NATIONAL TRANSPORTATION SAFETY BOARD
Office of Research and Engineering
Materials Laboratory Division
Washington, D.C. 20594

December 13, 2021

MATERIALS LABORATORY FACTUAL REPORT Report No. 21-059

A. ACCIDENT INFORMATION

Place	:	Camp Dwyer, Afghanistan
Date	:	April 20, 2020
Vehicle	:	Sikorsky S-61N, N908CH
NTSB No.	:	DCA20LA100
Investigator	:	Dan Bower, AS-10

B. COMPONENTS EXAMINED

Portions of wire rope assemblies from the rotary rudder flight control system of the accident vehicle

C. DETAILS OF THE EXAMINATION

On April 20, 2020, at approximately 0800 local time, a Sikorsky S-61N, N908CH, experienced a loss of control in flight and rolled on its side during an emergency landing at Camp Dwyer, Afghanistan. The three crew members onboard were seriously injured, and the helicopter sustained substantial damage. The flight was operating under the provisions of 14 CFR Part 135 as a cargo flight under contract to the Department of Defense. In accordance with ICAO Annex 13, the NTSB accepted delegation of the investigation from the Afghanistan Civil Aviation Authority.

A total of seven portions of wire rope (cable) assemblies, some connected via turnbuckles, were received for examination as shown in figure 1. Portions of cables were initially labeled A through G in the order examined. Two lengths of cable assemblies were received with no apparent fractures. The other five lengths of cable assemblies were fractured on at least one end of the cable run. After all portions received were measured and compared to specified cable lengths and index numbers in Table 201 and Figure 202, respectively, in the Sikorsky S-61N Maintenance Manual for the Rotary Rudder Flight Control System[1], it was possible to correlate the cables and fracture locations to the index numbers assigned to each cable in the system. All wire ropes examined were consistent with a right regular lay construction consisting of 7 strands of 19 wires (7x19) and had an average diameter of approximately 0.16 inch. All threaded terminals were stamped “MS21260.” All intact cable sections did not show any apparent signs of excessive wear or corrosion, and a greasy black-brown substance was observed on the cable exterior and interspersed between

[1] According to figure 202 and table 201 in Sikorsky Aircraft S-61N Maintenance Manual, based on length measurements, all eight cables identified were received and cables 2, 7, 25, 32, and 33 were received intact. Cables 3, 6, and 26 were received fractured. There were six turnbuckles (identified as 4, 5, 27, 28, 34, and 35) also received with the cables.

wires, consistent with a lubricant and soil mixture. Fractured areas of cables were generally drier and more reddish-brown in color consistent with residual dried lubricant and oxidation.

The first length of assembled cable that was examined, labeled A in figure 1, consisted of a threaded terminal connected to a length of cable with a ball and socket terminal at the opposite end with no apparent fractures. The assembly length was approximately 144 inches which was consistent with cable 25 as identified in the maintenance manual. Engraved alphanumeric characters consistent with part identification markings were observed on one of the flat circular sides of the ball end socket and on the shank of the threaded terminal as detailed in table I. The other non-fractured length of cable assemblies, labeled B in figure 1, consisted of a length of cable between two threaded terminals connected via a turnbuckle to another shorter length of cable between a threaded terminal and a ball and socket terminal. The total length of the assembly was approximately 266 inches and was consistent with cable 7 connected to cable 32 via turnbuckle 35 as identified in the maintenance manual. The turnbuckle retained a threaded terminal from each cable and both locking clips were present. The threaded terminal at the free end of the longer cable assembly was bent towards the grooved side of the reduced diameter threaded portion as shown in figure 2. Strings of alphanumeric characters consistent with part identification markings were observed engraved on the shanks of both threaded terminals on the longer portion of cable as detailed in table I.

The third length of assembled cables examined, labeled C in figure 1, consisted of a fractured cable connected via a turnbuckle to another shorter length of cable between a threaded terminal and a ball and socket terminal. The total length of the assembly was approximately 288 inches which was consistent with cable 6 (fractured) connected to cable 33 via turnbuckle 34 as identified in the maintenance manual. The turnbuckle was connected to the threaded terminals with both locking clips present. The threaded terminal on the fractured portion of cable was bent and exhibited deformation at the base of the shank as detailed in figure 3. The adjacent wire strands were flattened and permanently set in a curved profile consistent with localized contact and loading above the yield strength of the cable. There were no apparent fractured wires in this area.

The fourth length of assembled cable examined, labeled D in figure 1, consisted of a fractured cable with a threaded terminal connected to one side of a turnbuckle. The total length of the assembly was approximately 11-1/2 inches which was consistent with cable 3 (fractured) connected to turnbuckle 27 as identified in the maintenance manual. A locking clip was present at the turnbuckle-to-threaded terminal connection.

The fifth length of cable assemblies examined, labeled E in figure 1, consisted of a fractured cable approximately 17-1/4 inches long connected via a turnbuckle to another length of cable between two threaded terminals which was connected via another turnbuckle to a threaded terminal with fractured wires protruding from the base of the shank. The total length of the assembly was approximately 105-1/2 inches which was consistent with cable 2 (intact) connected to fractured ends of cables 6 (shorter end) and 26 (longer end) via turnbuckles 5 and 28, respectively, as identified in the maintenance manual. The longer section of fractured cable was retained in the turnbuckle with a locking clip and no locking clip was present at the connection to the intact cable. The threaded terminals were bent about the reduced diameter threaded section as shown in figure 4. Two broken wires were observed near the base of the threaded terminal shank of the intact cable. At the other turnbuckle connection, no locking clip was present at the intact cable connection and a portion of a locking clip was retained between the groove in the threaded terminal of the shorter fractured cable and the turnbuckle. The portion of locking clip was separated and bent away from the turnbuckle hole. Both threaded terminals were bent about the reduced threaded section. The end of the turnbuckle with the partially separated locking clip was deformed and partially torn and a gray-silver scrape mark extended across the length of the turnbuckle and threaded terminal as shown in figure 5. Small areas of yellow material transfer were observed along the scrape mark and a piece of foreign metallic material rich in aluminum as determined by x-ray florescence (XRF) spectroscopy, was observed wedged between the torn end of the turnbuckle and the bent threaded terminal. This turnbuckle was ultimately removed from the intact cable to facilitate closer examination of the fractured wires protruding from the base of the threaded terminal shank.

The sixth length of cable examined, labeled F in figure 1, consisted of a fractured cable connected to a ball and socket terminal. The total length of the assembly was approximately 148-1/2 inches which was consistent with a portion of cable 26 (fractured) as identified in the maintenance manual.

The seventh length of cable examined, labeled G in figure 1, was received later and was less greasy and more reddish brown in color especially in the vicinity of the fracture, consistent with the presence of oxidation and residual dried lubricant and soil. It consisted of a fractured cable with a threaded terminal connected to a turnbuckle. The total length of the assembly was approximately 140 inches which was consistent with cable 3 (fractured) connected to turnbuckle 4 as identified in the maintenance manual. The threaded terminal was bent about the reduced diameter threaded section as shown in figure 6 and a locking clip was present at the turnbuckle-to-threaded terminal connection.

The fractured sections of cables were examined more closely visually, with the aid of a 4X – 80X zoom stereomicroscope, and with the aid of a scanning electron microscope (SEM) equipped with energy dispersive x-ray spectroscopy (EDS).

Figure 7 shows a photograph of both sides of fractured cable 3. The fracture location was approximately 9 inches from the threaded terminal connection to cable 25 at turnbuckle 27 or approximately 140 inches from the threaded terminal connection to cable 7 at turnbuckle 4 as indexed in the maintenance manual. Strands and wires were raveled and splayed open approximately 2 to 4 inches from the fracture surface, consistent with a high energy fracture event. A section was extracted from cable segment G as indicated by the red dashed line in figure 7 which was subsequently cleaned ultrasonically using acetone for closer examination. Figure 8 shows a SEM image of typical fractured wires observed on the specimen. Necking deformation, evidenced by reduced wire cross-sections, was observed preceding the fracture surfaces which were of the cup-and-cone and slant type, consistent with tensile overstress separation. Residual lubricant and general surface corrosion areas were observed as irregular rough deposits near fractured wire ends.

Figure 9 shows a photograph of both sides of fractured cable 6. The fracture location was approximately 270 inches from the connection to cable 33 at turnbuckle 34 which was at the base of the threaded terminal connection to cable 2 at turnbuckle 5 as indexed in the maintenance manual. Strands and wires were raveled and splayed open approximately 7 inches from the fracture surface along the cable segment C side, consistent with a high energy fracture event. Wires were observed protruding in multiple directions from the base of the threaded terminal on the mating side of the fracture from cable segment E. The portion of cable segment E was subsequently cleaned ultrasonically using acetone for closer examination. Figure 10 shows a SEM image of typical fractured wires observed on the specimen. Necking deformation, evidenced by reduced wire cross-sections, was observed preceding the fracture surfaces which were of the cup-and-cone and slant type, consistent with tensile overstress separation.

Figure 11 shows a photograph of both sides of fractured cable 26. The fracture location was approximately 140 inches from the ball end terminal (approximately 18 inches from the connection to cable 2 at turnbuckle 28) as indexed in the maintenance manual. Strands and wires were raveled and splayed open approximately 4 to 6 inches from the fracture surface, consistent with a high energy fracture event. A section was extracted from cable segment E as indicated by the red dashed line in figure 11 which was subsequently cleaned ultrasonically using acetone for closer examination. Figure 12 shows a backscattered electron (BSE) image from SEM examination of typical fractured wires observed on the specimen. Necking deformation, evidenced by reduced wire cross-sections, was observed preceding the fracture surfaces which were of the cup-and-cone and slant type, consistent with tensile overstress separation. Residual lubricant and general surface corrosion areas were observed as irregular rough deposits near fractured wire ends.

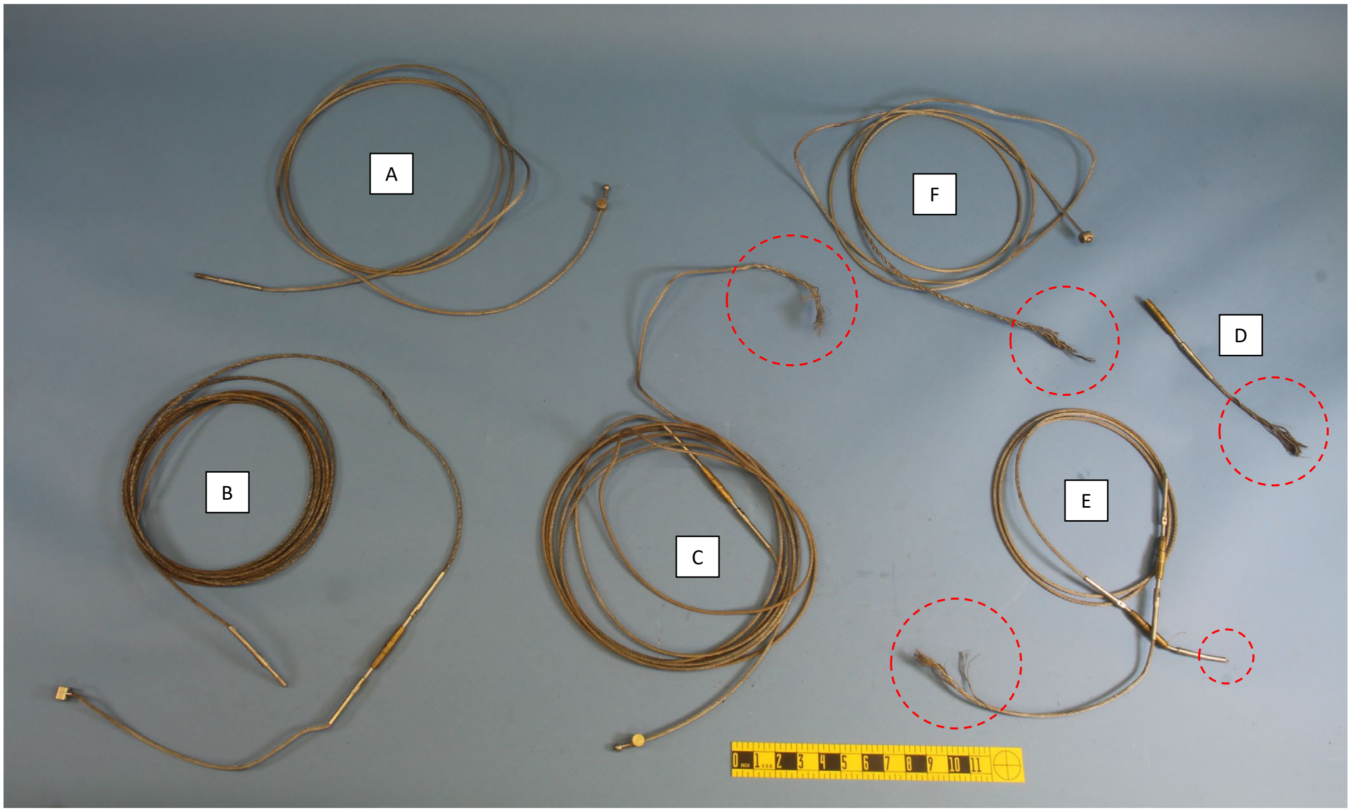
A section from cable G preceding the fracture and raveled strands was extracted for closer examination. The resulting specimen was cleaned using soapy water, a soft bristled brush, and ultrasonic agitation followed by acetone with ultrasonic agitation. A SEM supplemented with EDS was used to examine the composition of the cleaned specimen. Figure 13 shows BSE images of the specimen. The bright gray areas as viewed using a BSE detector correspond to elemental compositions with higher atomic weight such as iron and zinc where darker gray areas indicate the presence of lighter elements. Light gray areas of wire appeared smoother and more uniform where darker areas appeared as rough irregular shaped deposits on the surface of the wires. EDS spectra were acquired at the locations identified by solid yellow boxes in the right image of figure 13. Figure 14 shows the spectra acquired at locations 2 and 3 as identified in figure 13. Locations 1 and 2 (smooth light gray areas) were similar in composition to each other and showed major peaks of iron with minor peaks of zinc and other common alloying elements in steel and was consistent with galvanized steel. Locations 3 and 4 (rough dark gray deposits) were similar in composition, and relative to locations 1 and 2, showed a significantly lower concentration of iron and significantly higher concentrations of oxygen, zinc, phosphorus, and silicon consistent with galvanic corrosion product and residual lubricant and soil. No appreciable reduction in cross section was observed in the strands of wire.

Michael Meadows
Materials Engineer

Table I: Identification markings observed on portions of received cable assemblies

Identification Information Location	Cable [1]	Nearest Cable Connection [1]	Identification Information
Threaded terminal shank	7	32	54878 R6140-65612-17 PL 01/09
	7	3	FAA-PMA-ROTAIR INDS. R6140-66612-17 SIKORSKY MODELS S61 L/N/NM
	25	3	78286 ASSY S6140-62701-1 MFR 54878 78286- S6140-62701-1 PL MFR 59157 9/00
	26	2	MFR 54878 FAA-PMA ROTAIR IND R6140-62701-2 78286ASSY S6140-62701-002 REV. C
Ball end socket	25	N/A	S6140-65615-0
	26	N/A	S6140-66615-0

[1] Cable identification number as indexed in the Sikorsky S-61N Maintenance Manual for the Rotary Rudder Flight Control System



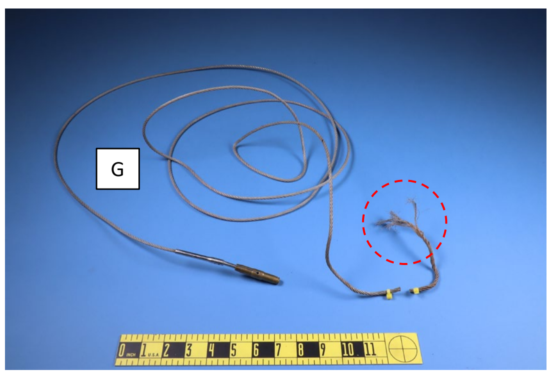


Figure 1: Photographs of the portions of cable as received. Locations where cables were fractured are circled in red. Identification labels A through G were assigned based on order of observation.

Figure 2: A photograph of the threaded end terminal of cable B (7) as received, which exhibited bending deformation.

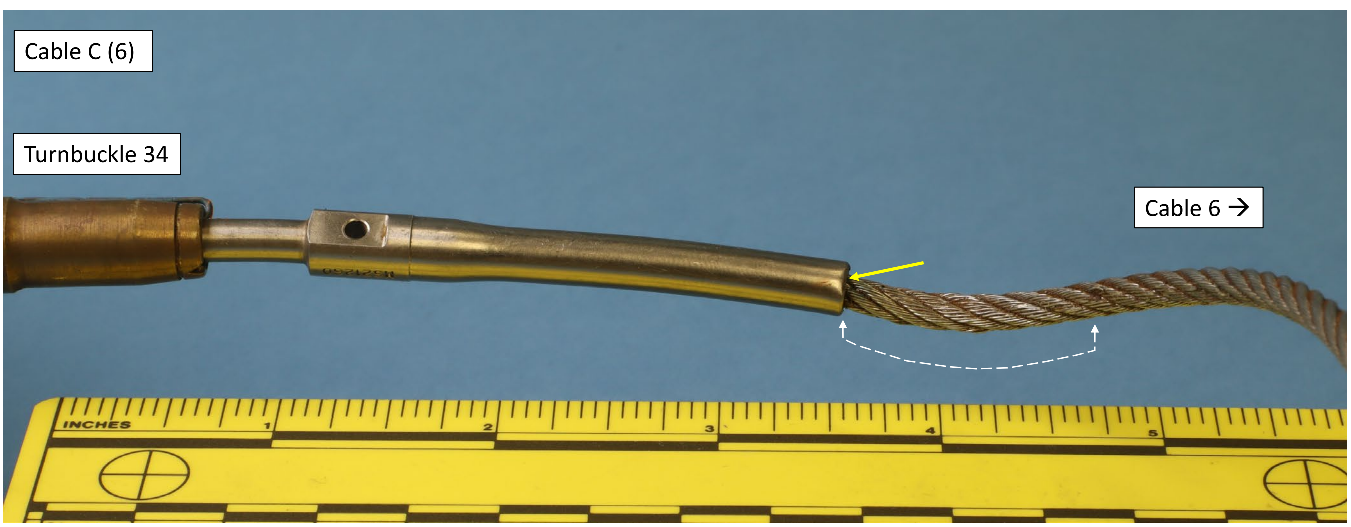


Figure 3: A photograph of the threaded end terminal of cable 6 which exhibited bending deformation. The base of the terminal was locally deformed as indicated by the yellow arrow and adjacent strands were flattened and permanently set in a curved profile as indicated by the white bracket, consistent with local contact and loading above the yield strength of the cable.

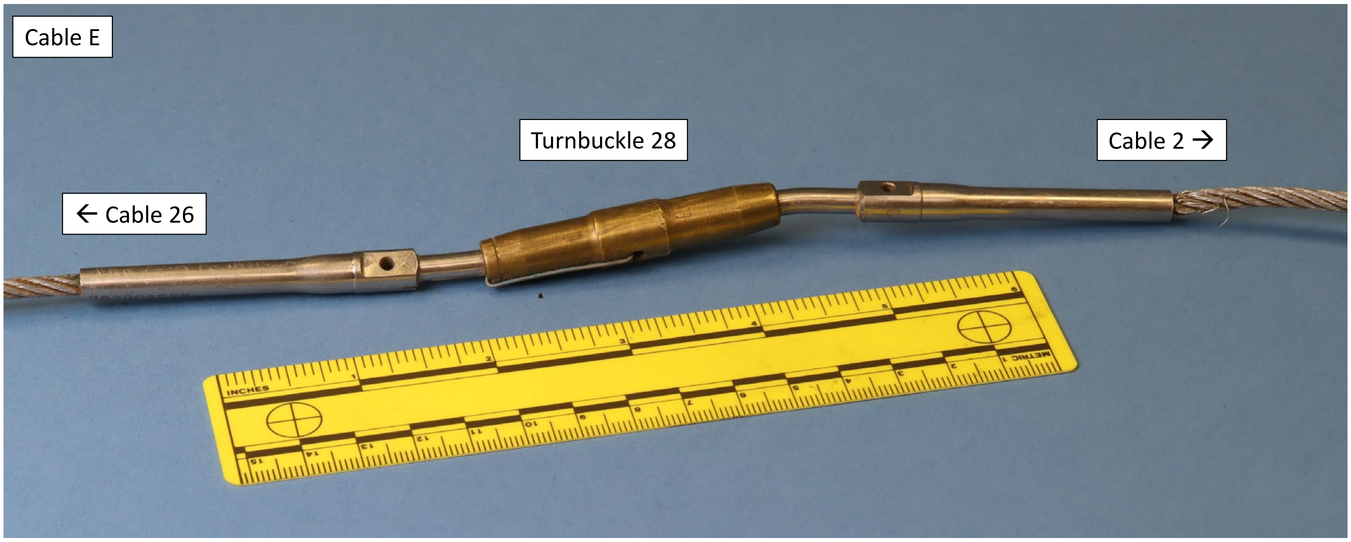


Figure 4: A photograph of the connection of cables 26 and 2 at turnbuckle 28. The threaded terminals on both cables exhibited bending deformation. Two broken wires were observed at the base of the cable 2 threaded terminal.

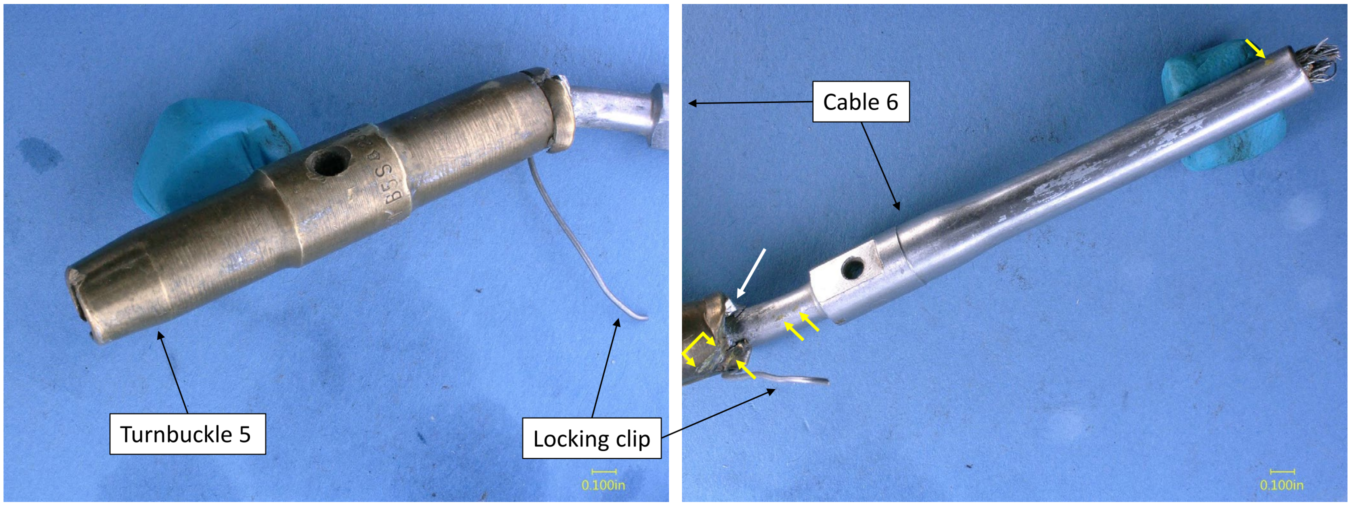


Figure 5: Digital microscope images of turnbuckle 5 (left) connected to the shorter fractured portion of cable 6 (right). A gray-silver scrape mark was observed along the span of the turnbuckle and threaded terminal. The turnbuckle was deformed and torn at the connection to cable 6 as observed in the top right area of the left image and the lower left area of the right image. A piece of aluminum rich metallic material was wedged between the damaged turnbuckle and threaded terminal as indicated by the white arrow. Yellow arrows indicate areas of yellow material transfer along the scrape mark.

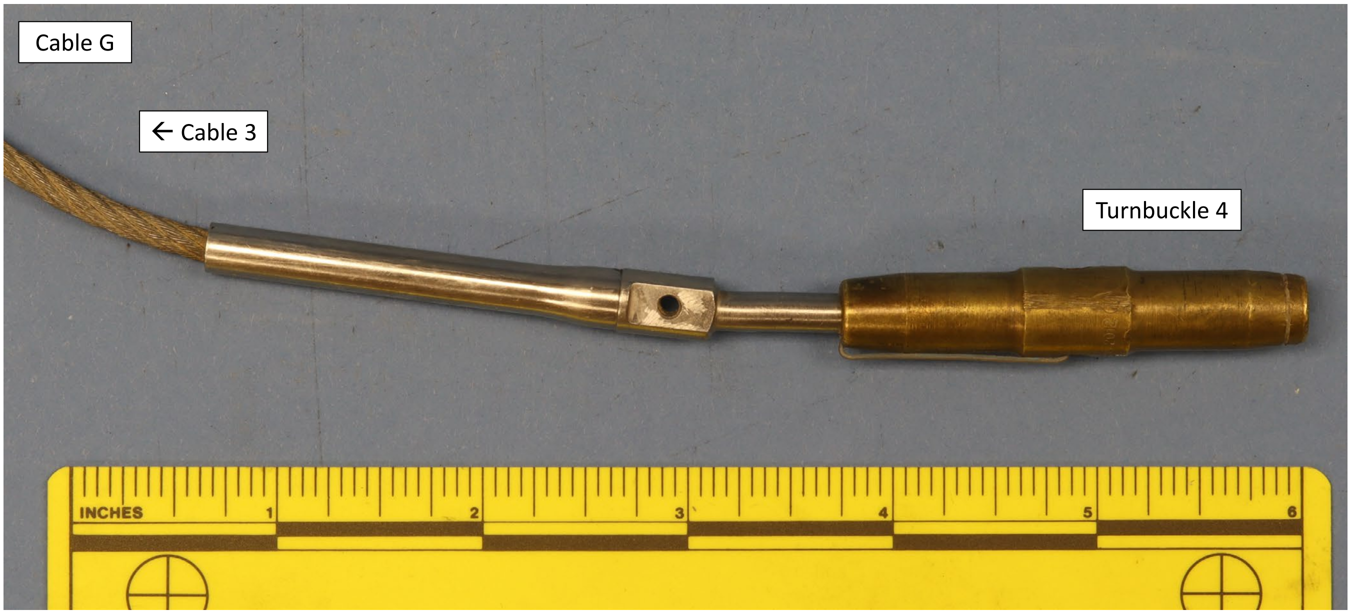


Figure 6: A photograph of the threaded end terminal of cable 3 as received, which exhibited bending deformation.

Figure 7: A photograph of both sides of fractured cable 3. Strands and wires were raveled and splayed open approximately 2 to 4 inches from the fracture surface. The red dashed line indicates the approximate location of a section cut made in cable G to facilitate closer exam of fractured wires using SEM.

Figure 8: A secondary electron image of typical wire fracture surfaces observed in cable 3.

Figure 9: A photograph of both sides of fractured cable 6. Strands and wires were raveled and splayed open approximately 7 inches from the fracture surface along cable segment C. Wires were observed protruding in multiple directions from the base of the threaded terminal from cable segment E.

Figure 10: A secondary electron image of typical wire fracture surfaces observed in cable 6.

Figure 11: A photograph of both sides of fractured cable 26. Strands and wires were raveled and splayed open approximately 4 to 6 inches from the fracture surface. The red dashed line indicates the approximate location of a section cut made in cable E to facilitate closer exam of fractured wires using SEM.

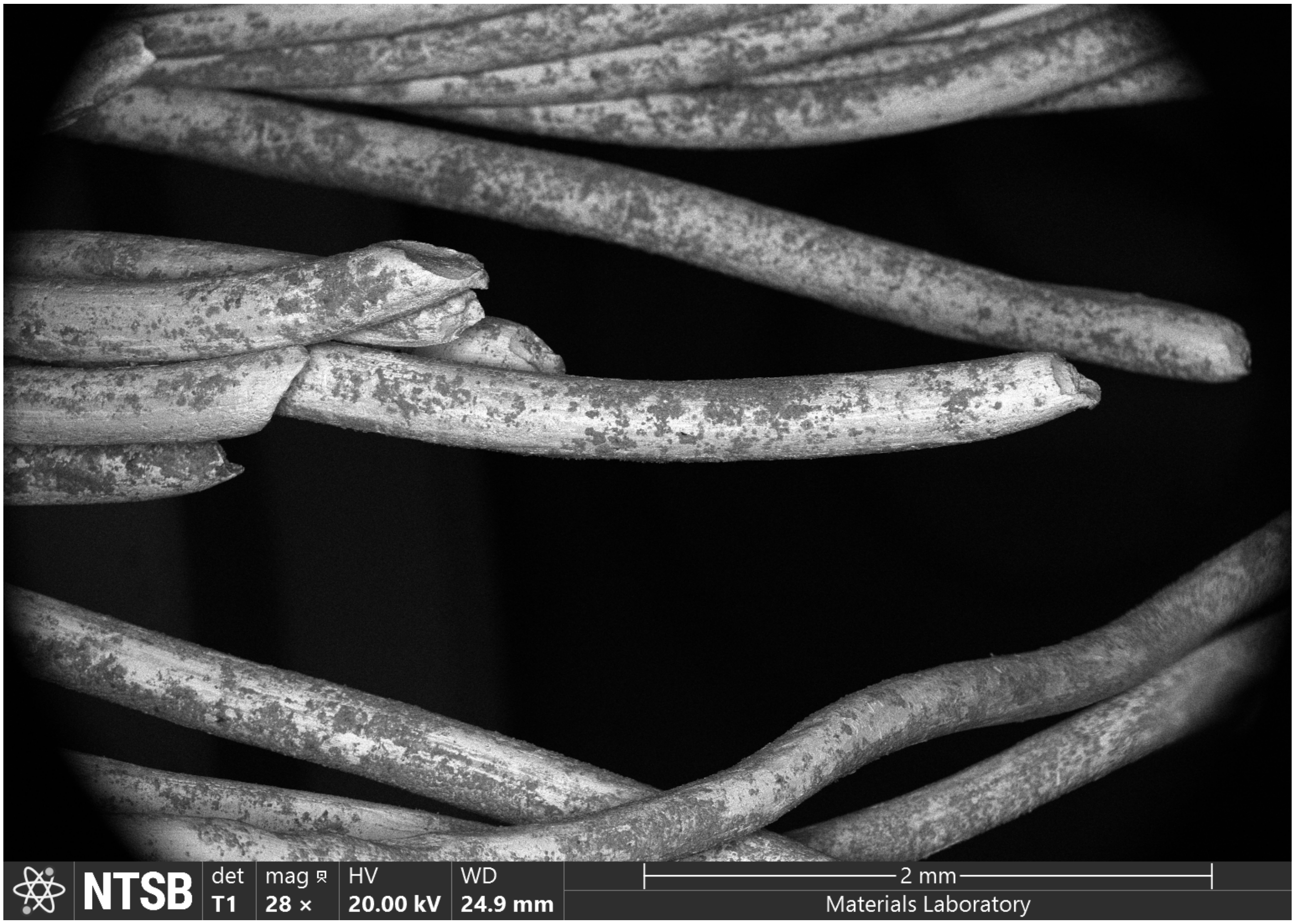


Figure 12: A backscattered electron image of typical wire fracture surfaces observed in cable 26.

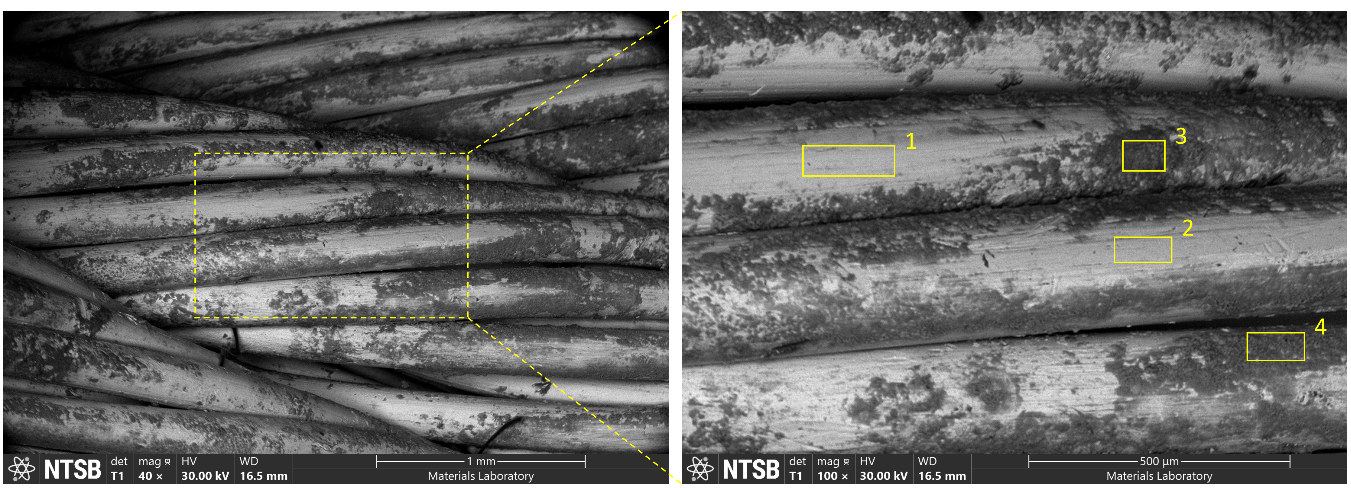


Figure 13: A backscattered electron image of a specimen extracted from cable G which preceded the fracture location. The image on the right is a closer view of the area highlighted by a dashed yellow box. The numbered solid yellow boxes on the right image indicate locations where EDS spectra were acquired.

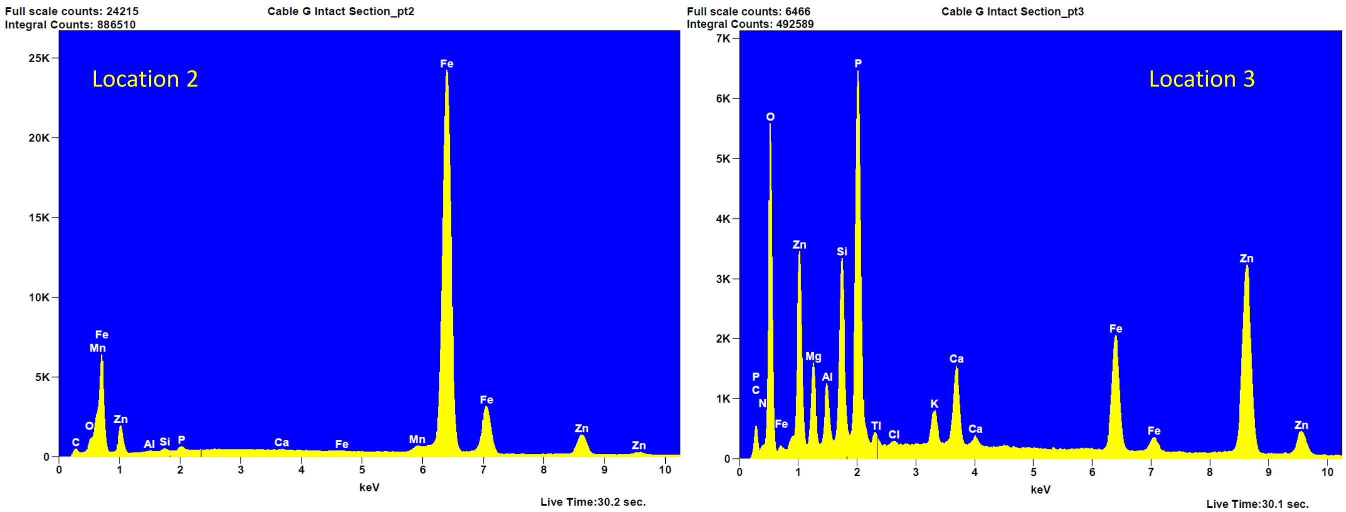


Figure 14: EDS spectra acquired from locations 2 (left) and 3 (right) as identified in the previous figure.