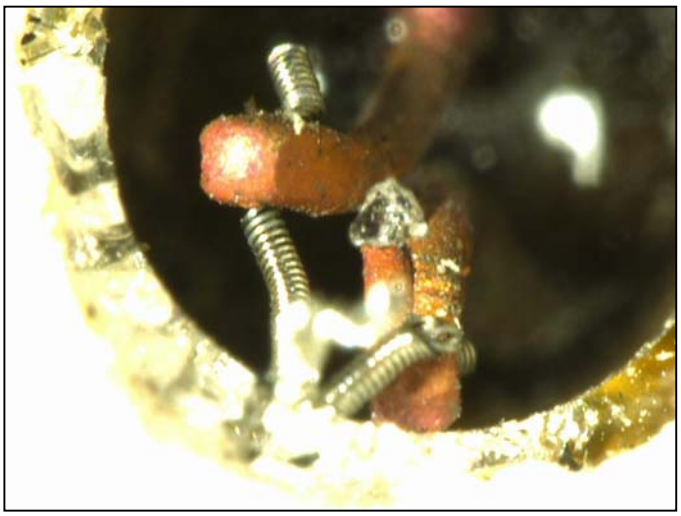


A4L, RIGHT ENG VIB

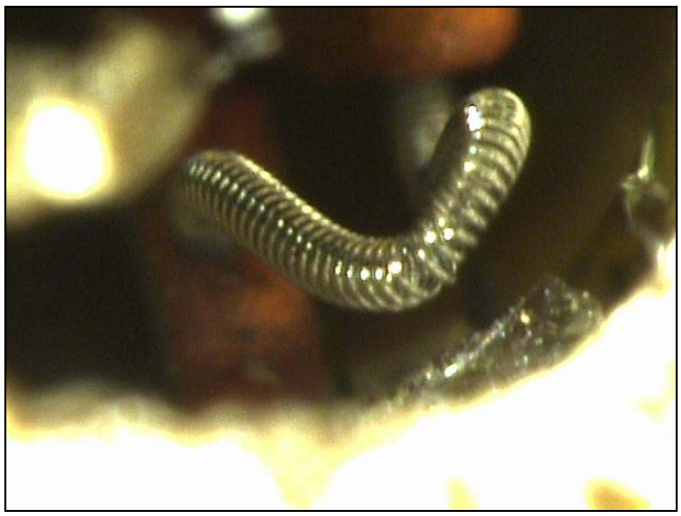
B4L, RIGHT TR DEPLOY

B4R, RIGHT TR DEPLOY

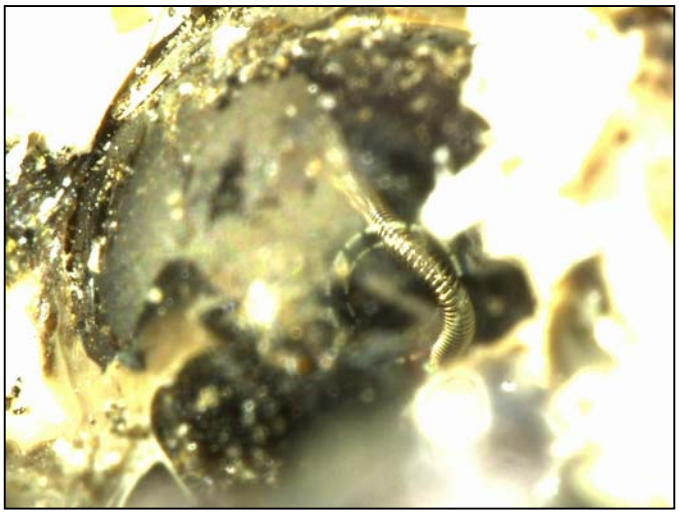
C4L, RIGHT TR UNLOCK



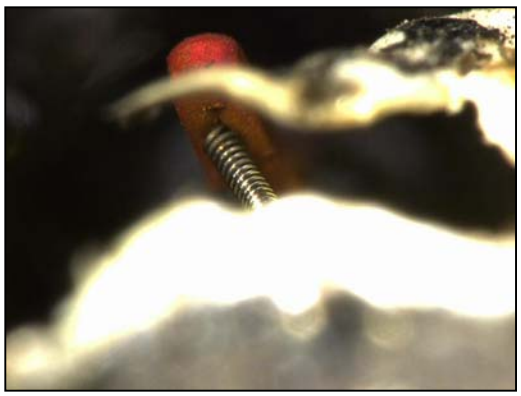
C4R, RIGHT TR UNLOCK



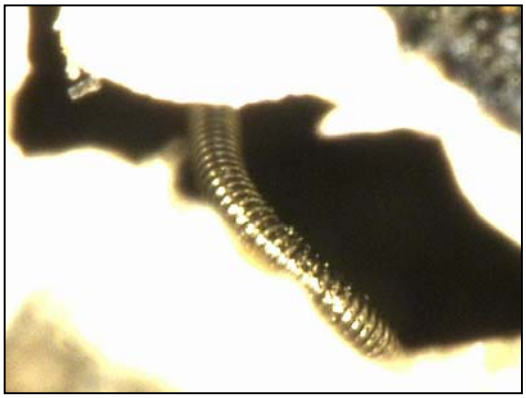
D4L, RIGHT TR ARM



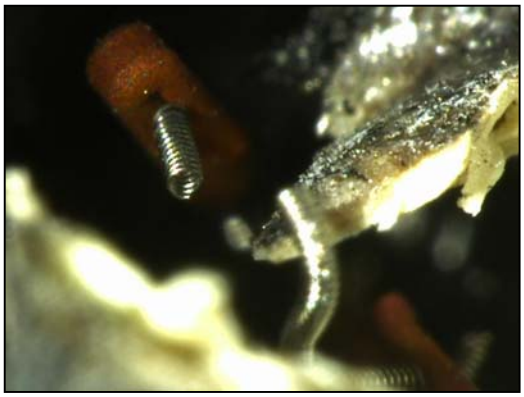
D4R, RIGHT TR ARM



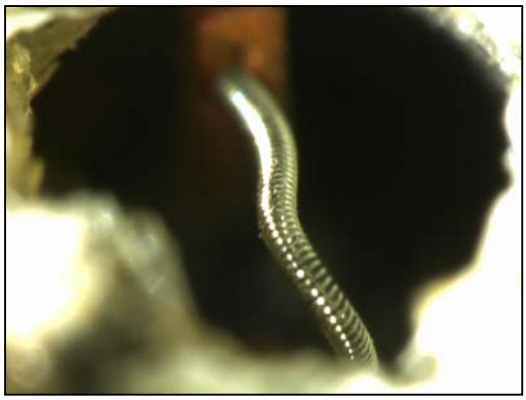
A5L, RIGHT BLEED AIR



A5R, RIGHT BLEED AIR

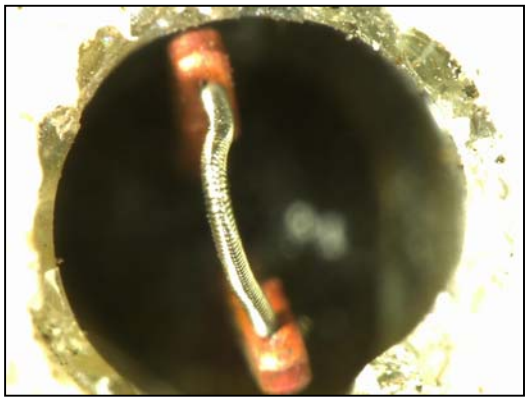


B5L, RIGHT WSHLD DEFOG



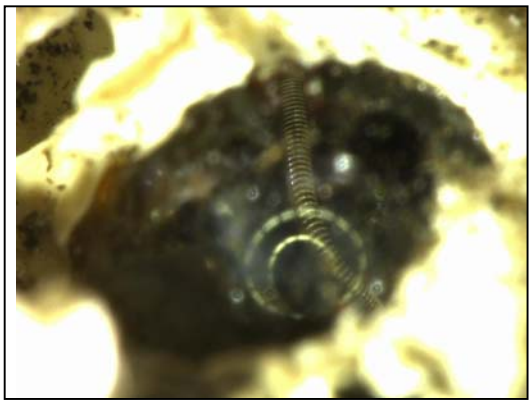
B5R , RIGHT WSHLD DEFOG

C5L, RIGHT NAC HEAT



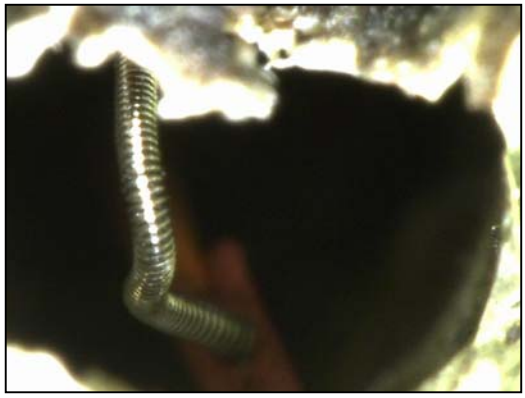
C5R , RIGHT NAC HEAT

D5L, ALC LOW

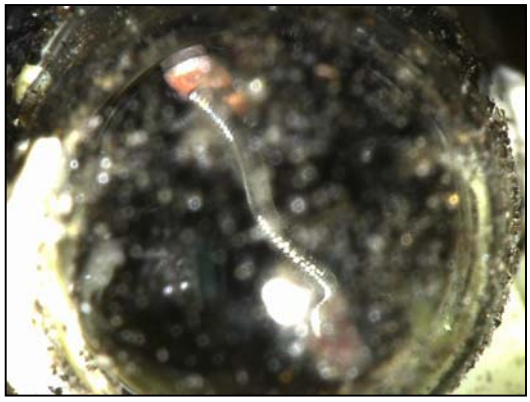


D5R, ALC LOW

A6L, LEFT BLEED AIR



A6R, LEFT BLEED AIR



B6L, LEFT WSHLD DEFOG

B6R, LEFT WSHLD DEFOG

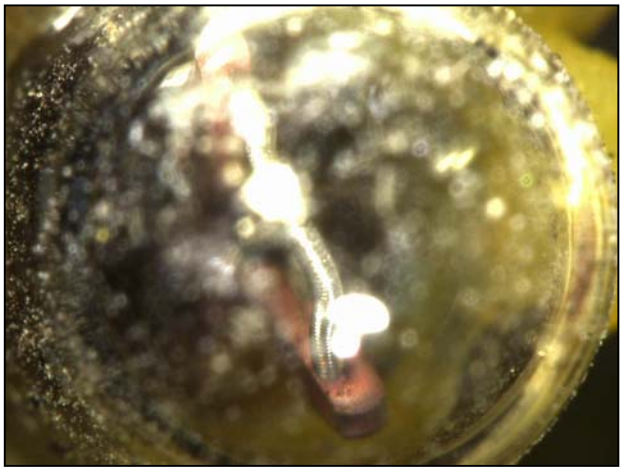
C6L, LEFT NACELLE HEAT

C6R, LEFT NACELLE HEAT

D6L, NACELLE HEAT ON

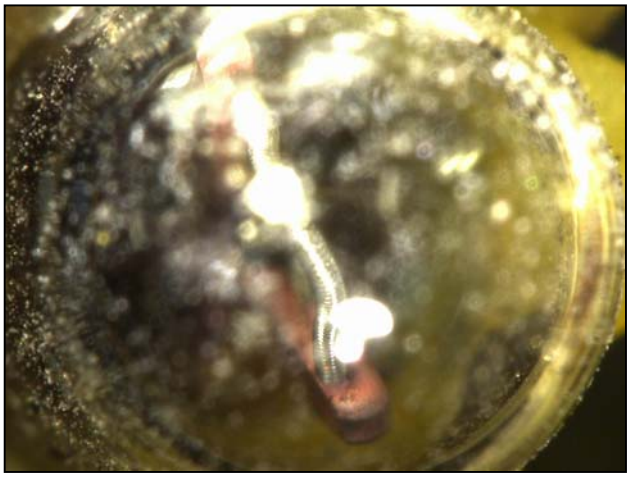
D6R, NACELLE HEAT ON

A7, WSHLD OVHEAT unusable

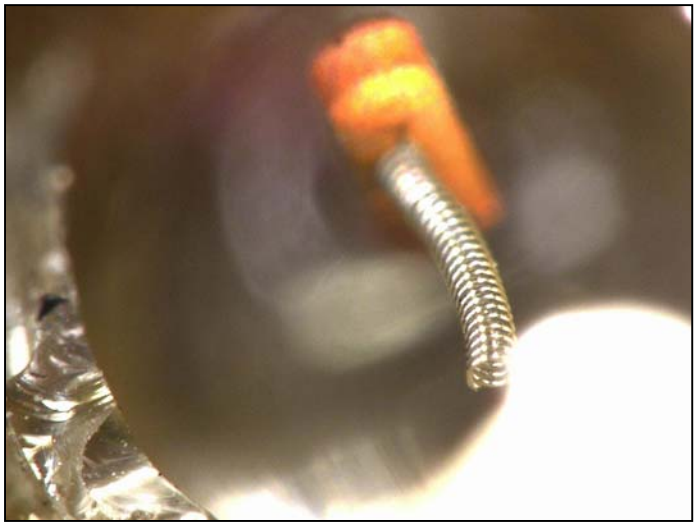


B7L, WSHLD HEAT

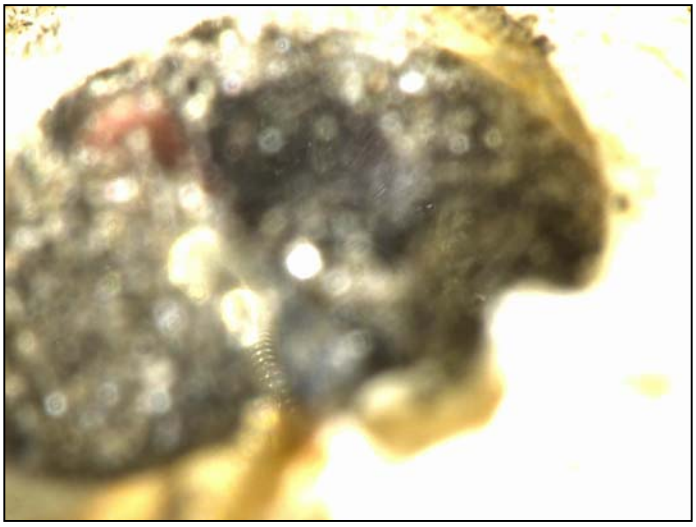
B7R, WSHLD HEAT



B7R, WSHLD HEAT 2nd fragment

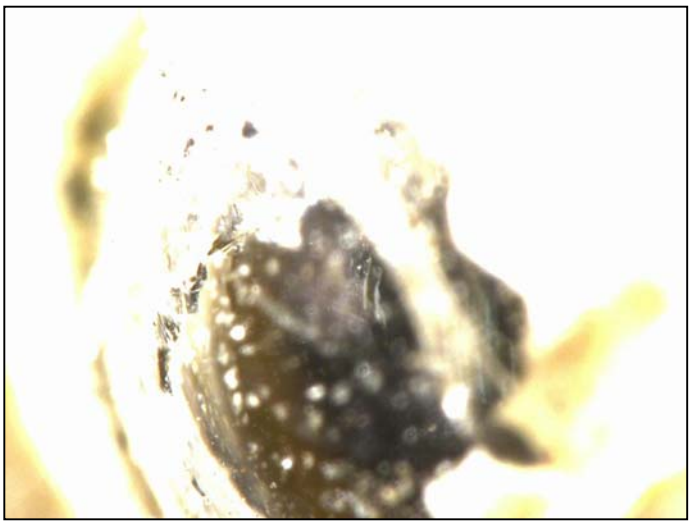


A8L, WING HT



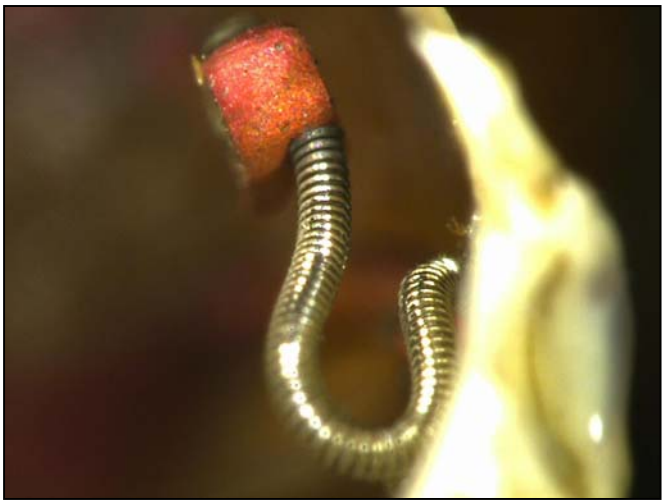
A8R, WING HT

[NO BULB
IN SOCKET B8L]

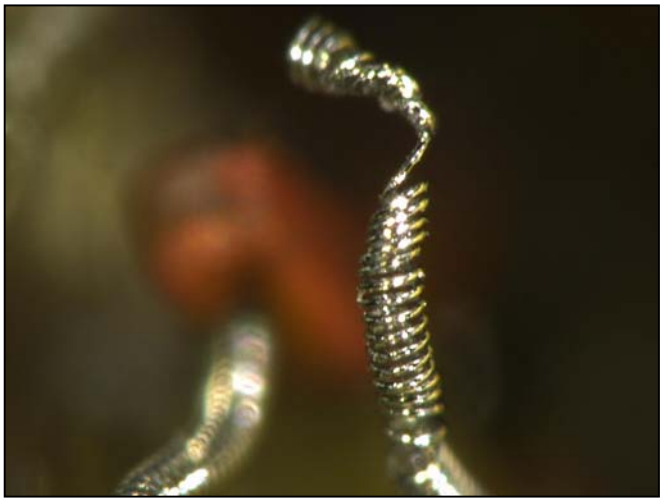


B8R, STAB HT

A9L, PITOT HEAT



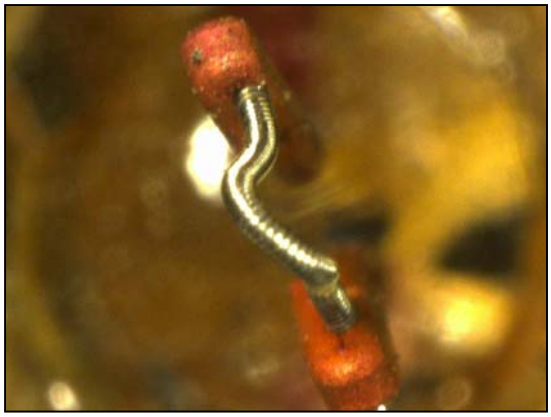
A9R, PITOT HEAT



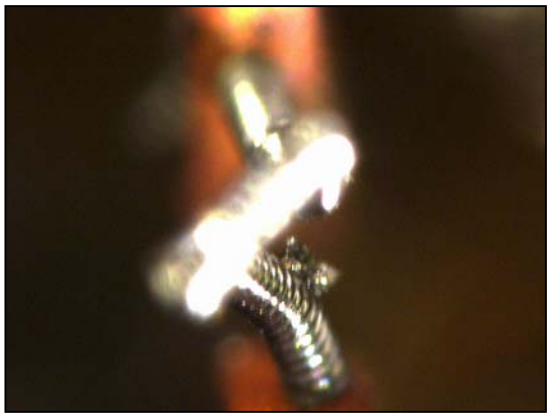
A9L, PITOT HEAT closeup

[THE B9 POSITION IS A SPARE]

A10L, EMER PRESS

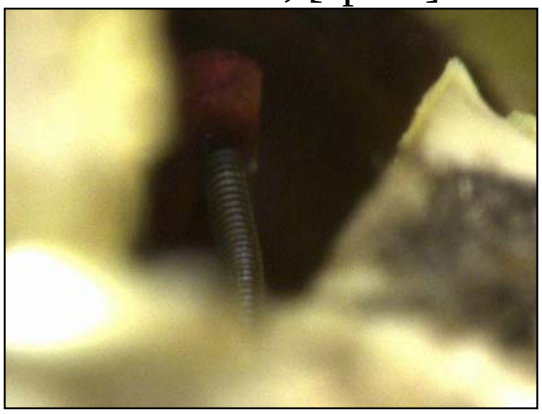


A10R, EMER PRESS



B10L , [spare]

[THE B10 POSITION IS A SPARE. NO BULB IN RIGHT SOCKET]



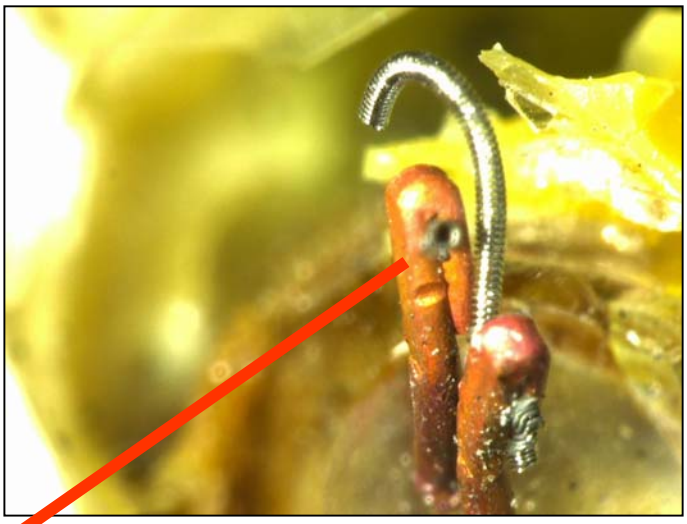
A11L, PRESS SYS

A11R unusable

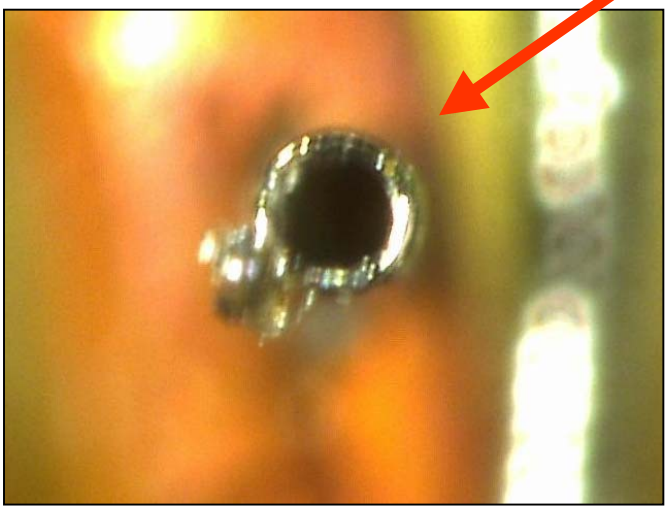
B11L, DUCT OVHT

B11R, DUCT OVHT

A12L, EXT DOORS



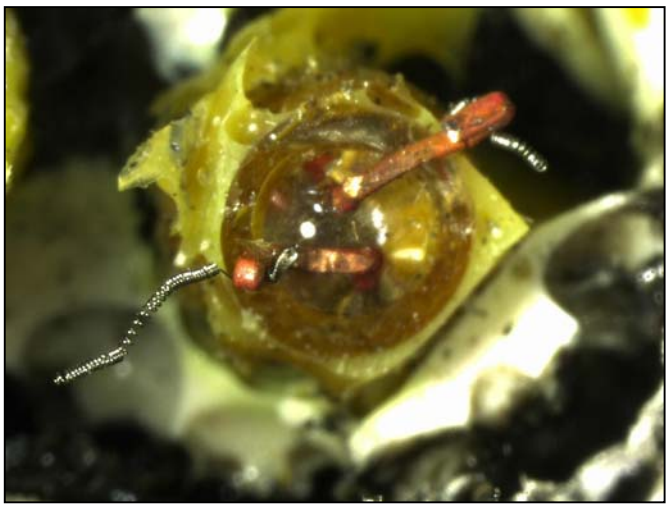
A12R, EXT DOORS



A12R, closeup 1

A12R, closeup 2

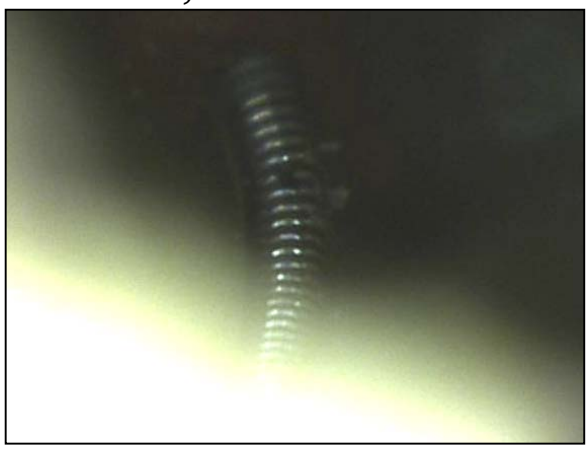
B12L , [spare]



B12R , [spare]

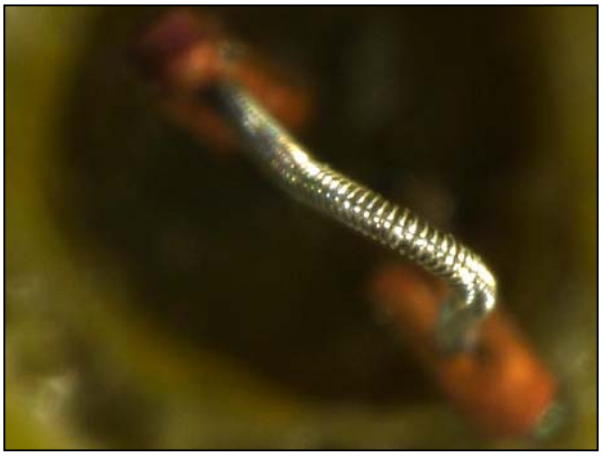
A13L, ENTRY DOOR

A13R, AFT CAB DOOR



A14L, [spare]

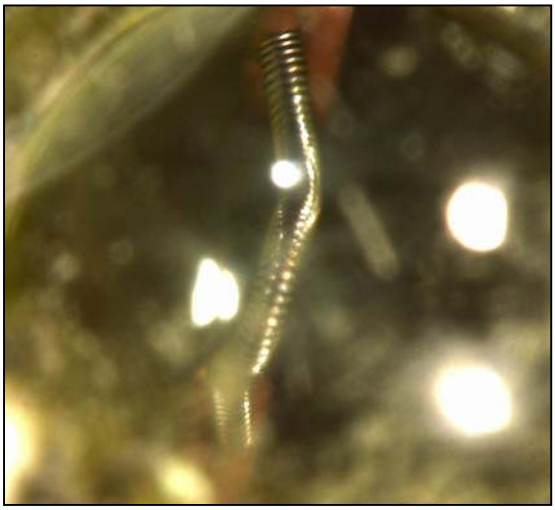
A14R, [spare]



B14L, INSTR FAN

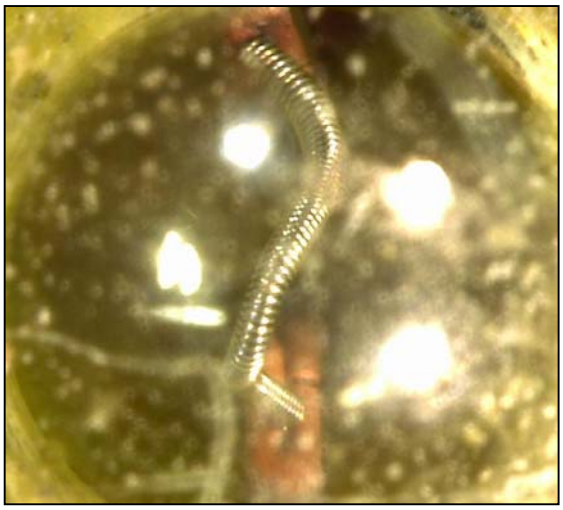
B14R, INSTR FAN

B14R, Detail of break

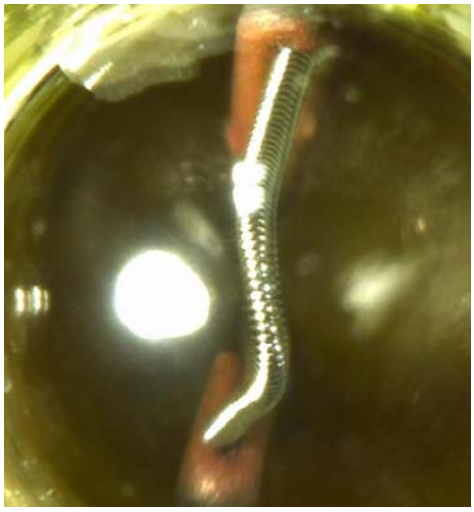


A15L, [spare]

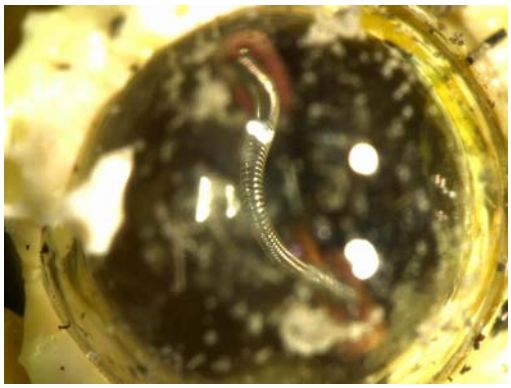
A15R, [spare]



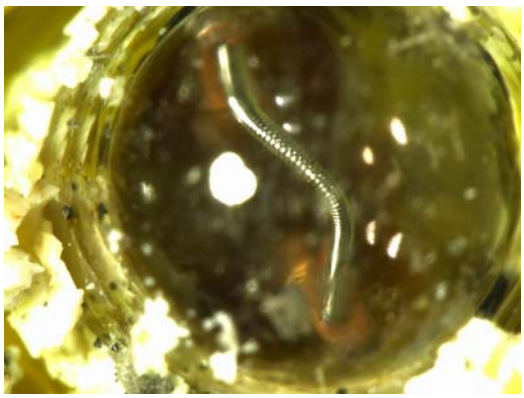
B15L , [spare]



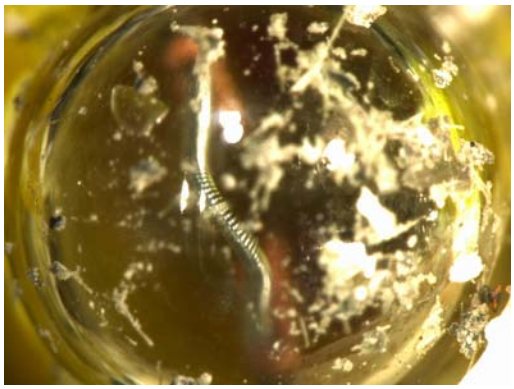
B15R , [spare]



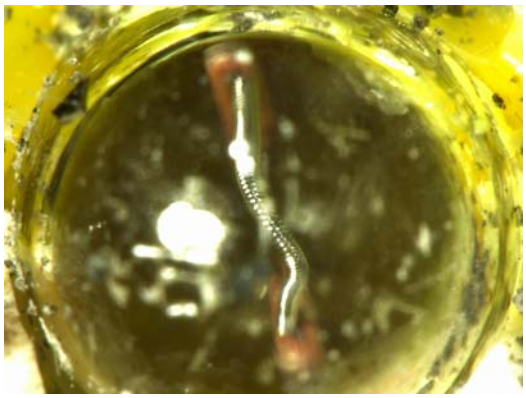
A16L, RIGHT GEN



A16R, RIGHT GEN

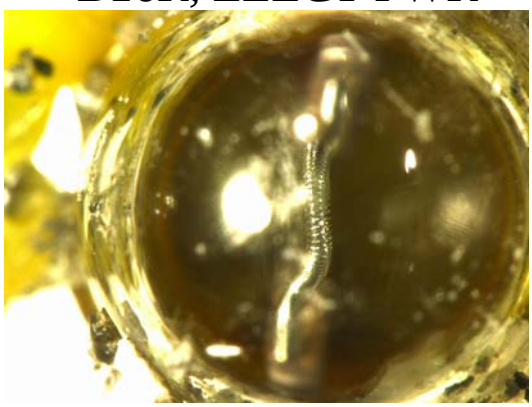


B16L, ELECT PWR

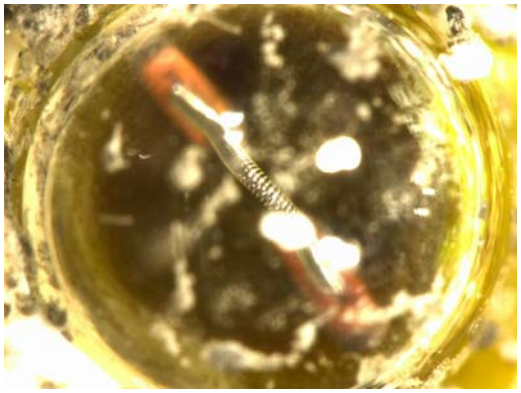


B16R, ELECT PWR

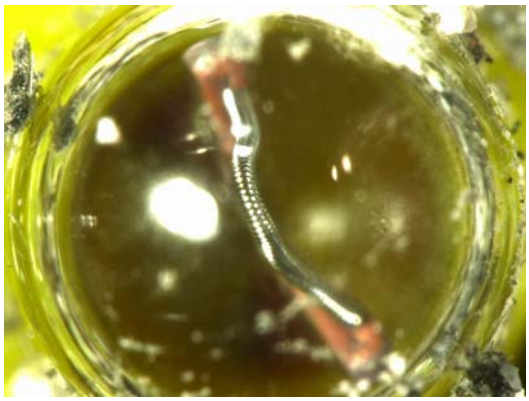
A17L, LEFT GENERATOR



A17R, LEFT GENERATOR

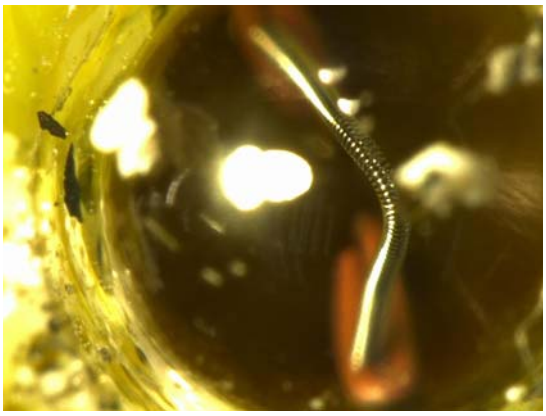


B17L, [Illegible]

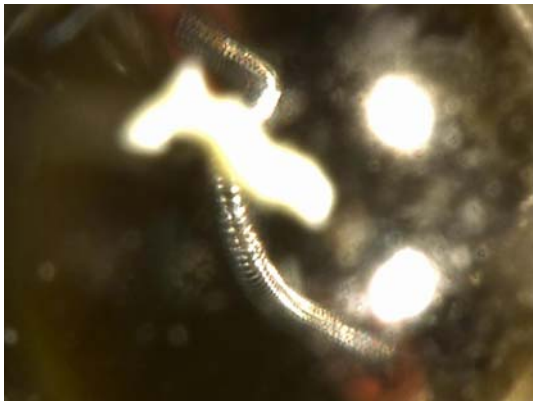


B17R, [Illegible]

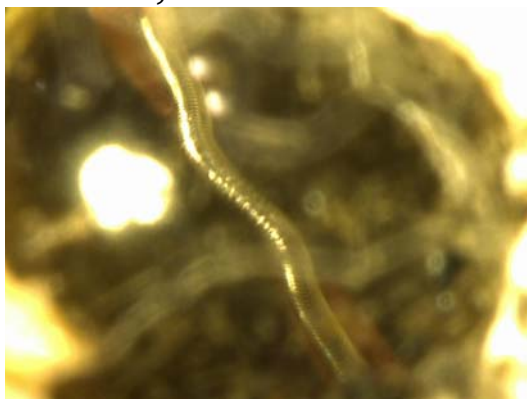
A18L, PITCH TRIM



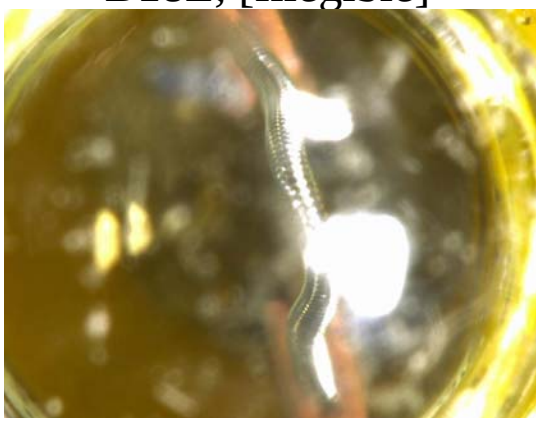
A18R, PITCH TRIM



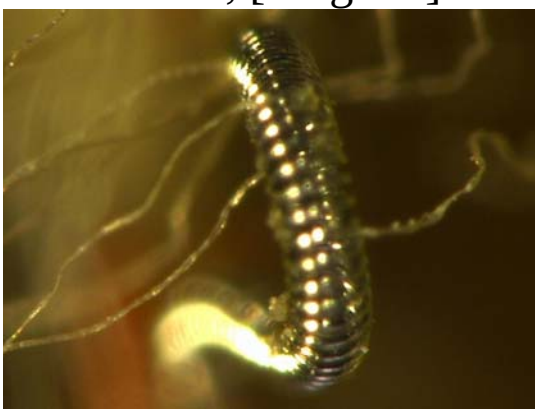
B18L, [Illegible]



B18R, [Illegible]

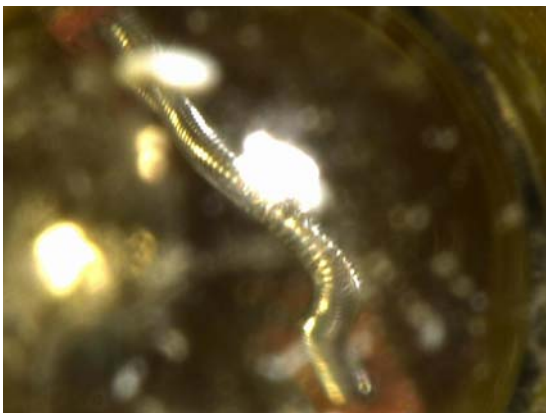


A19L, RIGHT STALL

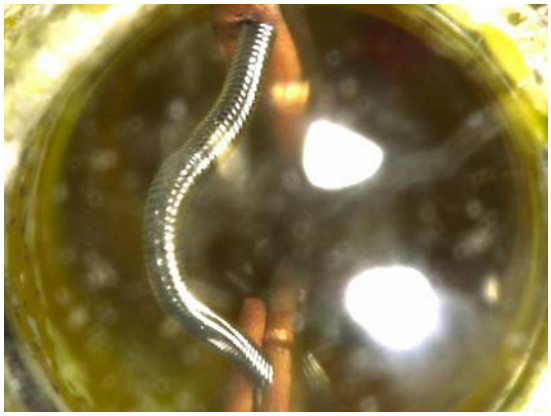


A19R, RIGHT STALL

B19L, MAC TRIM

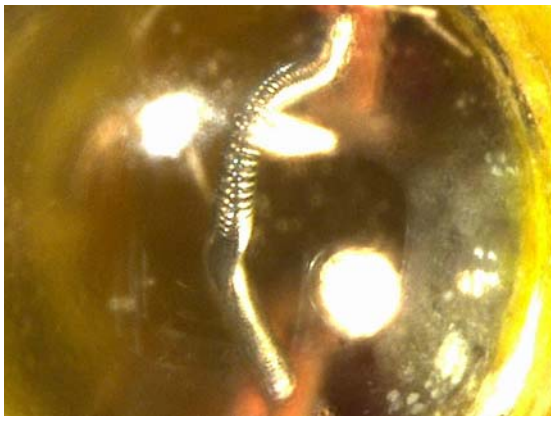


B19R, MAC TRIM

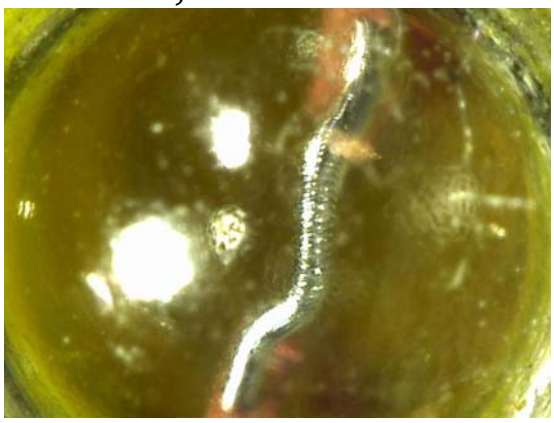


A20L, LEFT STALL

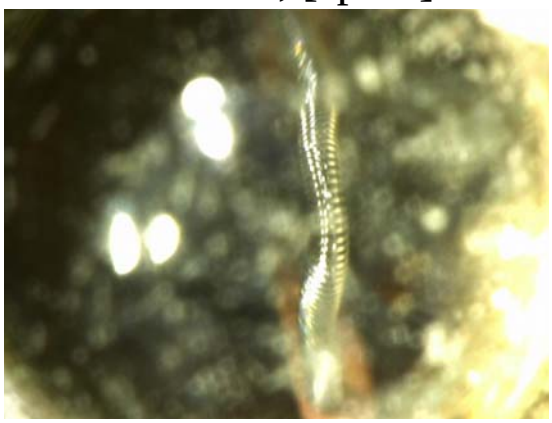
A20R, LEFT STALL



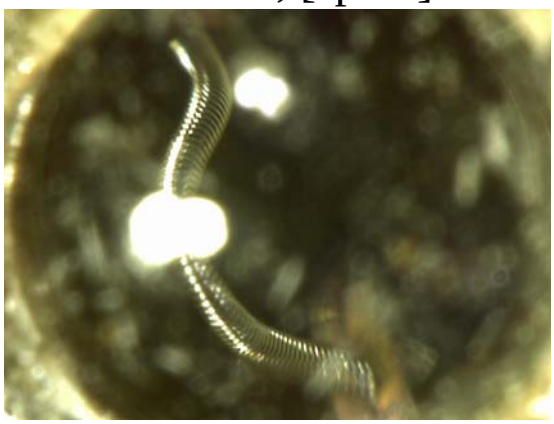
B20L, [spare]



B20R, [spare]

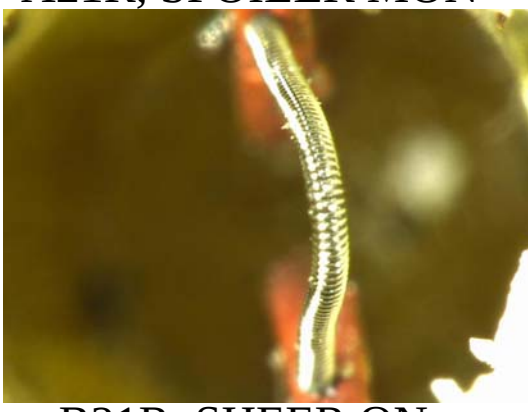


A21L, SPOILER MON

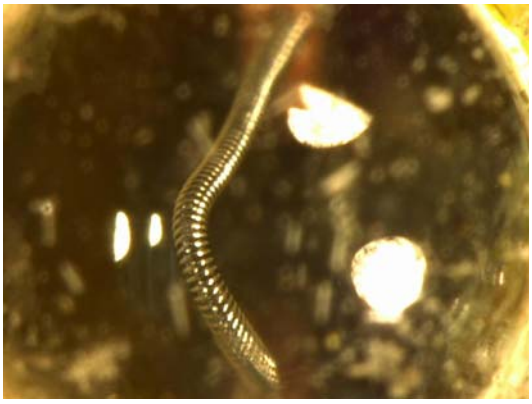


A21R, SPOILER MON

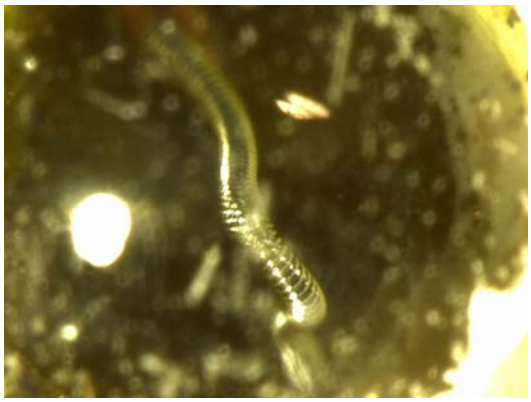
B21L, SHEER ON



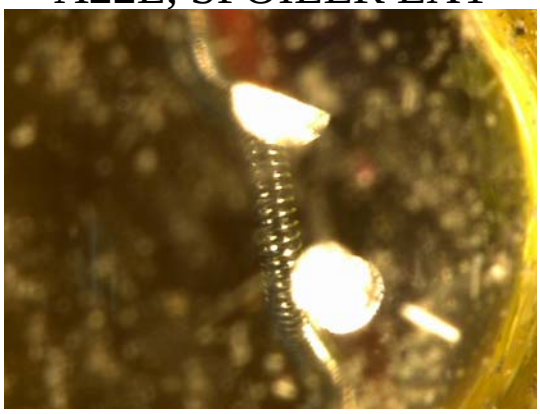
B21R, SHEER ON



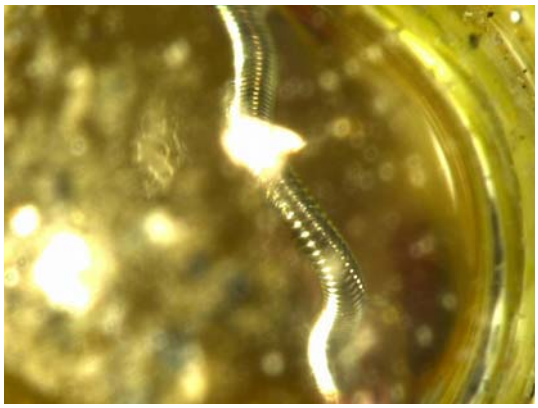
A22L, SPOILER EXT



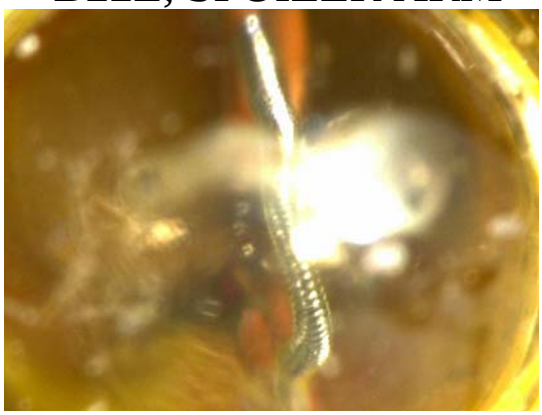
A22R, SPOILER EXT



B22L, SPOILER ARM



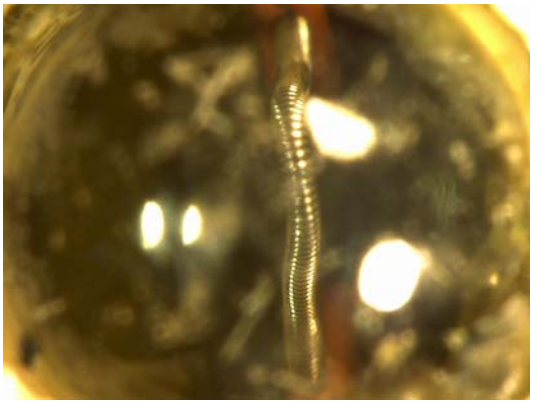
B22R, SPOILER ARM



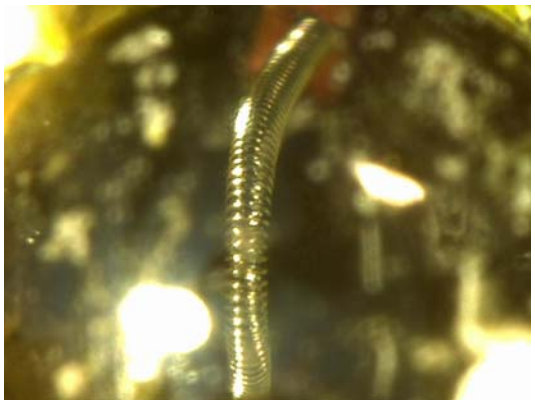
A23L, RIGHT HYDR PRESS

A23R, RIGHT HYDR PRESS

A23R, RIGHT HYDR PRESS (lower fragment)



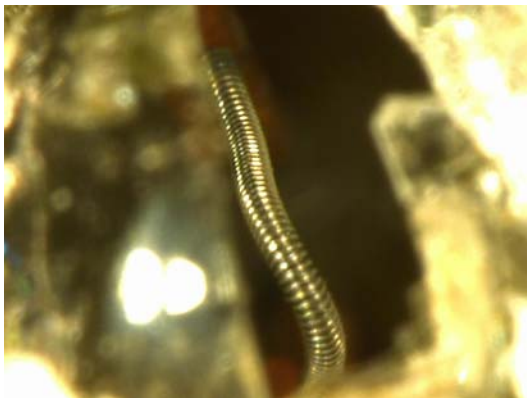
B23L, LOW FUEL



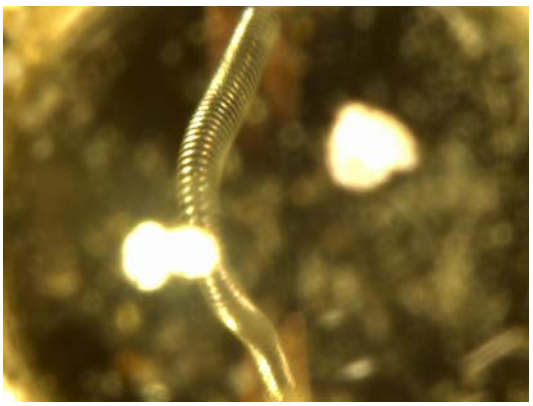
B23R, LOW FUEL

[Intentionally blank]

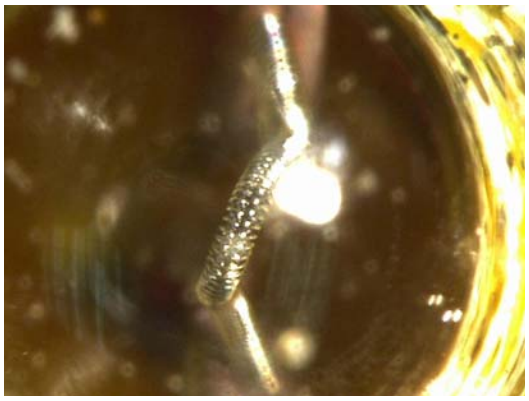
C23R, FUEL SYS



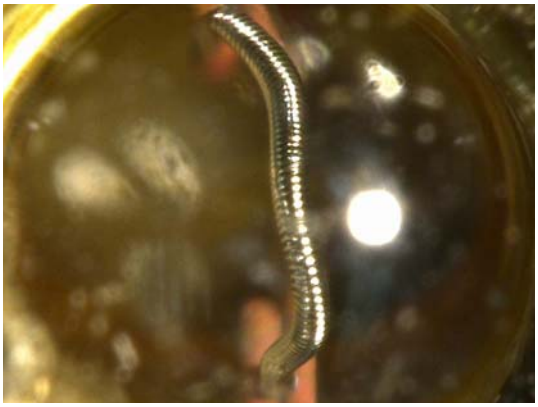
D23L, ENG SYNC



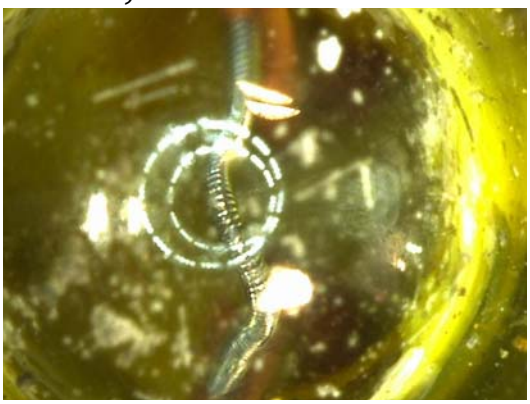
D23R, ENG SYNC



A24L, LEFT HYDR PRESS



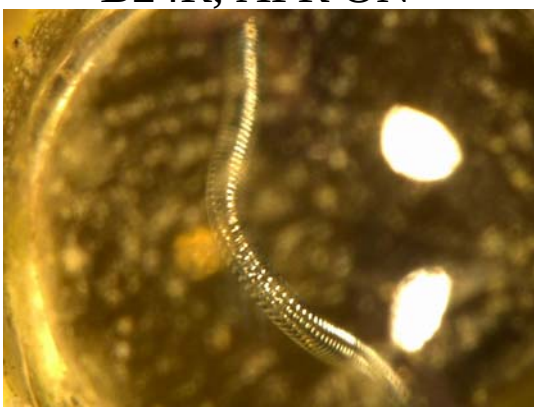
A24R, LEFT HYDR PRESS



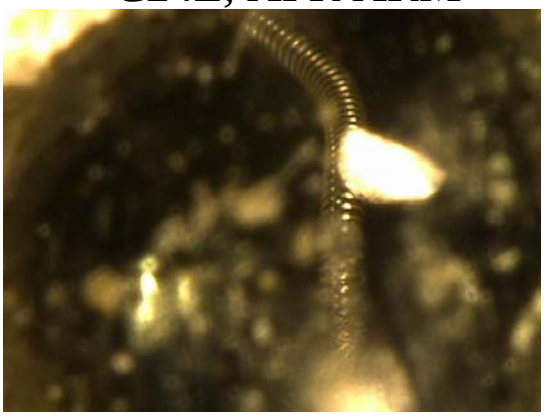
B24L, APR ON

B24R, APR ON

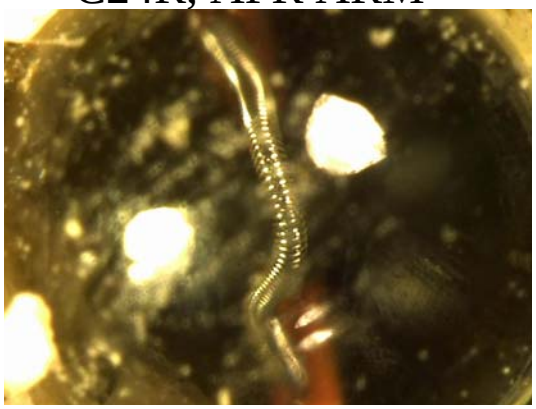
C24L, APR ARM



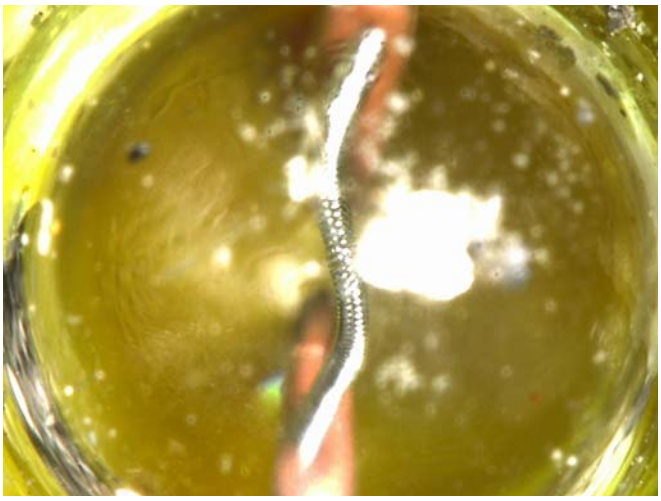
C24R, APR ARM



D24L, EDS FAULT



D24R, EDS FAULT



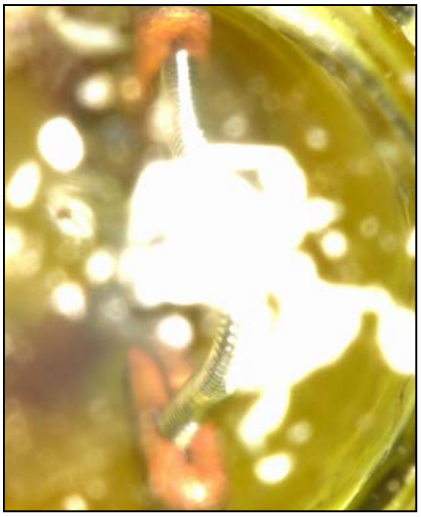
A25L, LEFT ENG VIB

A25R, LEFT ENG VIB

[Intentionally blank to group the left

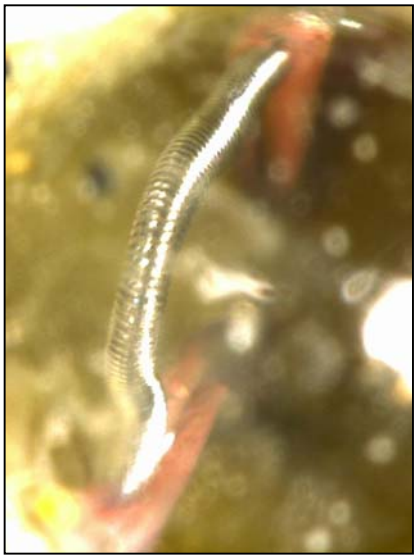
thrust reverser annunciators on next page.]

B25L, LEFT TR DEPLOY

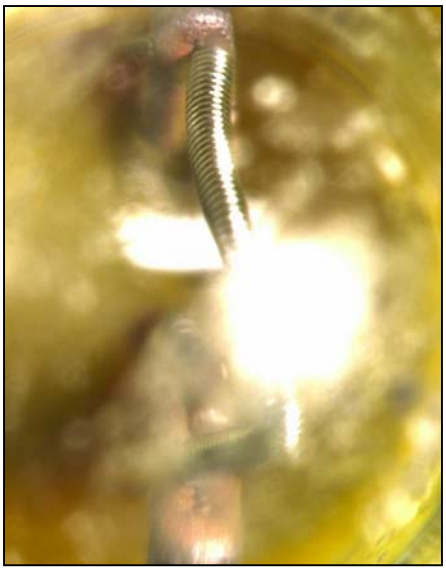


B25R, LEFT TR DEPLOY

C25L, LEFT TR UNLOCK

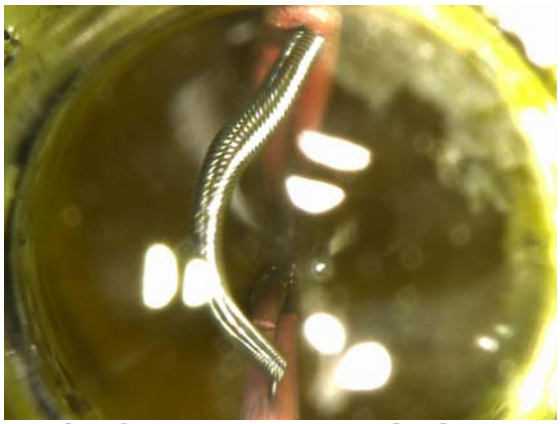


C25R, LEFT TR UNLOCK

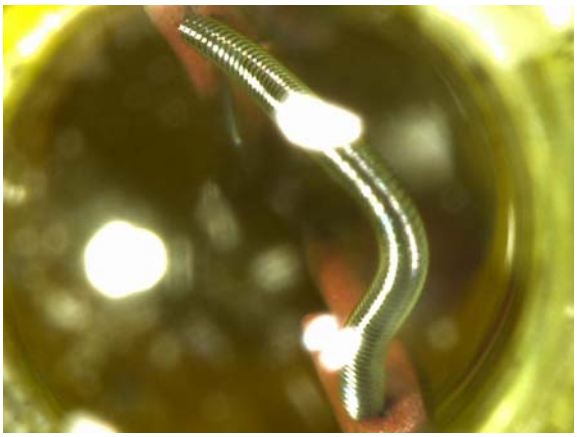


D25L, LEFT TR ARM

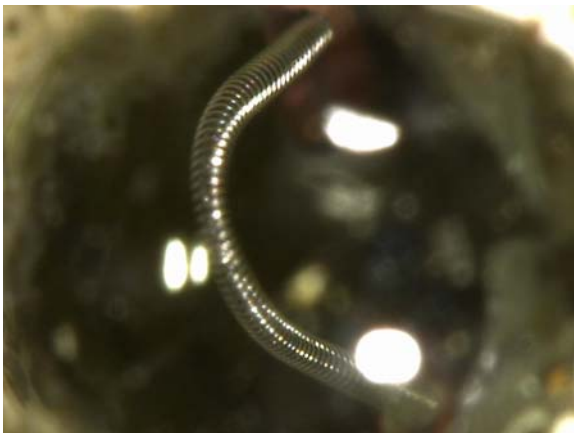
D25R, LEFT TR ARM



A26L, LEFT ENG CHIP

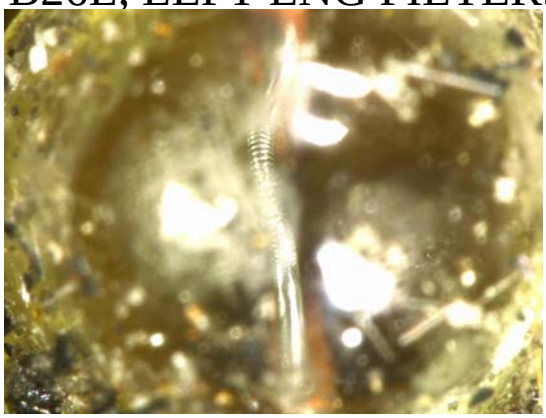


A26R, LEFT ENG CHIP



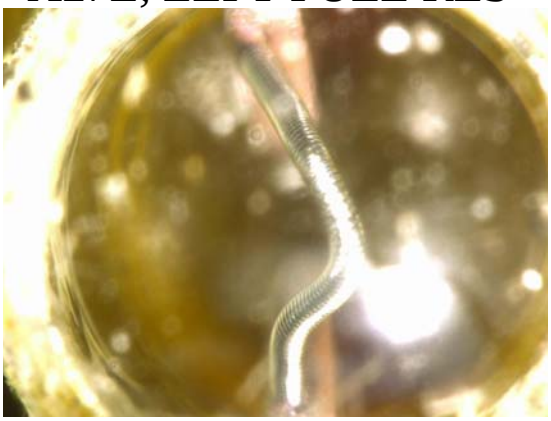
B26L, LEFT ENG FILTERS

B26R, LEFT ENG FILTERS

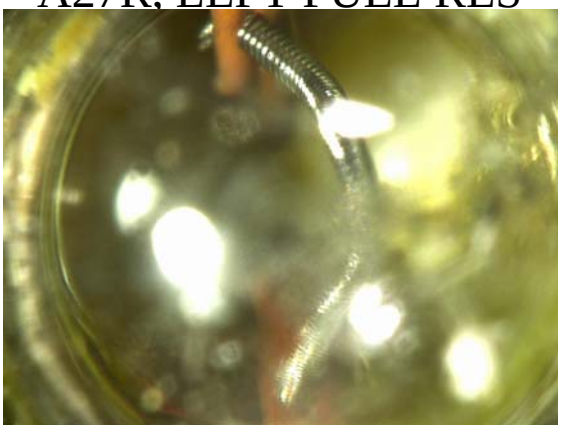


A27L, LEFT FUEL RES

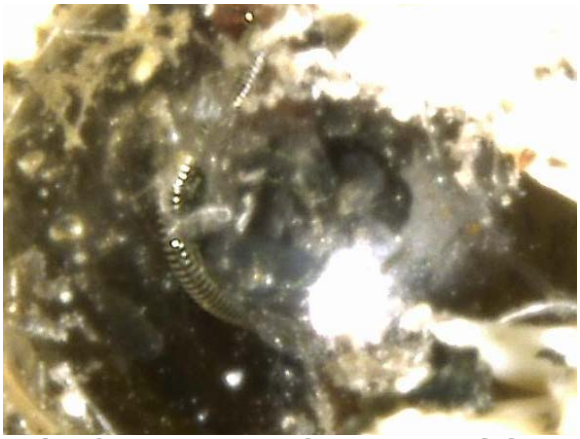
A27R, LEFT FUEL RES



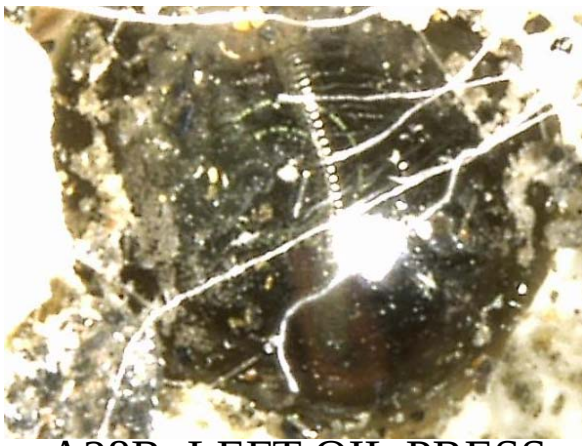
B27L, LEFT ENG CMPTR



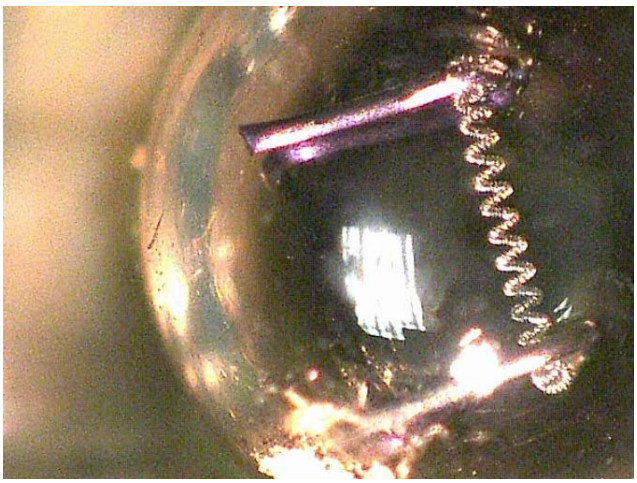
B27R, LEFT ENG CMPTR



A28L, LEFT OIL PRESS

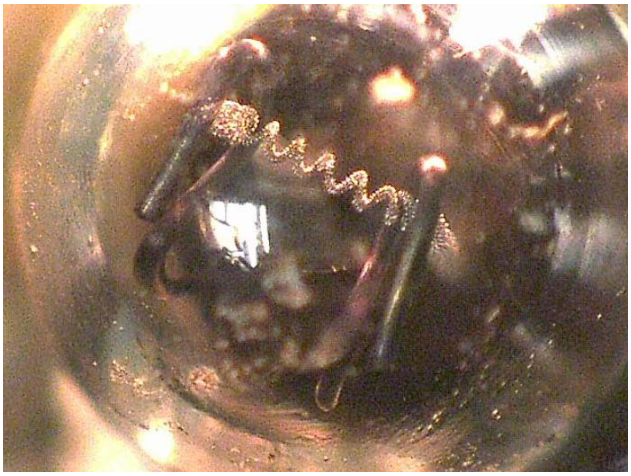


A28R, LEFT OIL PRESS

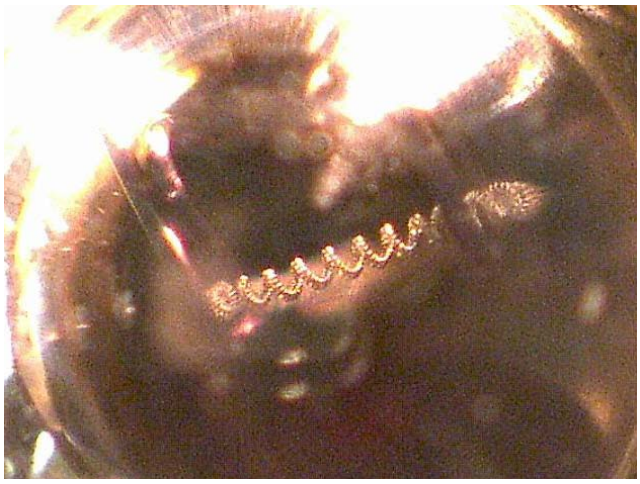


Captain’s master WARNING,
upper left bulb

Captain’s master WARNING,
upper right bulb



Captain’s master CAUTION,
lower left bulb



Captain’s master CAUTION,
lower right bulb