ATTACHMENT 2

Boeing EQA Report AS11733:

Examination of Nose Landing Gear Components Removed from Southwest Airlines 737-300 Airplane PS765

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14 December 2012
66-ZB-H200-ASI-18687

Tom Jacky
US National Transportation Safety Board
490 L'Enfant Plaza East
Washington, DC 20594

Subject: EQA Report – Southwest Airlines 737-300 N379SW Wheel Well Structure Fracture at El Paso – 27 July 2012

References: (a) EQA Report AS11733

Dear Mr. Jacky:

In support of the reference (a) investigation, components from the subject airplane were examined at the Boeing Equipment Quality Analysis laboratory in the presence of NTSB and Southwest Airlines personnel. Please find enclosed the reference (a) EQA report document the findings from that examination.

The information included with this correspondence is controlled under the US Export Administration Regulations (15 CFR Parts 300-799) and has been categorized as ECCN: 9E991. Information categorized as ECCN 9E991 is acceptable for public release.

Please feel free to contact us if you have any questions.

Best regards,

[redacted]

Michelle E. Bernson
Chief Engineer
Air Safety Investigation

Enclosure: EQA Report AS11733

cc: Dave Keenan, US FAA
Dennis Post, Southwest Airlines

Equipment Quality Analysis Report

Boeing Commercial Airplanes

TO: Air Safety Investigation (ASI)

EQA NUMBER: AS11733

DATE: December 5, 2012

CUSTOMER: SWA

MODEL NUMBER: 737-300

AIRPLANE NUMBER: PS765 / N379SW

SUBJECT: ***Examination of Nose Landing Gear Components Removed from Southwest Airlines 737-300 Airplane PS765***

IDENTIFICATION:

Part name:	Nose Landing Gear (NLG) Retract Actuator
Boeing part number:	65-44610-4
Serial number:	ES770
Part name:	NLG Transfer Cylinder
Boeing part number:	69-14106-7
Serial number:	3118
Part name:	NLG Modular Package
Boeing part number:	65-44691-6
Serial number:	2749
Part name:	Retract Actuator Hose Assembly
Boeing part number:	BACH8A04EE-0263S
PT date:	A1/92
Part name:	NLG Door Operator Crank Assembly
Boeing part number:	65C27360-5
Mtg. date:	8/20/unreadable

REFERENCES: (a) Service Request (SR) 1-2270189140
(b) Continued Operational Safety Program, (COSP) report # 2012-0999
(c) Component Maintenance Manual (CMM) 32-30-41, revision 21
(d) CMM 32-40-01, revision 23
(e) CMM 32-09-11, revision 15

BACKGROUND:

Per references (a/b), Southwest Airlines (SWA) reported that on July 27, 2012 the flight crew of Flight 1871 reported hearing a “loud pop” from the nose gear on gear extension while on approach to El Paso International Airport (ELP). The aircraft performed an uneventful landing at ELP. The aircraft taxied to the gate with no issues but upon subsequent inspection, the operator found evidence of a hydraulic leak forward of the nose gear and buckling of the nose gear actuator retract beam.

Airplane PS765 was delivered to SWA in February of 1994 and had accumulated 59,933/49,776 hours/cycles at the time of the reference (a/b) event.

In support of the investigation by the National Transportation Safety Board (NTSB), the following items were removed from the incident airplane and under the direction of the NTSB, submitted to Boeing Equipment Quality Analysis (EQA) and Boeing Research and Technology (BR&T) for joint examination, testing and analysis.

The NLG retract actuator, part number (PN) 65-44610-4, the NLG Transfer Cylinder PN 69-14106-7, the NLG Modular Package PN 65-44691-6 the BACH8A04EE-0263S hose the 65C27360-5 NLG door operator crank assembly were received at EQA for examination and testing.

Structural items that were damaged in the event were also removed. The structural items were submitted to Boeing Research and Technology (BR&T) for examination and analysis. The results of the examination of those items will be reported separately.

SUMMARY:

All of the parts received were under the control and administration of the NTSB. Examinations and testing were conducted in the presence of personnel from the NTSB, SWA, and Boeing.

The 65-44610-4 NLG retract actuator was tested per the reference (c) CMM, page 101, section 1, paragraph D, items 1 through 4. The actuator was cycled 5 times rather than

the 25 cycles called out in item 3. The actuator appeared to function normally and snubbing was observed in both directions. During disassembly of the unit, it was found that the 66-22711-1 restrictor had been installed where the MS21902-6 union should have been installed and vice versa.

The 69-14106-7 NLG transfer cylinder was tested per the reference (d) CMM 32-40-01 page 101, section 1, paragraph C items 4 and 6. The unit was functionally acceptable.

The 65-44691-6 NLG modular package was tested per the reference (e) CMM 32-09-11 page 101, section 1, paragraph D. The unit was functionally acceptable.

The BACH8A04EE-0263S hose assembly was found to have a rupture approximately 8.5 inches from the “A” end of the hose. The “A” end of the hose is the end with the identification tag attached. The rupture was coincident with section of missing spiral wrap and abrasion marks on the corrosion resistant steel (CRES) wire braids. The wire braids were also noted to be bent over towards the “B” end of the hose. A black substance was embedded in the CRES wires in and near the abrasion. Samples of the black material were extracted from the CRES braids and submitted to BR&T for analysis. The BR&T analysis concluded that the black material was consistent with a nose gear tire sidewall material. See Enclosure A for the full BR&T report.

The 65C27360-5 NLG door operator crank assembly was visually examined. The crank assembly had some evidence of wear but was otherwise unremarkable.

EXAMINATION and TEST RESULTS:

An examination and testing of the submitted parts occurred on November 15th and 16th, 2012 at the Boeing EQA facility in Seattle, WA. In attendance were representatives of the NTSB, Boeing and SWA.

The parts were received in two sealed boxes under the control of the NTSB; see Figure 1 through Figure 5.

Figure 1: The two boxes "as received" with the shipping labels affixed to the top of each box.

Figure 2: Box 1, side view. The shipping label removed.

Figure 3: Box 1, opposite side view.

Figure 4: Box 2, side view. The shipping label was removed.

Figure 5: Box 2, top view.

The boxes were opened and the contents were catalogued. Box 1 contained the 65-44610-4 NLG retract actuator. The actuator was removed from the box. The actuator was wrapped in a plastic bag and the bag was sealed with yellow “QUARANTINE” tape; see Figure 6 and Figure 7.

Figure 6: Box #1 opened, the contents was the NLG retract actuator.

Figure 7: The 65-44610-4 NLG retract actuator removed from the box. The bag is sealed with “QUARANTINE” tape.

Box number 2 was opened and the contents were catalogued. The contents of box 2 were the 69-14106-7 NLG transfer cylinder, the 65-44691-6 NLG modular package, the BACH8A04EE-0263S retract actuator hose assembly and the 65C27360-5 NLG door operator crank assembly. The contents were removed from the box; see Figure 8 and Figure 9. All parts were in separate plastic bags with the yellow “QUARANTINE” tape intact and unbroken.

Figure 8: Box #2 opened.

Figure 9: The contents of box #2, from left to right: the 69-14106-7 NLG transfer cylinder assembly, the 65C27360-5 NLG door operator crank assembly, the 65-44691-6 NLG modular package and the BACH8A04EE-0263S retract actuator hose.

The “QUARANTINE” tape on the retract actuator was removed and the retract actuator was removed; see Figure 10. The manufacturing information was recorded from the identification tag (the tag is shown in Figure 11):

BAC ASSEMBLY
Part No. 65-44610-4
Serial No. ES770

Figure 10: The 65-44461-4 actuator assembly removed from the plastic bag.

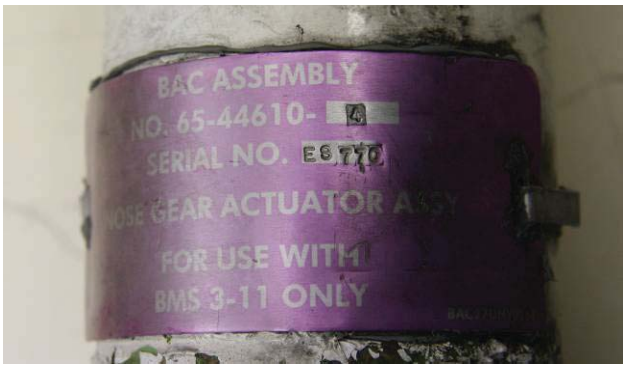

Figure 11: The ID tag on the actuator.

The actuator assembly was visually examined. The hydraulic ports were capped with metal caps and they were beyond hand tight. The unit was dirty and there was paint flaked off of the exterior but there was nothing to indicate that the unit was excessively damaged. A green SWA “Repairable Parts Tag” was attached to the actuator assembly.

The green tag was removed and the actuator was subjected to a digital radiographic (DR) examination. The examination did not reveal any obvious disruption or internal damage to the actuator.

The yellow “QUARANTINE” tape on the bag on the 69-14106-7 NLG transfer cylinder was removed and the transfer cylinder was then removed from the bag. The hydraulic ports on either end of the transfer cylinder were both capped with metal caps; both caps were beyond hand tight; see Figure 12. The transfer cylinder had a green SWA “Repairable Parts Tag” attached. The identification label had a broken securing tab on the left had side. The unit was dirty. The manufacturing information was recorded off of the identification tag (Figure 13 shows the identification tag):

TRANSFER CYLINDER ASSY
BOEING P/N 69-14106-7
Serial No. 3118

Figure 12: The 69-14106-7 transfer cylinder removed from the plastic bag.

Figure 13: The identification tag for the transfer cylinder.

The transfer cylinder had a green SWA “Repairable Parts Tag” attached.

The yellow “QUARANTINE” tape was removed from the bag containing the 65-44691-6 NLG modular package assembly. The modular package was removed from the bag. The unit was dirty. A white SWA “Unserviceable Removal” tag in a clear plastic holder was attached to the modular package as was a green “Repairable Parts Tag”; see Figure 14. All hydraulic ports were capped or plugged with metal caps/plugs. All of the caps/plugs were beyond hand tight. The manufacturing information was recorded off of the identification tag (Figure 15 shows the identification tag):

BOEING ASSY
Part No. 65-44691-6
Serial No. 2749

The two subassembly relief valves on the modular package were documented as:

Part Number: BAC10-60599-1
Serial Number 1: 19139M
Serial Number 2: 19181M

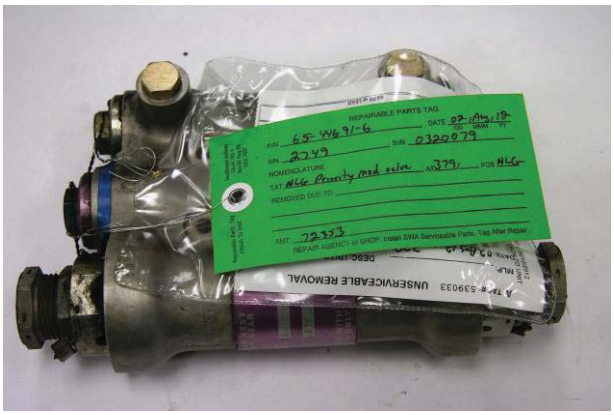

Figure 14: The 65-44691-6 modular package assembly removed from the plastic bag.

Figure 15: The identification tag for the modular unit.

The yellow “QUARANTINE” tape was removed from the bag with the BACH8A04EE-0263S retract actuator hose assembly inside. The hose was removed from the bag; see Figure 16.

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Figure 16: The BACH8A04EE-0263S retract actuator hose assembly removed from the bag.

The hose was covered with a black spiral wrap, as required by the specification for hoses with an “S” suffix. A two-inch segment of the spiral wrap was missing approximately 8 to 10 inches from the “A” end of the hose; see Figure 17.

Figure 17: Missing spiral wrap.

The CRES reinforcement wires in the area with no spiral wrap were worn in an oval shape running lengthwise along the hose. The damage extended approximately 1.25 inches in length. The worn area was widest in the center and tapered towards both ends; see Figure 18. Multiple CRES wires were worn through. In the center of the area where the CRES wires were missing a rupture in the polytetrafluoroethylene (PTFE) inner liner could be seen; see Figure 19. Some of the CRES wires were bent over in one direction; towards the “A” end of the hose. The hose was also slightly bent in the area of the damage as can be seen in Figure 18. A black substance was noted surrounding the rupture. The substance was soft but dense; see Figure 20

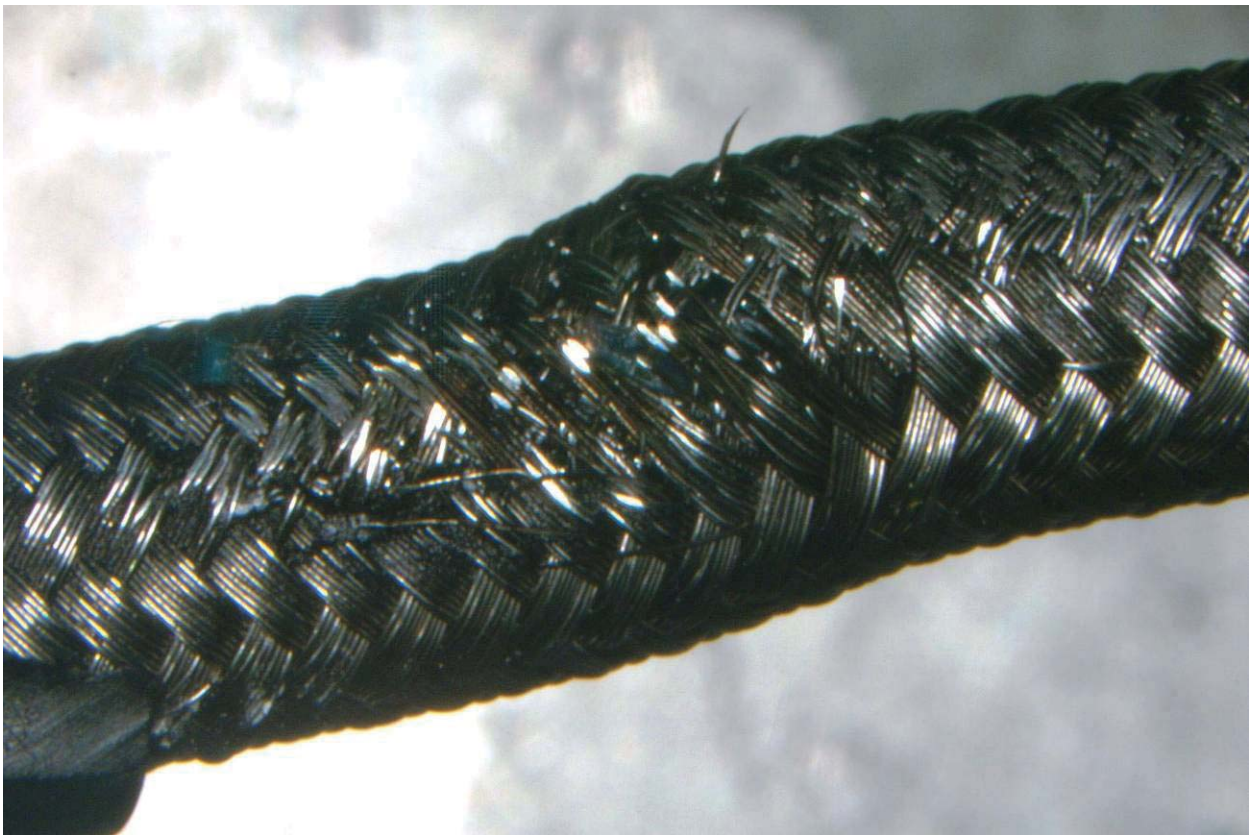

Figure 18: The damaged area to the CRES wires.

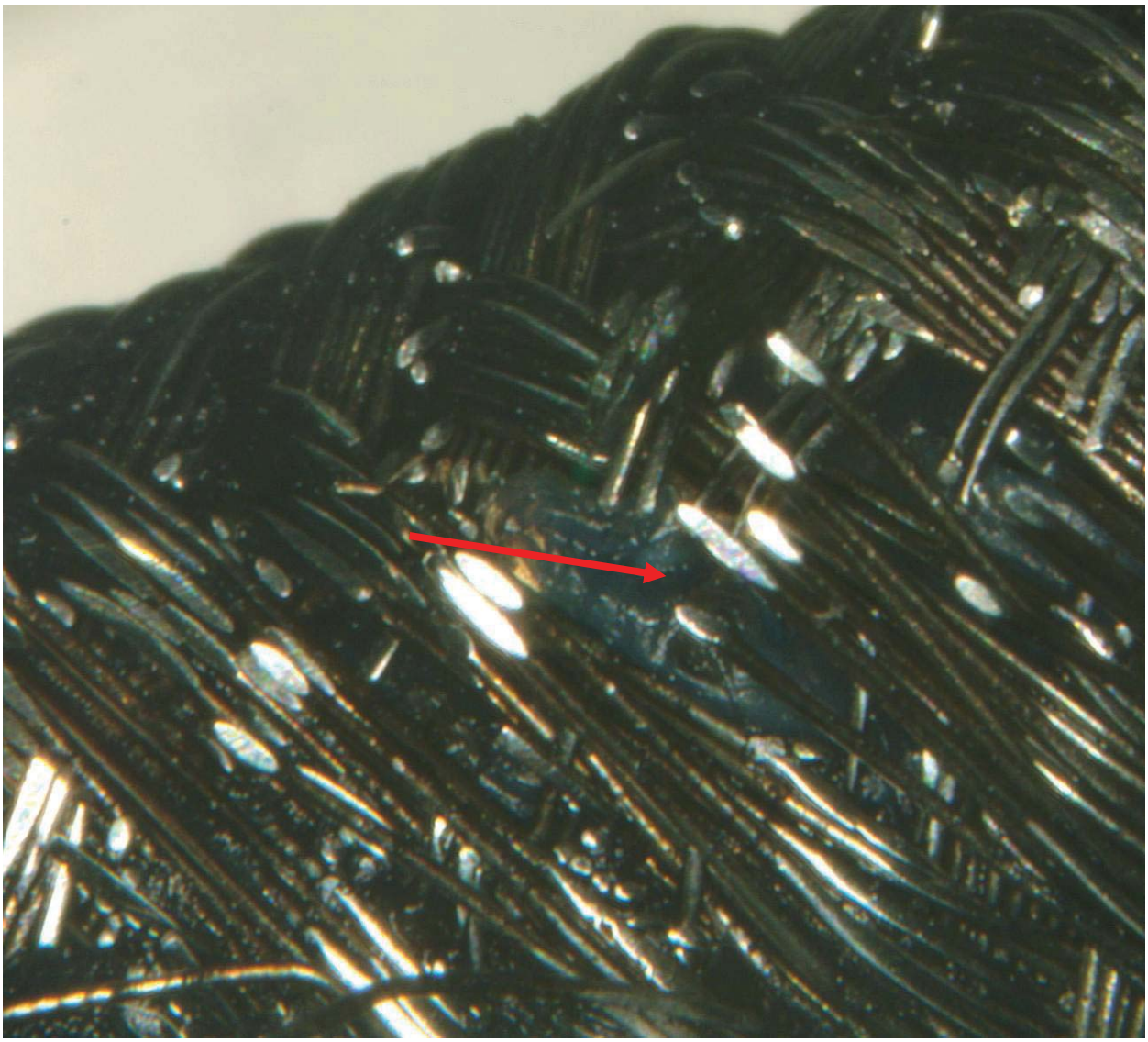

Figure 19: The PTFE inner liner is ruptured in the area of damaged CRES wires. Note the ends of individual CRES wires are worn to a point.

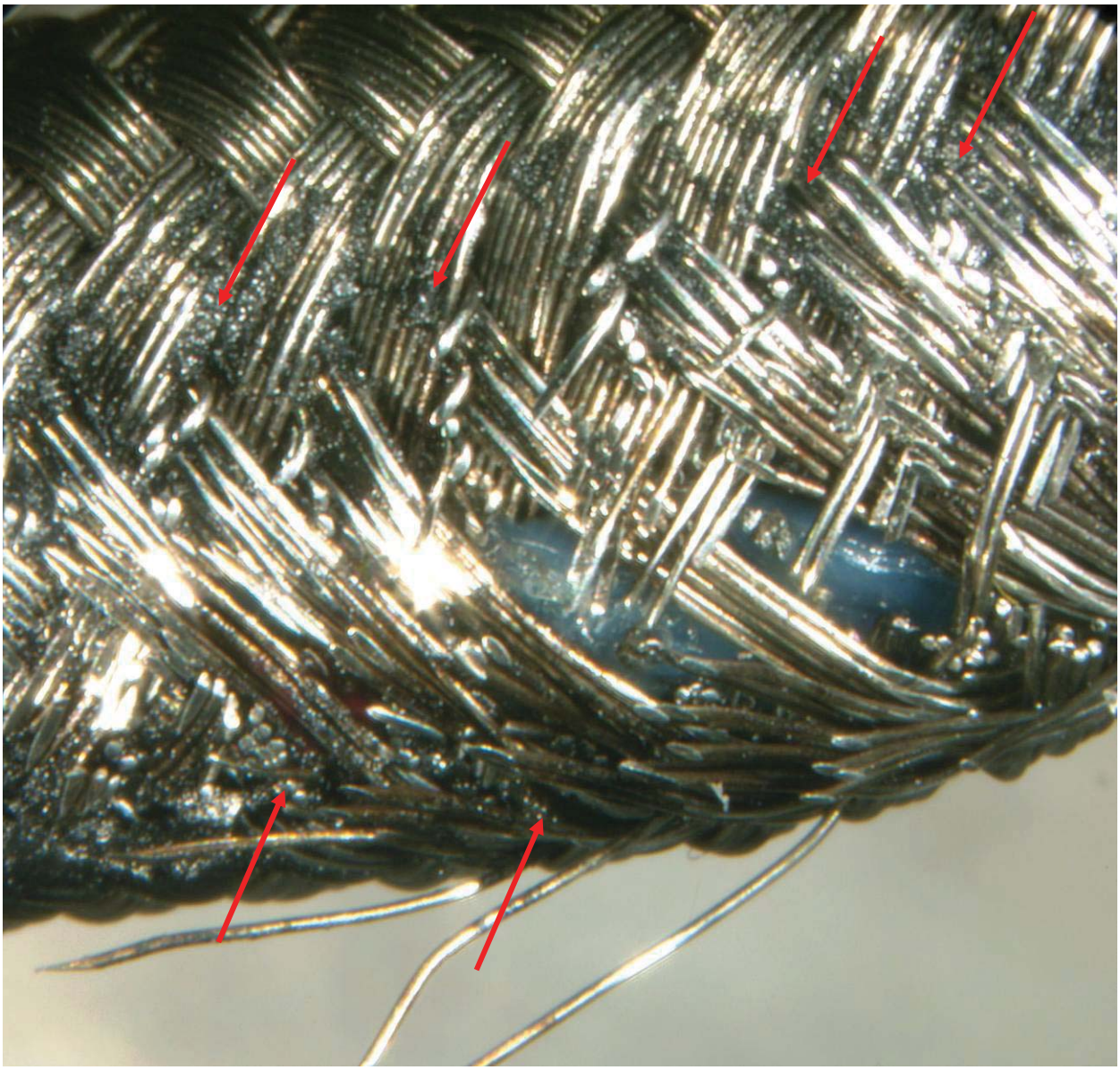

Figure 20: Black material surrounding the rupture. Also note the bent CRES wires.

Samples of the black material were collected and submitted to the BR&T Chemical Analysis group for identification. BR&T identified the material as being consistent with rubber from a tire sidewall. See Enclosure A for the full BR&T report.

The 65-45819-139 support beam was visually examined to look for wear where the hose could have possibly rubbed against; no wear consistent with CRES braid abrasion was noted.

65-14106-7 NLG Transfer Cylinder

The cylinder was installed on the EQA hydraulic test bench #1 and the leakage and operational tests were conducted. The tests were conducted per CMM 32-40-01, page 101, section 1, paragraph C items (4) and (6).

The results of the transfer cylinder testing were as follows:

Test Per Paragraph C item 4

Test was performed with 3,000 PSI applied to one end for one minute; measured 21 cc leakage out opposite end. Performed same test with pressure applied to the opposite end. Leakage measured 14 cc. Maximum allowable leakage is 40 cc.

Test Per Paragraph C item 6

The cylinder was held on the bench deck and a non-metallic rod was inserted into one end of the cylinder. No load piston movement measured 1.4 inches. The total piston stroke play was measured as 3.75 inches, which was within test tolerance (in middle of acceptable range).

The transfer cylinder passed the CMM Leakage and Operational Tests with no faults found. The group decided that disassembly of the cylinder was unnecessary.

65-44691-6 NLG Modular Package

A functional test per CMM 32-09-11, page 101, section 1, paragraph D was performed on the hydraulic modular package. The hydraulic modular package was installed on the EQA hydraulic test bench #1 for the test. The results of the test are recorded in Table I.

Table I

65-44691-6 NLG Modular Package						
Test	Plugged port	Pressurized port	Applied PSI	Flow measurement		
				Flow from (Form) Port	Rate of Flow	Results
1	None	4	3000	5	0.41-0.49	0.44
2	Slowly apply pressure to port 4 until the flow from port 5 is 0.94 GPM. Pressure differential between ports 4 and 5 must be 3500-3960 PSI					3642
3	None	5	3000	4	0.41-0.49	0.45
4	2	3	3000	1	0.15-0.190	0.16
5	Slowly apply pressure to port 3 until the flow from port 1 is 0.66 GPM. Pressure differential between ports 3 and 1 must be 3500-3960 PSI					3642
6	2	1	3000	3	0.15-0.190	0.16
7	3	1	400	2	2.30-2.90	2.37
8	3	1	3000	2	2.30-2.90	2.34
9	3	2	400	1	2.30-2.90	2.60
10	3	2	3000	1	2.30-2.90	2.54

The hydraulic modular package assembly passed all ten elements of the functional test, with no faults found. Based on this finding, the group determined that a disassembly of the unit was not necessary.

65-44610-4 NLG Retract Actuator

The actuator was installed the EQA hydraulic test bench #1 and a functional test of the actuator was conducted in accordance with the CMM 32-30-41, page 101, section D, paragraph 4. The air was bled from the actuator by cycling it fully in the extended and retracted directions five times at 500 PSI. The actuator appeared to operate normally.

Per CMM section D, paragraph 4, the actuator was operated for five complete extend and retract cycles at 3,000 PSI. Actuator snubbing was apparent at both ends of the stroke. No external leakage was noted during the testing.

Based on a discussion amongst the participants of the analysis, additional testing beyond the CMM was conducted on the actuator. The actuator was extended as if in the gear retract position. Then, without hydraulic pressure applied, the gear retract hose was removed, which would be similar to opening the cylinder retract port to atmosphere, in an attempt to simulate a ruptured hydraulic hose. Leakage started as a drip and progressed as a steady stream; see Figure 21.

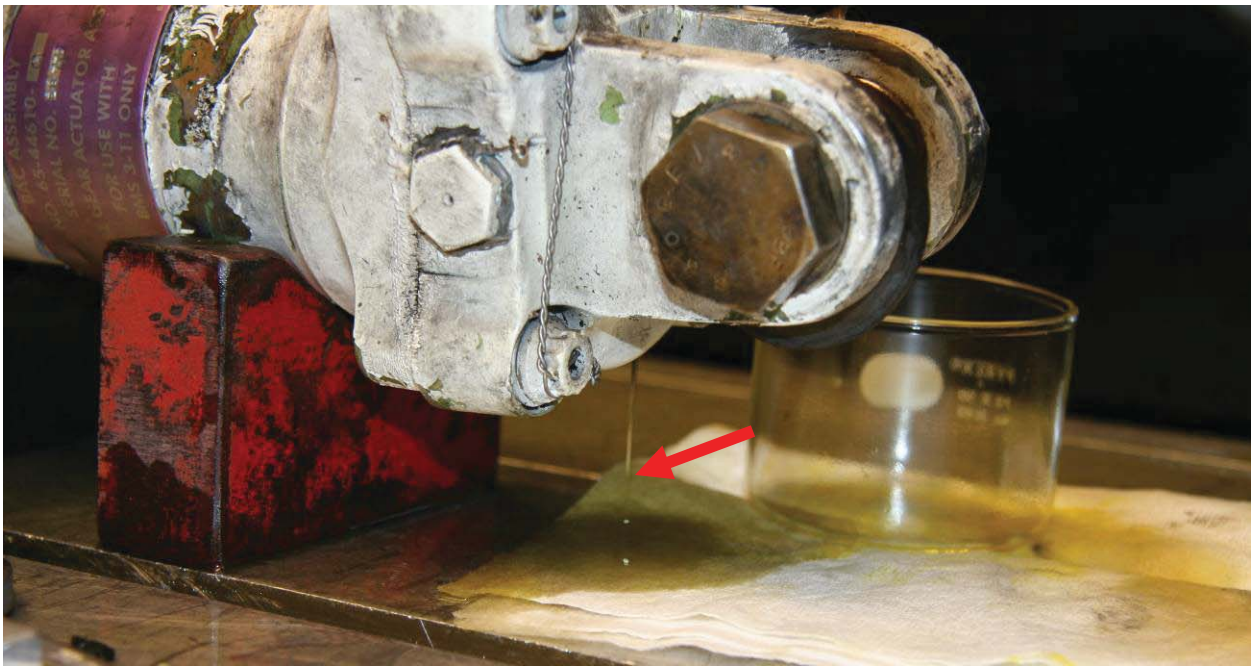

Figure 21: With the hose removed, the cylinder leaked at a full stream.

At the conclusion of the testing, a discussion amongst the participants of the analysis decided that no further examination was required for the 69-14106-7 NLG transfer cylinder, the 65-44691-6 NLG modular package, the 65C27360-5 NLG door operator crank assembly or the BACH8A04EE-0263S retract actuator hose assembly. These components were placed in their respective shipping containers for return shipment to SWA.

It was decided by the participants that the 65-44610-4 NLG retract actuator would be disassembled for examination.

65-44610-4 NLG retract actuator disassembly
The retract actuator was disassembled in accordance with CMM 32-30-41, paragraph 1, procedure C.

Figure 22 is an extract of the illustrated parts list (IPL) for the retract actuator. The item numbers shown in Figure 22 will be used for reference in describing the disassembly of the retract actuator.

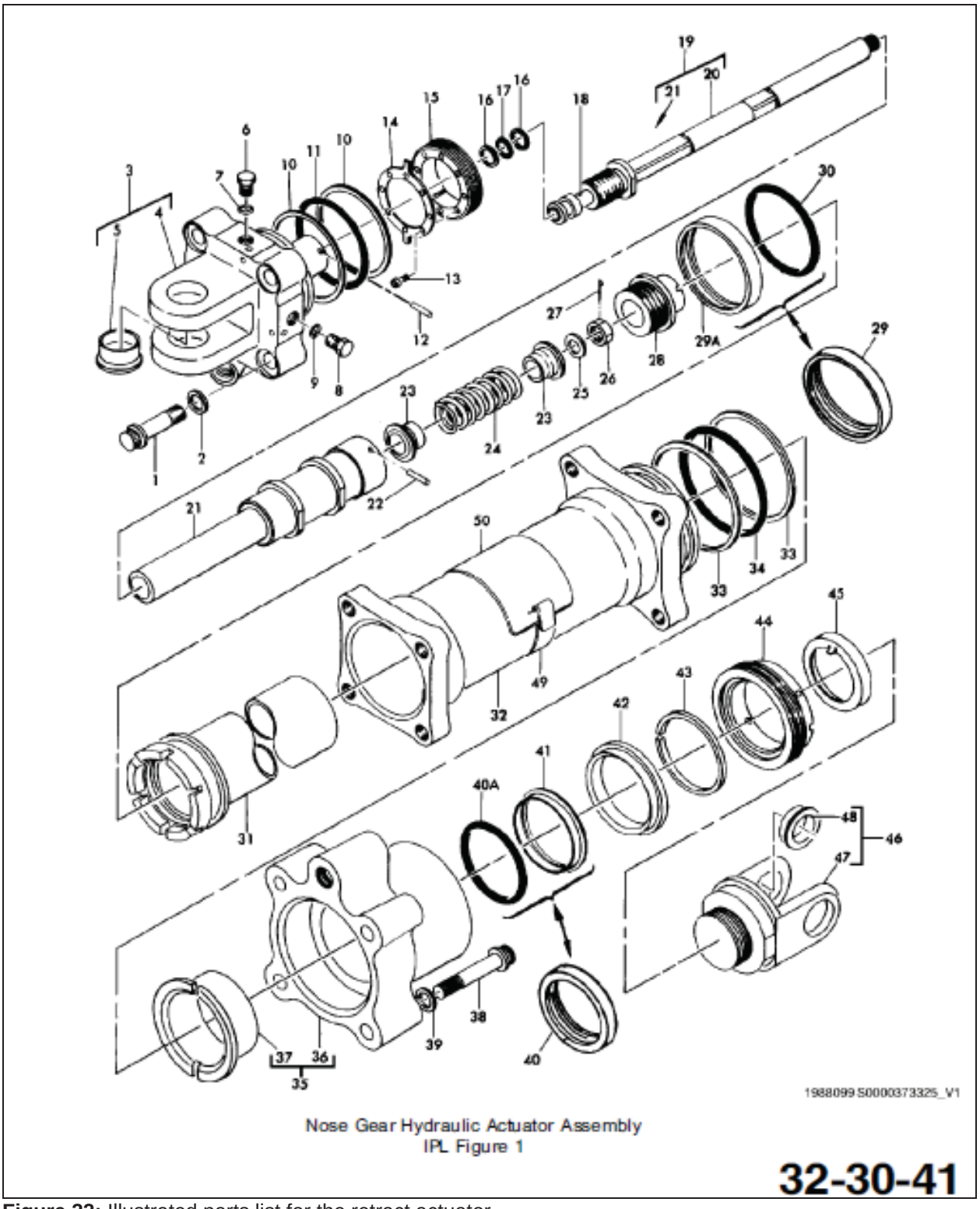

Figure 22: Illustrated parts list for the retract actuator.

The safety wire securing the four bolts on each end of the actuator was intact and correctly installed.

The eight bolts were removed (items 1 and 38) from the head (item 4) and the cap (item 36). The torque value required to loosen each bolt was recorded and is shown in Table II. The actuator was marked with a black felt marker adjacent to the bolts to identify where they were removed from; see Figure 23 showing the head end. All eight bolts were in good condition. The parts were unremarkable.

Table II: Bolt removal torque (inch pounds)

	Bolt 1	Bolt 2	Bolt 3	Bolt 4
Head end	190	150	130	<50
Rod end	135	loose	90	200

Figure 23: Bolts removed from head (item 4) end. Bolt locations are marked in counter-clockwise orientation.

The lock-wire securing the plugs (items 6 and 8) in the head was installed correctly. The lock-wire was cut and removed. The two plugs in the head were removed. The parts were unremarkable.

The fitting was removed from the head end. It was noted that the fitting had a restricted orifice; see Figure 24. Per the IPL, the fitting in the head should have been a non-restricted union. The fitting installed in the cap was removed. A visual examination of

the fitting noted that it was a restrictor fitting. An examination of the fitting under magnification found a vibro-engraved part mark on the fitting; 66-22711-1. The orifice was measured using pin gages; the orifice measured 0.070 inch which is correct for the 66-22711-1 restrictor. Per the IPL, the non-restricted union should be installed in the cap.

The fitting from the cap end was removed. The fitting removed was not a restricted fitting; see Figure 25. Per the IPL, the 66-22711-1 the restrictor fitting should be installed in the cap.

Figure 24: Restrictor fitting installed in the head end.

Figure 25: Union fitting installed in cap end.

The head (item 4) was removed from the cylinder (item 32). The back-up rings and packing in the head were in good condition; see Figure 26.

The bushing (item 37) was loosened from the cylinder (item 32); see Figure 27. The parts were unremarkable.

Figure 26: The back-up rings and packing in the head.

Figure 27: The bushing loosened from the cylinder.

The spring pin (item 12) was removed from the head; see Figure 28. The slide (item 20) was removed from the head; see Figure 29. The parts were unremarkable.

Figure 28: The removal of the spring pin.

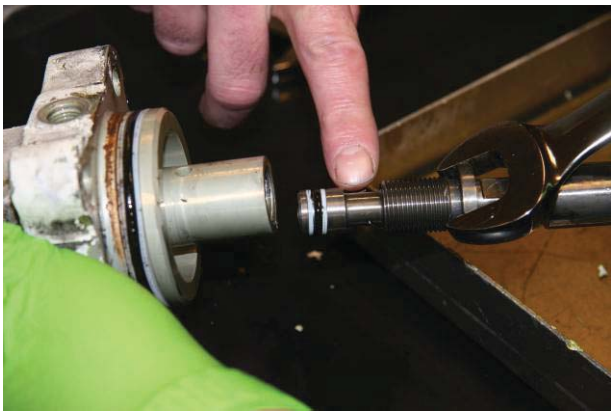

Figure 29: The slide removed from the head.

The 8 screws (item 13) were removed from the retainer nut (item 14); see Figure 30. The retainer nut was removed and the snubbing nut (item 15) was loosened and removed from the cylinder; see Figure 31. The parts were unremarkable.

Figure 30: The screws removed from the retainer nut.

Figure 31: The retainer nut and snubbing nut removed.

The spring pin (part 21) was removed from the sleeve (part 21); see Figure 32. The sleeve retaining nut (part 28) was removed from the sleeve; see Figure 33. The parts were unremarkable.

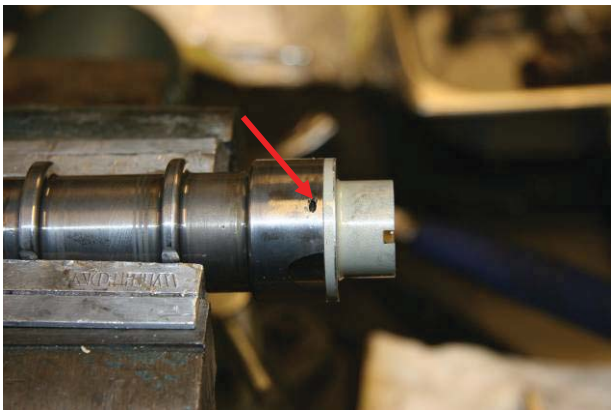

Figure 32: The spring pin was removed from this location.

Figure 33: The sleeve retaining nut was removed.

The cotter pin (part 27) the nut and washer (parts 25 and 26) the spring guides and spring (parts 23 and 24) were removed from the slide (part 20). The slide was removed from the sleeve; see Figure 34. The slide was unremarkable.

Figure 34: The slide removed from the sleeve.

The bore of the cylinder was also unremarkable; see Figure 35.

Figure 35: The bore of the cylinder.

No further testing or disassembly was performed on the retract actuator. The components were packaged back into the box it was received in for return shipment to SWA.

ANALYSIS:

The black material removed from the retract actuator hose assembly was analyzed by BR&T. The results of the BR&T analysis concluded that the material was consistent with a tire side wall material from an exemplar Goodyear 275K22-1/276K22T1 nose gear tire.

See Enclosure A for the full BR&T report.

DISPOSITION:

After the completion of this analysis on November 15th and 16th, 2012, the parts were re-packaged for shipment back to SWA as requested.

The preceding is being provided for information purposes.

ENCLOSURE:
A. BR&T Report SR 13196 737 Report

Background

Samples of dark spongy material were provided to the Fluids and Lubricants lab labeled as EQA 11733 with a request to characterize the material, and if possible, provide comparison to reference samples provided.

Experimentation and Results

Samples of dark spongy material were provided to the Fluids and Lubricants lab labeled as EQA 11733. It was indicated that the samples were expected to be covered in hydraulic fluid. One of the spongy pieces was selected and analyzed using Fourier Transform Infrared Spectroscopy (FTIR) attenuated total reflectance method with a germanium crystal; the spectrometer was overwhelmed with hydraulic fluid, so the sample was rinsed with acetone and the experiment repeated. Once an acceptable FTIR spectrum was obtained, the sample was mounted on a planchette and analyzed using Electron Probe MicroAnalysis (EPMA).

Additionally, a reference sample of nose gear sidewall tire material (Goodyear, Label SR 1-518478157) was provided for analysis. FTIR and EPMA analyses were performed on the sample for comparison to EQA 11733 samples provided.

FTIR comparison of the reference nose gear tire material and the EQA 11733 sample material indicates the materials are consistent. EPMA data also indicates common elements between the reference material and the samples; there are no elements contained in the reference material that are not contained in the sample material. The sample contains additional elements, however environmental exposure may explain the presence of those elements. EPMA scans of the surface of the black spiral wrap on the outside of the braided wire are very similar to the EQA 11733 samples material, while internal scans indicate the material does not contain any inorganic fillers. This suggests similar environmental exposure which accounts for additional elements observed on the EQA 11733 samples

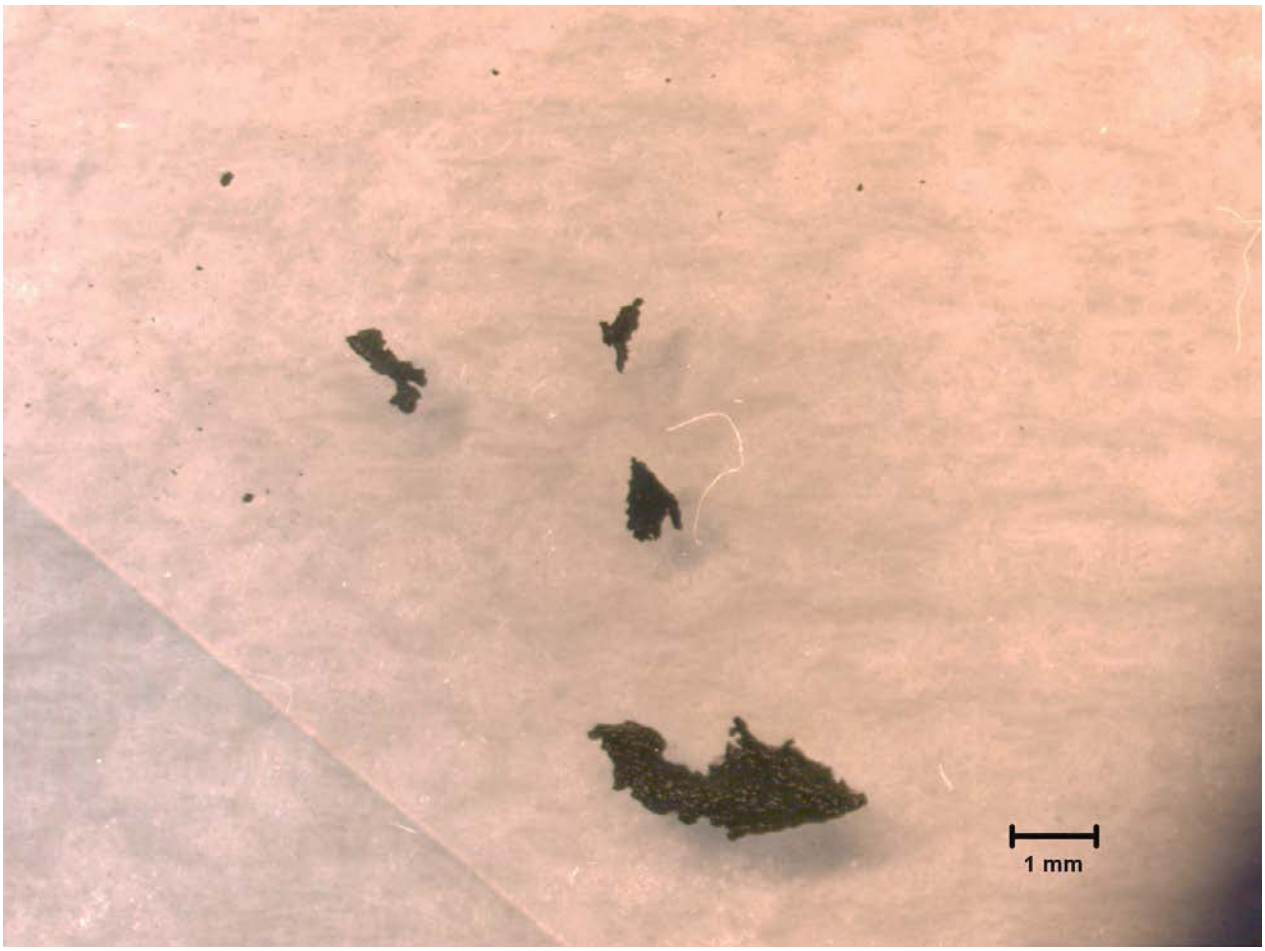

Figure X. EQA 11733 samples as submitted

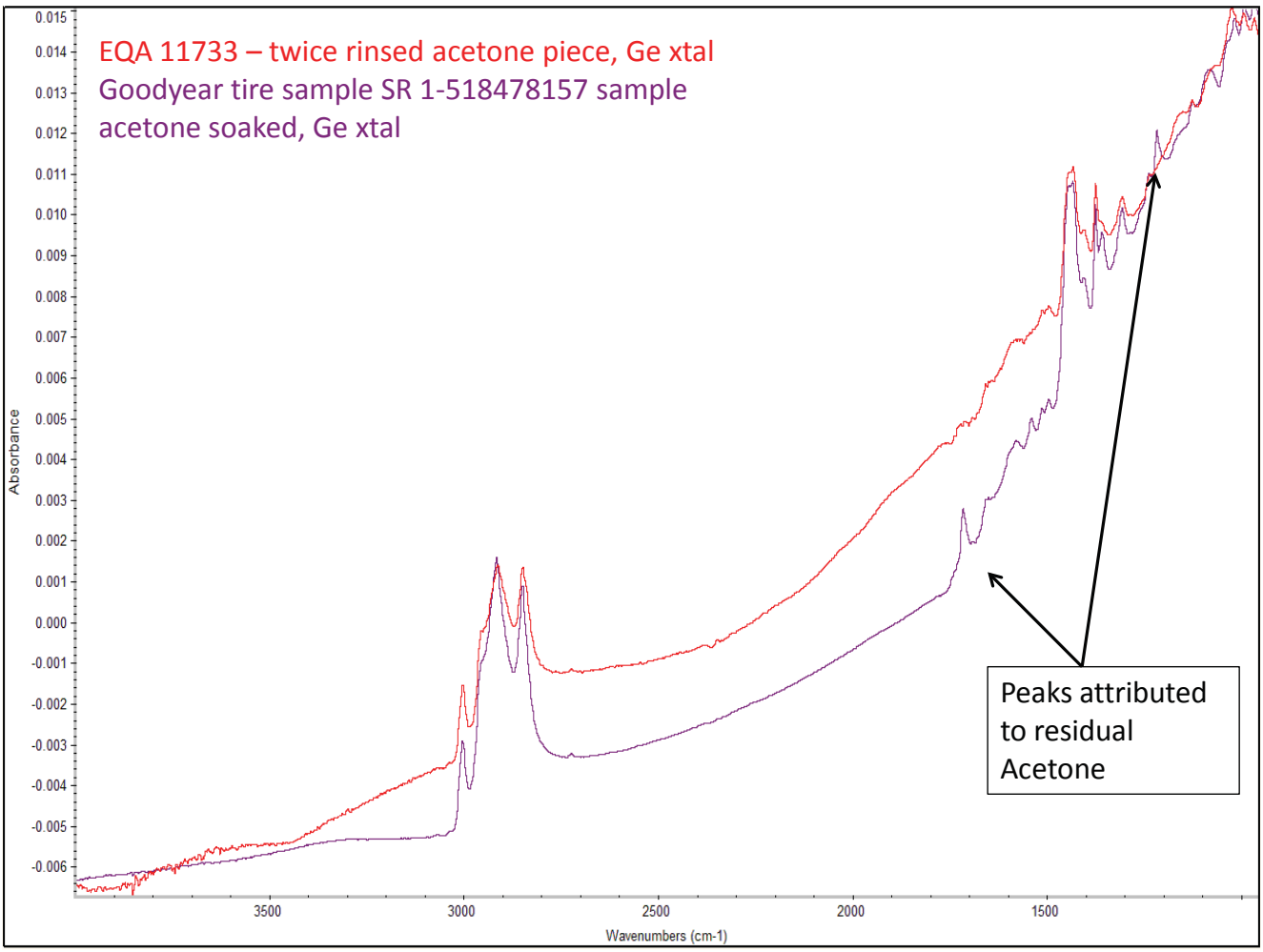

Figure X. FTIR comparison between EQA 11733 dark spongy material and Goodyear tire sidewall reference sample

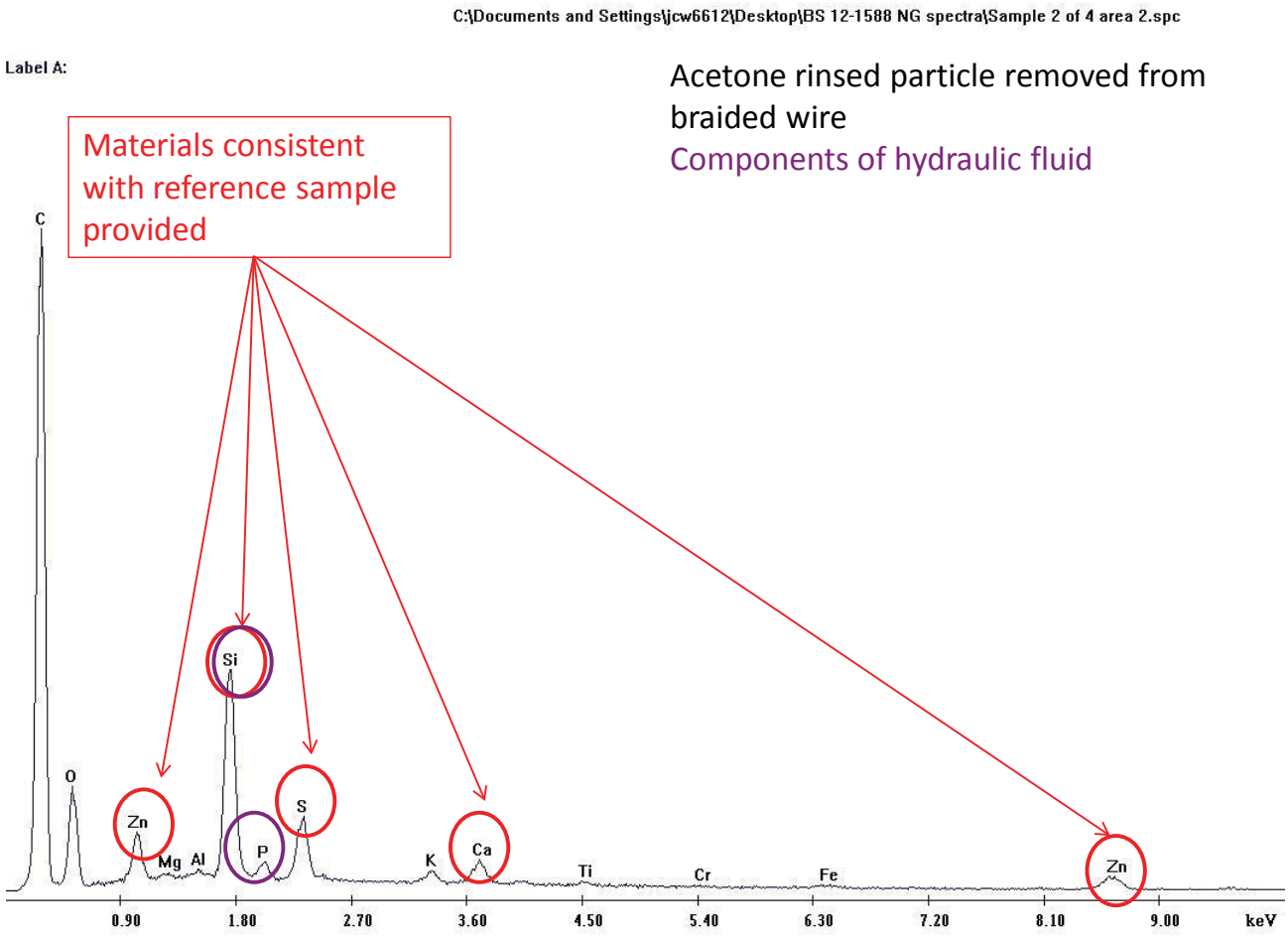

Figure X. EPMA scan of acetone rinsed particle, indicating similarities to the reference material

Conclusions

The dark spongy material recovered from the hydraulic fluid line was analyzed and compared to nose gear tire side wall reference material provided. FTIR and EPMA analysis indicate the dark spongy material is consistent with the nose gear tire side wall reference material provided.