National Transportation Safety Board
Office of Aviation Safety
Washington, DC 20594

ANC22FA047

AIRWORTHINESS

Group Chair's Factual Report

January 26, 2023

Table of Contents

A. ACCIDENT

Location:	Clear, AK
Date:	June 26, 2022
Time:	1938 Alaska Daylight Time 0338 UTC
Helicopter:	Bell UH-1B

B. AIRWORTHINESS GROUP

Group Chair	Van S. McKenny IV NTSB / AS40 Washington, DC
Investigator-In-Charge	Brice Banning NTSB / AS10 Washington, DC
Group Member	Todd Murray FAA / Flight Standards District Office Fairbanks, AK
Group Member	Matthew Leonard Kamatics Corporation Bloomfield, CT

C. SUMMARY

On June 26, 2022, about 1938 Alaska daylight time, a Bell UH1B helicopter, N9970F was destroyed when it was involved in an accident near Clear, Alaska. The pilot and sole occupant was fatally injured. The helicopter was operated as a Title 14 *Code of Federal Regulations* Part 133 Rotorcraft External-Load Operations flight.

The single piloted UH-1B was positioning over an external load staging area with a 125-foot-long line and hook, in an approximate 150-foot hover. A loud "bang" was heard by witnesses and the helicopter rolled to the right, nose down, and impacted the ground. A post-crash fire immediately erupted.

D. DETAILS OF THE EXAMINATION

1.0 Helicopter Information

The Bell UH-1B is a single piloted, conventionally configured helicopter with a two bladed teetering main rotor and two bladed tail rotor, with a skid type landing gear (Figure 1). The helicopter is powered by a single Ozark T53 series, 1,100 hp turboshaft engine. It has a maximum gross weight of 8,500 pounds. The fuselage consists primarily of two longitudinal beams with transverse bulkheads and metal covering. The main beams are the supporting structure for the cabin, landing gear, fuel tanks, transmission, engine, and tailboom. The external cargo suspension unit is attached to the main beams near the center of gravity of the helicopter. The tailboom section is bolted to the aft end of the fuselage and extends to the aft end of the helicopter. It is a tapered, semi-monocoque structure comprised of skins, longerons, and stringers. The tailboom supports the tail rotor, vertical fin, and synchronized elevator. It houses the tail rotor driveshaft and some electronic equipment.

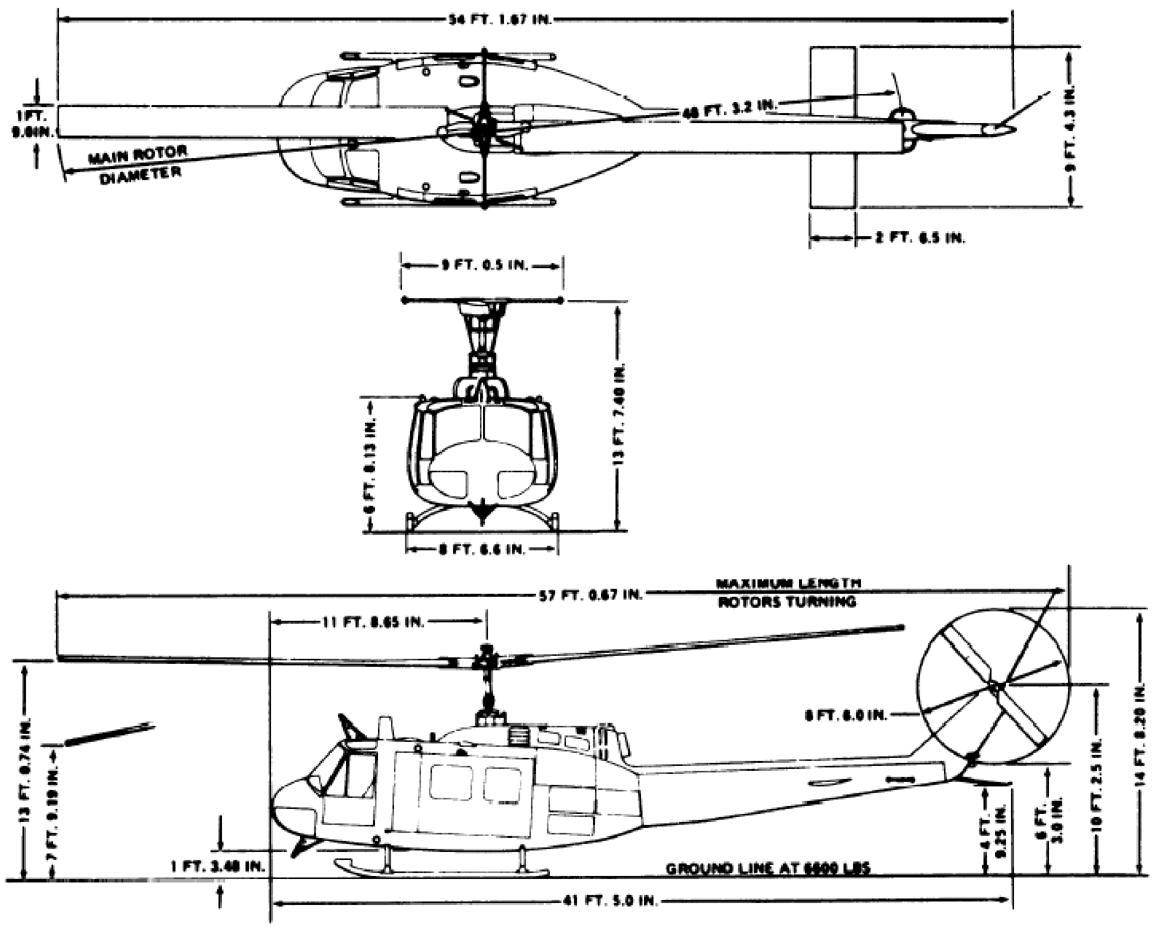


Figure 1. Principal dimensions diagram[1].

1.1 Accident Helicopter Information

The accident helicopter, Bell UH-1B, serial number (SN) 60-3568, was originally donated to the Michigan State Police by the United States Government on August 6, 1976, and registered as N9970F. It was subsequently purchased by the Southern

[1] US Army Operators Manual, TM 55-1520-210-10, Chapter 2

Aero Corporation on April 19, 1990, and issued a restricted category special airworthiness certificate on June 28, 1990. On November 15, 1991, the helicopter was purchased by Northwest Helicopters, Olympia, WA. On March 04, 1992, Northwest Helicopters changed the helicopter registration number to N70NW. On March 18, 1996, the helicopter was sold to Northern Exploration Co, DBA Northern Pioneer, Anchorage, AK. On January 4, 2017, the Northern Exploration Co changed the helicopter registration number to N9970F on a restricted category airworthiness certificate.

The FAA airworthiness documentation for N9970F have the following major airframe changes under various supplemental type certificates (STC); electrical system installation and bubble door for external cargo operations, cargo hook manual release, Kamatics main drive shaft, installation of a Ozark T53-L-13 series engine, installation of a 24 inch tail boom extension plug, installation of a tailboom Global Vertical Fin, installed high skid gear cross tubes, installed Van Horn Tail Rotor Blades, installation of a catch tank for the overboard combustion drain system, and installed Helicopter Technology Company main rotor blades.

2.0 Wreckage Documentation

An on-scene examination of the wreckage was conducted June 28, 2022at the accident site (Figure 2). The wreckage was then recovered and transported to a storage facility in Wasilla, AK, for storage.

The wreckage was located in the center of a paved helispot used to stage and transport equipment and personnel for state forest fire fighting operations. The elevation of the accident site was 548 feet mean sea level (msl). The helicopter rested on its left side. The cockpit and cabin area had extreme damage from the post-crash fire. The engine was on its left side aft of the cabin. The main transmission, rotor mast, and rotor had been liberated during the accident sequence and was about 10 yards southeast of the main wreckage. One main rotor blade (identified as “B”) had extreme fire damage, and the other rotor blade (identified as “A”) exhibited a set downward bend. Both main blades remained attached to their blade grips on the rotor hub.

Figure 2. Main wreckage.

The outboard half of the tail boom, including vertical fin and tail rotor had been liberated from the main fuselage and was about 20 yards to the south of the main wreckage. It did not exhibit any fire damage.

2.1 Cockpit

The cockpit sustained extreme fire damaged. The cockpit/cabin area was oriented on its left side, and most of the left side had been destroyed by fire. The pilot and copilot steel seat frames were in the cockpit, but the cushion material had been consumed by the fire. The right seat collective was present but separated at the base. The left seat collective was present and remained attached to the collective torque tube. Neither cyclics were located. Both right seat pedals had been liberated from their pedal supports and were a few feet away from the main wreckage, along with what was likely chin bubble plexiglass. Both left seat pedals remained attached to their supports and connected to their bell crank.

The instrument panel had thermal damage, but most individual instruments remained in the panel. The instrument readings were not readily visible and not recorded. Instruments located in the area of the right-side pilot's door were visible and recorded:

Table 1. Cockpit instrument readings.

Nf (power turbine speed) / Nr (rotor speed)	0 / 0 % rpm
Torque (TQ)	0 pounds per square inch (psi)

Exhaust Temperature	200° C
Load Indicator	Digital
Ng (compressor speed)	0 % rpm

The cockpit Nf/Nr gage had been liberated from the instrument panel. The Nf needle was trapped by the instrument case deformation at 65% and Nr pointer was at 10%.

Table 2. Cockpit systems switch positions.

GOV (Engine)	AUTO
FUEL	ON
FUEL TRANS PUMP	OFF
START	OFF
FORCE TRIM	ON
HYD CONT	ON

2.2 Flight Controls

2.2.1 System Description[2]

The flight control system is a hydraulic assisted positive mechanical type, actuated by conventional helicopter controls. Complete controls are provided for both pilot and copilot. The system includes a cyclic system, collective control system, tail rotor system, force trim system, synchronized elevator, and stabilizer bar. The flight control hydraulic system provides power to operate flight control power cylinders. A gravity feed reservoir is used. The basic system includes a variable delivery axial-piston pump, reservoir, filter, relief valve, solenoid valve, directional flow check valves, servo valves, irreversible valves, power cylinders, pressure switch, low pressure caution light, couplings for connection of a ground test stand and connecting lines, and a control switch located on the pedestal.

2.2.2 Flight Control Examination

Both collectives were visually located in the cockpit. Control tubes and linkages aft of the cockpit were destroyed by the post-crash fire. The collective flight control servo had been liberated from its mount and separated from the upper control rod and the lower (input) control rod. The remaining section of the upper flight control rod was attached to the collective sleeve lever.

[2] System description extracted from US Army Technical Manual TM 55-1520-210-23-2.

Neither cyclics were located within the cockpit and presumed to have been destroyed by the post-crash fire. The cyclic center bell crank was located with the lateral force gradient spring. Four partial sections of control rods were connected to the cyclic mixing lever assembly. Two flight control servos were located near the front of the engine, both had been liberated from structure, and both control rods (input and output) were separated from the servo. Both cyclic scissor and sleeve assemblies were attached to the mast with the pitch change tubes connected.

The right-hand cockpit anti-torque pedals had been liberated from their mounts. The left-hand copilot anti-torque pedals were mounted on the pedal supports, and control tubes were connected to the mixing bell crank. Control tubes aft of the cockpit, back to the bell crank cable quadrant were destroyed. The hydraulic power cylinder had extreme thermal damage that left only the piston rod and valve assembly. Both ends had been liberated from their connecting bell cranks. The tail rotor control cable ends were present in the area of the bell crank quadrant. Both cables extended to the severed end of the tail boom, where the cable ends were broomstrawed. The severed tail boom and vertical tail section contained both ends of the tail rotor control cables, the severed ends exhibited broomstrawed characteristics. The cable was routed up to the 90° gearbox and the cable chain was attached to the pitch change sprocket.

The synchronized elevator control rod clevis was attached to the swashplate; however, the control rod shaft had pulled away from the clevis shaft, showing sheared rivets. The rod shaft was not bent or deformed. The elevator lever and support assembly was attached to the transmission case, the lower control rod clevis was attached at the lever and fractured about 6 inches past the rod end. The control rod linkages between the lever support and tailboom transition were not located and presumed to have been destroyed by the post-crash fire. The series of control rods and bell cranks were identified as melted debris laying on thermally deformed tailboom skin and longeron structure out to the tailboom separation. The elevator had been liberated from the tail boom by an inflight main rotor strike to the tail.

2.3 Main Rotor Drive System

2.3.1 System Description[3]

The helicopter main transmission is mounted forward of the engine and coupled to the power turbine shaft at the intake end of the engine by the main driveshaft. The main transmission is a reduction gearbox, used to transmit engine power at a reduced speed to the rotor system. A freewheeling unit is incorporated in the main transmission to provide a quick-disconnect from the engine if a power failure occurs. This permits the main rotor and tail rotor to rotate to accomplish a safe autorotational landing. The tail rotor drive is on the lower aft section of the

[3] System description extracted from US Army Technical Manual TM 55-1520-210-23-2.

transmission. Power is transmitted to the tail rotor through a series of drive shafts and gearboxes. The tachometer generator, hydraulic pump, and main direct current generator are mounted on and driven by the transmission. A self-contained pressure oil system is incorporated in the main transmission. The oil is cooled by an oil cooler and turbine fan. The engine and transmission oil coolers use the same fan.

2.3.2 Main Rotor Drive System Examination

The main transmission, part number (PN): 204-040-01605, serial number (SN): AB6-109, had separated from the airframe structure. All five isolation mounts were present. The right rear mount had fractured the corner of the transmission case, leaving a portion of the transmission case attached to the isolation mount and airframe (Figure 3). The fracture surfaces were granular in texture, bright silver/gray in color, with 45° angular shear lips. The hydraulic and lubrication pumps were in place. There was no electrical generator installed on the transmission. The main transmission input was manipulated by hand and could be rotated in the freewheel direction and locked in the drive direction resulting in synchronous movement of the rotor mast.

Figure 3. Main rotor and transmission. Transmission support case fracture shown in the red inset box.

The KAFlex drive shaft connecting the engine output to the main transmission input quill had separated from its flex frames at both ends; the main drive shaft section was found behind the engine in the thermally consumed inboard tailboom section. Portions of flex frame elements were attached to the flange structure at both the engine connection and the transmission connection. Frame elements were bent and fractured, with some liberated portions located in the outer debris areas. A frame element on the engine side had a frame connecting bolt in place on the frame without a nut. A frame element on the transmission side exhibited gaps between the frame elements at a corner connection. The drive shaft exhibited radial damage and metal tearing at both ends of the shaft.

The lift link remained attached to the bottom of the transmission case (Figure 4). The end of the lift link that attaches to the airframe lift beam also remained attached to the lift beam flange. The lift beam flange had torn away from the lift beam box structure. The fracture surfaces of the lift beam web were jagged and matte gray in color, consistent with tension overload.

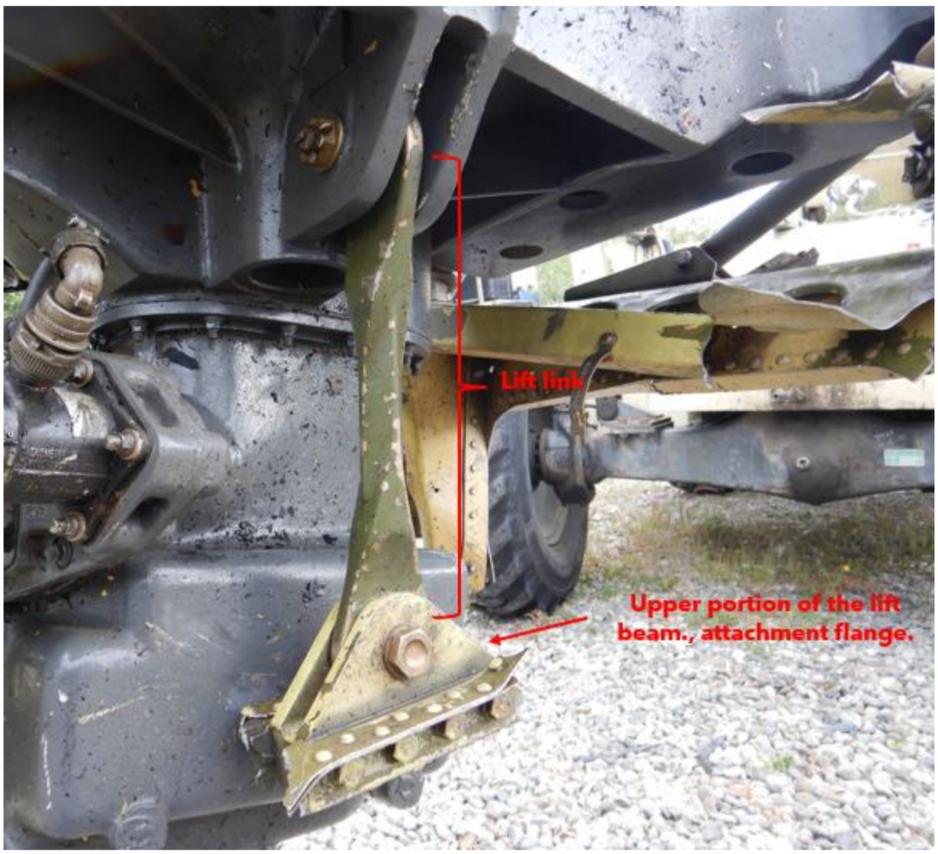


Figure 4. Lift link and attached airframe lift beam flange.

2.3.3 Tail Rotor Drive Examination

The presence of all 5 sections of the tail rotor drive were established by accounting for the driveshaft connections, hanger bearings, and recovered drive shaft segments. The drive shafts had separated from both ends of the intermediate gearbox. The intermediate 42° gear box rotated smoothly. The magnetic drain plug was removed and was free of debris.

The tail rotor 90° gearbox was split open circumferentially. Visual examination of the drive gear inside the gearbox showed all teeth present, and no gear damage or discoloration. The tail rotor mast was connected, and the tail rotor hub had impact damage, both blade roots were connected, the pitch links were connected from the blades to the pitch change beam.

2.4 Main Rotor

2.4.1 System Description

The main rotor is a two bladed semi-rigid, teetering type. The two blades are connected to a common yoke by blade grips and pitch change bearings with tension straps to carry centrifugal forces. The rotor assembly is connected to the mast with a nut. The nut has provisions for hoisting the helicopter. A stabilizer bar is mounted on the trunnion 90° to the main rotor. Blade pitch change is accomplished by movements of the collective and cyclic controls. The main rotor is driven by the transmission through the mast. The mast is tilted 5° forward.

2.4.2 Main rotor Examination

The main rotor head was attached to the mast. The mast was bent about 30° toward blade "B". The stabilizer bar and the pitch change rods for both blades were attached. The damper tubes were attached to the stabilizer bar, the dampers had separated from the mast mounts. Both blades remained attached to their blade grips.

Blade "A"'s data tag contained the following information: Helicopter Technology Company (HTC), PN 204P2100 – 101, SN A099, Weight 203.8 lbs. [pounds] (Figure 5).

Figure 5. Blade "A"

Blade “A” was bent slightly down about 7 feet from the grip. There was afterbody spar separation present about 4 feet from the grip and extending to the tip. There was slight leading edge impact damage present from about 12 feet from the grip extending to the tip with blue/purple paint transfer observed. Chordwise scratching was present about span length 16 feet through 18 feet. Chordwise skin afterbody separations were present between span length 12 feet and 18 feet. The pitch horn had “pulled out” of the blade grip. No fretting was observed on faying surfaces. The inserts remained on the bolts. No pounding witness marks were identified on the stabilizer bar or pitch horn.

Blade “B”’s data tag contained the following information: Helicopter Technolog (partially obscured due to fire damage), PN 204P2100 – 101, SN A100, Weight 208.7 lbs. (Figure 6).

Figure 6. Blade "B"

The "B" was largely consumed by the post-crash fire. The outboard 6-inches sustained impact damage to the top side of the leading edge. Leading edge impact damage was present from about span length 13 feet through 15 feet. The blade was bent down near the grip. Leading edge separation and thermal debonding started between span length 4 – 4 ½ feet and was bent upwards starting at that point. Blade had come to rest inverted.

2.5 Tail Rotor

2.5.1 System description

The tail rotor is a two-bladed semi-rigid delta-hinge type. Each blade is connected to a common yoke by a grip and pitch change bearings. The hub and blade assembly are mounted on the tail rotor shaft with a delta-hinge trunnion and a static stop to minimize rotor flapping. Blade pitch change is accomplished by movement of the antitorque pedals which are connected to a pitch control system through the tail rotor 90° gearbox. Blade pitch change serves to offset torque and provide heading control.

2.5.2 Tail rotor examination

The tail rotor was attached to the tail rotor gearbox mast (Figure 7). One blade was bent 90°. The opposing blade was fractured chordwise at the furthest outboard root doubler.

Figure 7.. Tail rotor assembly

2.6 Engine

2.6.1 Engine Description

The accident engine was a single Ozark T53L-13B turboshaft, SN LE-18935. The T53L-13B is capable of producing1,400 horsepower (hp) at 99.6% N1. It has a five-stage axial and single stage centrifugal compressor, with an external annular combustion chamber, two-stage gas producer turbine and two stage power turbine. The power shaft drives the reduction gearbox through the output shaft.

2.6.2 Engine Examination

The Ozark T-53 engine was positioned on its left side in the wreckage (Figure 8) and was thermally damaged. The inlet had been consumed by the fire. A visual examination of the compressor inlet did not reveal any compressor blade damage

(Figure 9). A visual examination of the second stage power turbine blades did not reveal any damage (Figure 10).

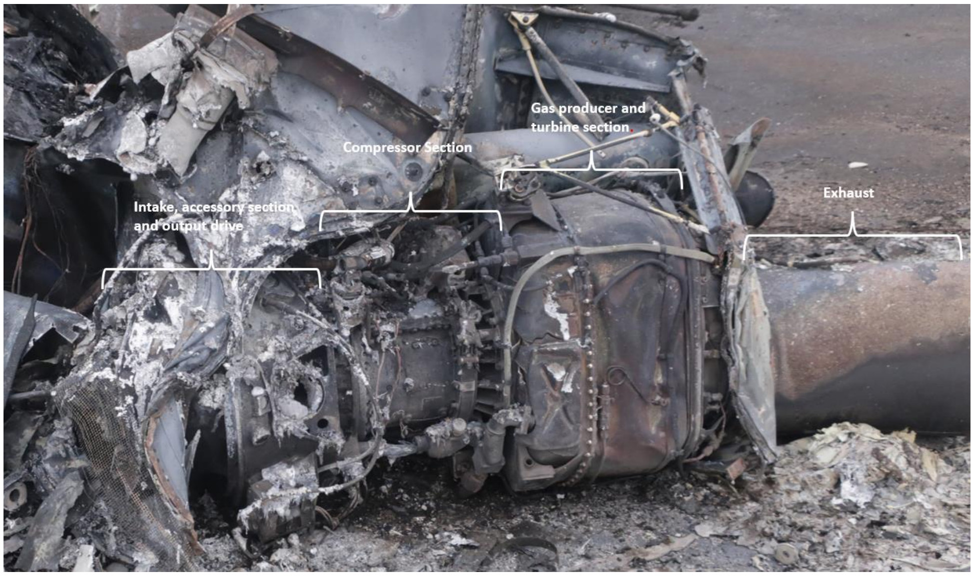


Figure 8. The engine as found in the wreckage.

Figure 9. Compressor inlet, a section of the first stage compressor blades visible.

Figure 10. Second stage power turbine section showing no missing, ruptured, or burned blades.

3.0 KAFlex Drive Shaft Examination

The KAFlex is a flexible driveshaft designed and manufactured by the Kamatics Corporation. The KAFlex end fittings, frames fragments, and interconnect were examined at the Kamatics facility, Bloomfield, Connecticut, on April 25, 2023, under the oversight of the NTSB.

The KAFlex drive shaft provides the power connection between the engine and main transmission. It provides a flexible connection that is tolerant to angular and axial misalignment caused by relative motion of the engine, gearbox, rotor system, flight loads, and thermal effects. The driveshaft consists of two end flanges with a raised cup in the center, each cup nests inside the interconnect shaft at each end, with the assembly components securely fastened together via a series of square frames using bolts, washers, spacers, and nuts (Figure 11).

Figure 9. Photo of an exemplar KAFlex drive shaft.

The original Kamatics work order for the main drive coupling assembly, PN SKCP2190-103, matched the serial numbers on the drive shaft removed from the helicopter wreckage; transmission fitting SN: 12159, interconnect SN: 6308, and engine fitting SN: 12168. The drive shaft was originally assembled on June 17, 1986.

Transmission side flange and frames. Interconnect shaft. Transmission side flange and frames.

Figure 10. KAflex assembly

Examination of the interconnect shaft and both end flanges showed evidence of contact between the interior of the interconnect shaft and the cup portion of each end flange, deforming the ends of the interconnect shaft. This contact evidence is consistent with the engagement of the drive shaft's failsafe feature, which can occur if there is a misalignment between the engine and transmission or a failure of a KAflex component. Examination of each of the fractures of the square frames revealed bending, cracking of the Sermatel coating, granular fracture faces with cup-cone features, and 45° shear features. All fractures were consistent with overload characteristics.

The bolt and nut that attached the transmission side frame assembly to the interconnect flange was not present on the assembly as recovered from the accident site. The interconnect flange at this location was torsionally deformed and the flange bolt hole was out of round. The hole measurement deviated from design tolerance by 0.0037 inches. The flange displacement and hole dissymmetry are consistent with the fastener having been present and installed during the accident sequence. All remaining fastener holes were measured and found to be within design allowances. All bolts were measured for stretch and found to be within the specified design requirements. Three joints on the transmission side of the KAFlex were observed to have bolt-nut fasteners but were missing the two washers that constitute the joint assembly. Close examination of these three joints revealed impact marks on the bolt heads, nut heads, and/or the joint frame. Additionally, these joints exhibited no evidence of operating in a loose condition. The missing washer hardware is attributed to the evidence that the joints had been subjected to impacts during the accident sequence.

4.0 Hydraulic System Examination

4.1 Hydraulic System Description[4]

The hydraulic pump is located on the main transmission sump case. System pressure of 950 to 1000 pounds per square inch gauge (psig) is produced by the variable delivery, pressure compensated pump, mounted on the main transmission, and driven at 0.65 engine drive shaft speed. Fluid is drawn from the reservoir by the hydraulic pump and pumped to the system through a check valve and a filter to a normally open, solenoid-operated system shutoff valve. When the HYD CONTROL switch is ON, this valve is open and system pressure is supplied to all four of the flight control power cylinders.

4.1.1 Hydraulic Pump and Filter Examination

The majority of the hydraulic system had been destroyed by the post-crash fire. However, since the hydraulic pump was located on the main transmission and the transmission had not been exposed to the post-crash fire, the hydraulic pump was in good condition and removed for examination (Figure 13).

The splined driveshaft of the pump could be rotated by hand and felt smooth with no binding. Disassembly of the hydraulic pump (Figure14) revealed that all components were in good condition and no evidence of gouging or overheating was observed. Residual hydraulic fluid (red fluid) retained its red color and viscosity.

[4] System description extracted from US Army Technical Manual TM 55-1520-210-23-2.

Figure 11. Hydraulic pump after removal from the transmission.

Figure 12. Hydraulic pump disassembly.

The hydraulic filter assembly and pressure switch (Figure 15) were located within the wreckage and recovered. The filter bowl was unscrewed, and the filter element removed (Figure 16). The paper element was carbonized but retained its shape. No metal particles were identified within the filter bowl or folds of the filter element.

Figure 13. Filter with attached pressure switch.

Figure 14. Hydraulic filter bowl unscrewed from the assembly and the filter element removed from the bowl.

5.0 Flight Control Actuator Examination

5.1 Actuator Functional Description[5]

Each power cylinder assembly includes a servo valve which is mechanically controlled by the flight control linkages. When the flight control linkage moves any

[5] System description extracted from US Army Technical Manual TM 55-1520-210-23-2.

servo valve control lever down, the cylinder retracts and when the linkage moves the lever up the cylinder extends. When the servo valve control lever is centered, system pressure is applied equally to both sides of the cylinder piston, but the system return port is shut off and the cylinder does not move in either direction. Irreversible valves are provided for each main rotor power cylinder to prevent feedback. When system pressure drops to approximately 500 psi, a spring-loaded sequence valve, in the irreversible valve closes and blocks both the system pressure and system return ports trapping fluid under 500 psi in the power cylinder servo valve and irreversible valve. Each irreversible valve incorporates a check valve to isolate surge pressure produced in the power cylinders from the system pressure lines. A differential relief valve opens automatically to relieve pressures in excess of 500 psi differential. The irreversible valves also incorporate another feature which allows the power cylinders to be operated manually. The same function is performed by the check valve which interconnects the system pressure line to the system return line adjacent to the tail rotor power cylinder. When no system pressure is available and the power cylinders are operated manually, fluid flows directly through the irreversible valve or the tail rotor check valve from the cylinder return port to the cylinder pressure. Hence the cylinder pumps fluid from one side of the piston to the other without attempting to pump fluid through the entire system.

5.2 Flight Control Actuator Examinations

There are four hydraulically operated actuators that are directly integrated into the flight controls and provide the pilots with hydraulic assistance in manipulating the controls. Three identical hydraulic actuators provide control boost to the main rotor (pitch and roll). A separate hydraulic actuator provides control boost to the tail rotor.

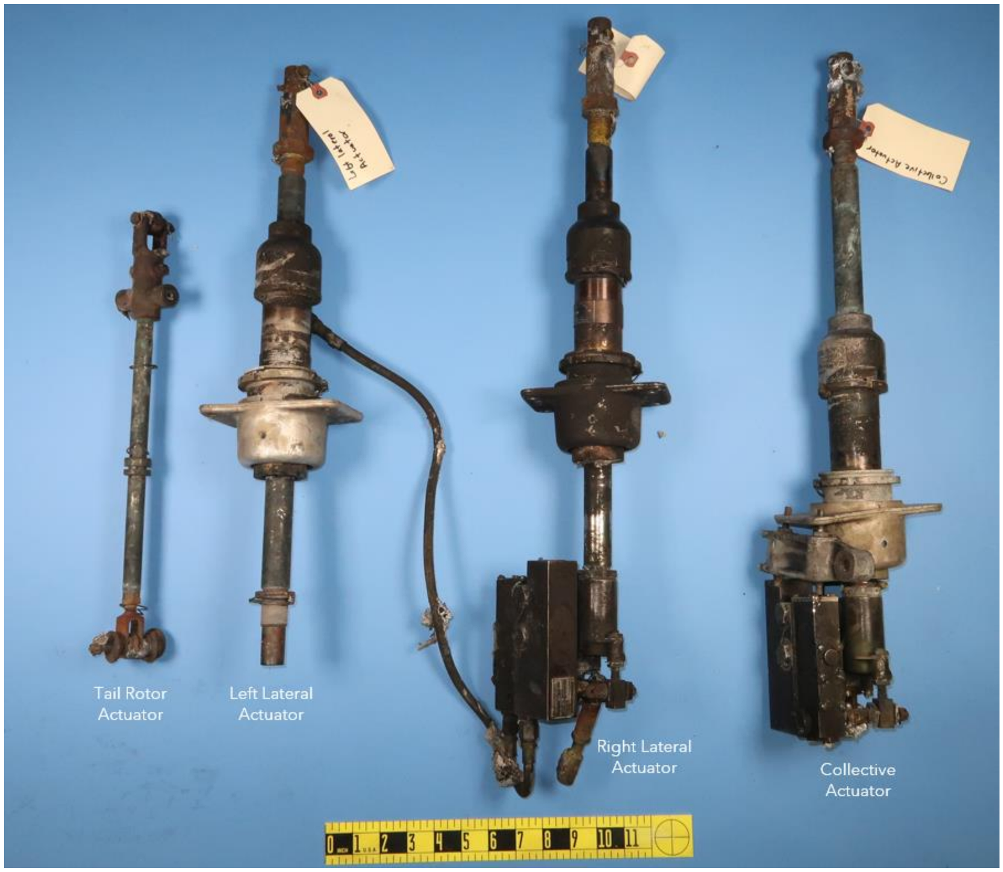


Figure 15. Flight control actuators.

All four flight control actuators were recovered from the wreckage (Figure 17). Each actuator position in the flight control system were identified by serial number and verified by entries in the maintenance records. The collective and right lateral servos had retained their hydraulic servo valves and irreversible valves, the left lateral actuator was missing its hydraulic servo valve and irreversible valve. However, the left actuator's irreversible valve was located within the helicopter wreckage and recovered. The three main rotor actuators were subjected to computed tomography (CT) examination[6]. The examination did not identify any significant foreign material that could have interfered with the proper function of the servo or irreversible valves, confirmed that all internal components were configured properly, and showed no evidence of preexisting damage of internal components. Bulging of the cover plates over the sequence valve were attributed to heat from the post-crash fire.

[6] Computed Tomography Specialist Factual Report ANC22FA047 is contained in the official docket of this investigation.

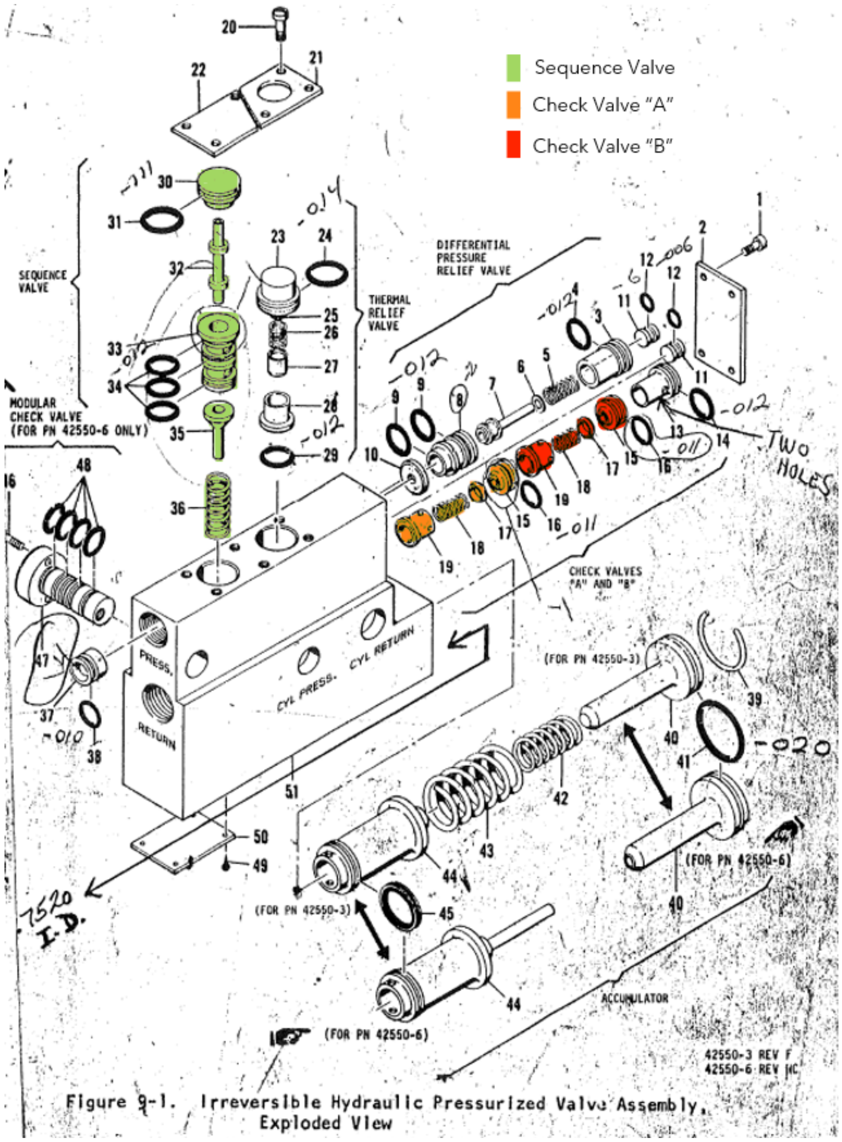


Figure 16. Irreversible valve assembly diagram extracted from the Textron overhaul manual.

The irreversible valve assemblies from the collective and right actuators were partially disassembled to examine the condition of the sequence valves and check valves (Figures 19, 20, and 21). Heat damage to the valve bodies were evident. The sequence valves and check valves were seized in position. A combination of penetrating oil and heat was applied to allow removal of the various assemblies. During the disassembly, remnants of o-rings damaged by heat from the post-crash fire were identified within each o-ring groove. The metering ports of the spool and slide assembly of the sequence valves were clear of debris and the metering edges had no spurs or deformations. The poppet movement of each of the check valves were verified before removal from the valve body.

The left actuator irreversible valve body was slightly deformed and appeared to have been exposed to more heat than the other irreversible valves. The sequence valve and check valves were seized inside the valve body and could not be extracted for examination.

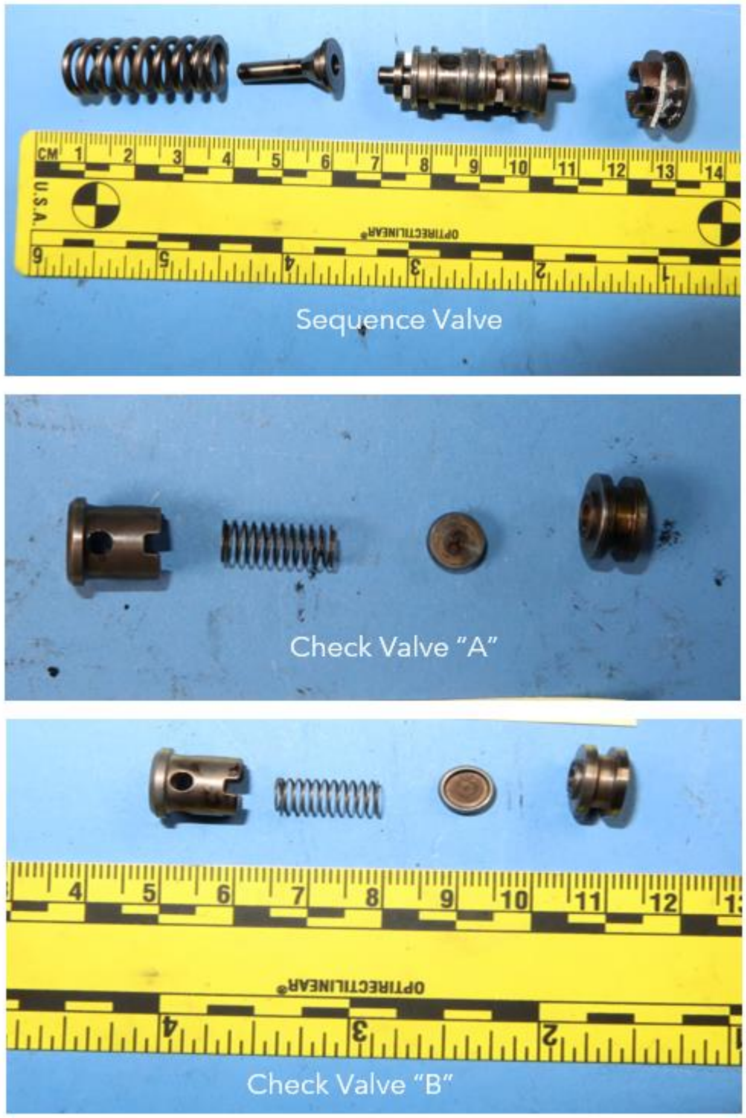
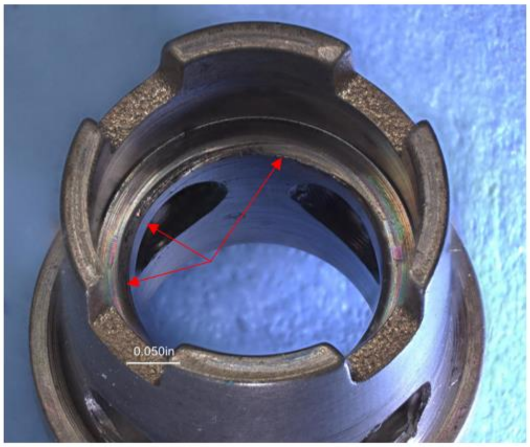
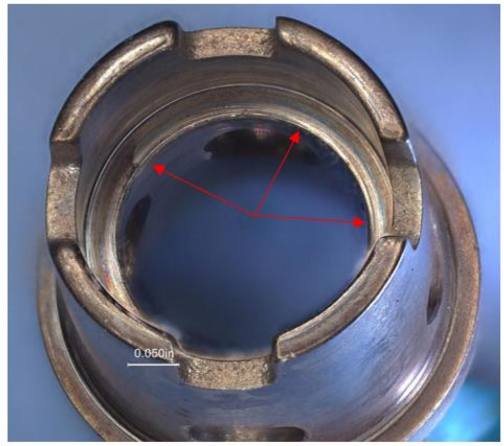


Figure 17. Right lateral irreversible valve components[7].

[7] Damage to the sequence valve cap was a result of the disassembly process.



Check valve “A” guide

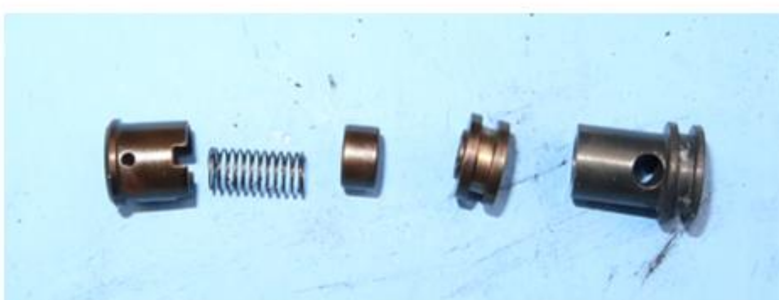


Check valve “B” guide

Figure 18. Right lateral check valves - heavy wear observed on the interior ring of the spring guide identified by the red arrows.

Sequence Valve

Check Valve “A”



Check Valve “B”

Figure 19. Collective irreversible valve components.

6.0 Caution Panel Examination

The caution panel (Figures 22 and 23) was removed from the cockpit instrument panel and sent to the NTSB materials laboratory for examination. Hot filament stretching can be an indicator that the light was illuminated during the accident impact sequence.

Figure 20. Caution panel as found installed in the instrument panel.

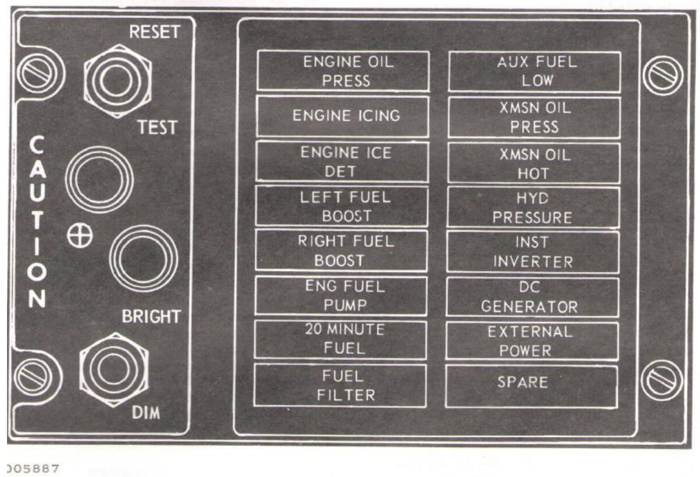


Figure 21. Typical caution light configuration.[8]

The annunciator panel consisted of sixteen (16) annunciator lights (two (2) columns with eight (8) lights in each column) (Figure 23). Each annunciator light contained two (2) incandescent bulbs. The annunciator was partially disassembled to allow for visualization of the individual bulbs within the annunciator lights. The annunciator lights were radiographed to determine the filament status of each of the bulbs within the individual annunciator lights. The layout of the panel with the filament status for each light is below. The actual layout of the accident panel could not be confirmed due to the fire damage to the faceplate of the panel. The radiograph for the HY PRESS light (according to the layout in the operations manual) is attached to this email. No hot filament stretching was found in any of the light bulb filaments in the accident panel. Figure 24 shows broken and unstretched filaments of the hydraulic pressure lightbulbs.

[8] Caution panel configuration provided by the operator.

ENGINE OIL PRESS BNS BNS	**AUX FUEL LOW** INS NS
ENGINE ICING INS BNS	**XMSN OIL PRESS** BNS BNS
ENGINE ICE DET BNS BNS	**XMSN OIL HOT** INS INS
LEFT FUEL BOOST BNS INS	**HYD PRESS** INS BNS
RIGHT FUEL BOOST BNS BNS	**INST INVERTER** BNS BNS
ENG FUEL PUMP BNS BNS	**DC GENERATOR** BNS BNS
20 MINUTE FUEL BNS BNS	**EXTERNAL POWER** BNS INS
FUEL FILTER INS INS	**SPARE** INS INS

Legend:
INS- Intact, not stretched.
BNS- Broken, not stretched.

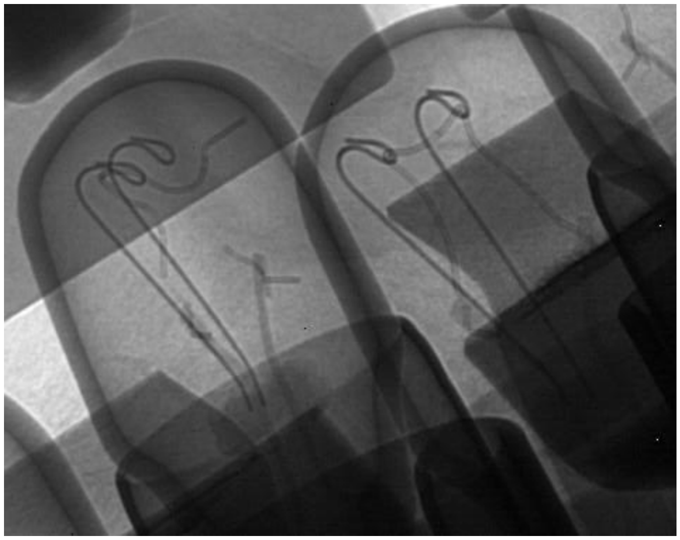


Figure 22. Radiograph showing broken and unstretched filaments of the HYD PRESS lightbulbs.

7.0 Accident Event Video

A firefighter on the ground in the landing zone area was taking video imagery of the helicopter at the time of the accident. The video is a 3 second clip of the accident. In the video the helicopter is shown overhead with a long line attached. The whirling of the rotor blades can be heard. A short muffled high-pitched sound is heard, after which the helicopter can be seen to pitch nose down and roll to the right. The helicopter exits the lower left of the video frame and then is recaptured while still airborne momentarily at the end of the recording. In the last couple of video frames, the main rotor and transmission is seen departing the airframe (Figure 25) before ground impact. Table 1 provides a timeline of the events seen on the accident video.

Figure 23. Screen capture of the end of the video showing the separation of the main rotor and transmission from the airframe before ground impact.

Table 3. Detailed sequence of events from the video over a 3 second period.

Helicopter in a hover. The long line is straight.
The helicopter "wobbles" pitch nose down with a slight right roll. The long line slackens. The main rotor is centered over the fuselage.
Right roll continues. Long line initiates sine wave reaction.
The right roll steepens. The main rotor is centered over the fuselage.
The nose pitch is down 30°. Helicopter roll is 90°. The main rotor is centered over the fuselage.
A finger obscures half of the field of view. The helicopter is falling vertically. The main rotor is centered over the fuselage. A puff of thin black smoke emanates from the engine exhaust area.

The finger moves out of the field of view. The helicopter is in a 120° right roll. The right engine cowling door opens. The main rotor is centered over the fuselage.
The helicopter is in lower left corner of frame and in a 120° right roll. The nose pitch is down 30°. The main rotor is centered over the fuselage.
The helicopter is out of the field of view. A view of a fire extinguisher fills the frame.
A full view of the helicopter belly is in the frame. The main rotor and transmission are departing. The tail boom is chopped at mid span (figure 22).

The momentary high-pitched sound at the beginning of the upset event could not definitively be attributed to the helicopter. The NTSB Vehicle Recorders Lab analyzed the sound spectrum and determined that the fundamental tone was about 1,380 hertz (Hz)[9] with additional noise or overtone activity in the 7,500 to 8,000 Hz range. This frequency range could not be associated with any rotating equipment speeds identified in the US Army's maintenance manual[10].

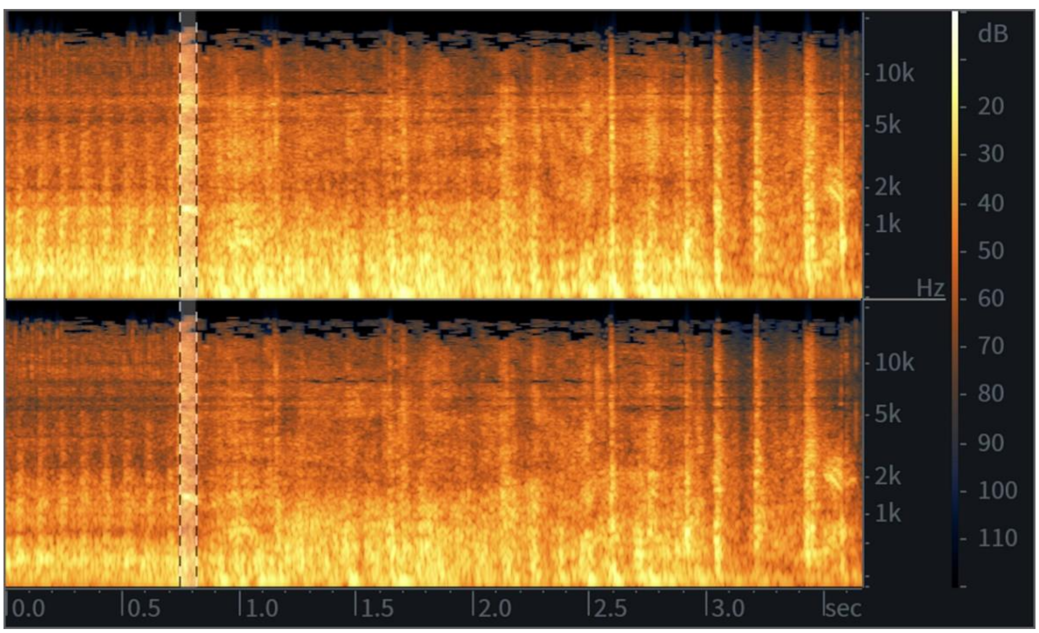


Figure 24. Fundamental tone of 1380 Hz isolated from the video of the accident associated with the initial upset.

[9] Hz is a standard unit of measure for a frequency defined a one per second (1/s). In this case it refers to the passing frequency in revolutions per second.

[10] US Army Technical Manual, TM 55-1520-210-23-1, Ch 5-140

8.0 Maintenance Record Review

The maintenance records were reviewed. Table 3 lists the significant maintenance performed on the airframe for the 24 months prior to the accident.

Table 4. Maintenance History

Date	Total Aircraft Time (hours)	Maintenance Activity
5/7/2020	13,148.9	Major maintenance on rotating controls, Removed and replaced main rotor hub, removed and replaced right hand lateral servo, removed and replaced transmission, replaced 5th mount.
9/25/2020	13,281.6	Blade inspection (AD 2018-02--07)
3/9/2021	13,283.3	Blade inspection (AD 2018-02--07)
4/1/2021	13,300.7	50hr inspection, removed and replaced vertical driveshaft cover hinge, blade inspection (AD 2018-02--07)
4/19/2021	13,305.3	Blade inspection (AD 2018-02--07)
4/26/2021	13,326.3	25hr inspection, blade inspection (AD 2018-02-07)
5/3/2021	13,333.7	IFR pitot and static transponder check
6/3/2021	13,336.5	25hr, 50hr, 100hr, 300hr, 600hr inspections. Removed and replaced right hand lateral servo, and control tube. Installed overhauled transmission. Vertical spar inspection. Blade inspection (AD 2018-02--07)
6/9/2021	13,338.4	Removed and replaced tail rotor blade grip bearings.
6/16/2021	13,361.0	25hr inspection. Blade inspection (AD 2018-02-07)
6/28/2021	13,467.0	Blade inspection (AD 2018-02--07)
7/1/2021	13,386.1	50hr inspection, blade inspection
7/9/2021	13,410.0	25hr inspection
7/17/2021	13,432.3	Blade inspection (AD 2018-02-07)
7/18/2021	13,435.8	100hr. Tail rotor maintenance. Vertical fin spar inspection.
7/21/2021	13,444.5	Removed and replaced 90-degree gearbox. Removed and replaced input seal on 42-degree gearbox.
7/26/2021	13,455.0	Blade inspection (AD 2018-02-07)
7/27/2021	13,458.4	25hr inspection
7/29/2021	13,469.6	Reviewed AD 2021-15-14 and found not applicable per modification (STC SR00026DE)
8/2/2021	13,478.0	Removed and replaced mixing levers
8/7/2021	13,487.3	50hr inspection. Blade inspection
8/17/2021	13,507.9	25hr inspection, blade inspection
8/20/2021	13,524.4	Removed and replaced tail rotor gearbox.

8/24/2021	13,530.4	Blade inspection (AD 2018-02-07)
9/13/2021	13,550.2	Blade inspection (AD 2018-02-07)
9/23/2021	13,566.6	Blade inspection (AD 2018-02-07)
10/7/2021	13,579.9	Blade inspection (AD 2018-02-07)
10/15/2021	13,588.2	50 hr, blade inspection (AD 2018-02--07)
10/29/2021	13,605.5	Mast RIN, Trunnion RIN, blade inspection (AD 2018-02--07)
11/21/2021	13,607.4	25hr, blade inspection (AD 2018-02-07)
12/5/2021	13,619.6	Blade inspection (AD 2018-02-07)
12/6/2021	13,620.4	Trunnion RIN
12/10/2021	13,620.4	Elevator maintenance
12/19/2021	13,629.6	Blade inspection (AD 2018-02-07)
1/5/2022	13,638.5	ELT inspection, new battery
1/10/2022	13,638.5	25hr, 50hr, 100 hr, 300hr inspection, vertical fin spar inspection, blade inspection (AD 2018-02--07). Cargo hook inspection.
1/13/2022	13638.5	Engine leak check. Test flight
1/28/2022	13643.8	Blade inspection (AD 2018-02--07)
2/11/2022		Blade inspection (AD 2018-02--07)
3/2/2022		Blade inspection (AD 2018-02--07)
3/14/2022	13658.7	Trunnion RIN count addition error
3/17/2022	13657.0	Blade inspection (AD 2018-02--07)
3/25/2022	13666.5	25hr, Removed and replaced tail rotor hub and control quill. Test flight. Blade inspection (AD 2018-02--07)
4/12/2022	13673.5	Blade inspection (AD 2018-02--07)
5/4/2022	13681.5	Blade inspection (AD 2018-02--07)
6/21/2022	13730.0	25/50 hr inspection

9.0 Transmission Pylon Structure Examination

On February 8, 2023, two NTSB investigators examined the transmission and pylon components that had remained attached to the transmission and the main rotor head. The transmission had remained stored with the helicopter wreckage at a facility in Wasilla, AK.

The transmission with rotor mast and rotor head was moved into a hangar for examination. The entire assembly was photo documented. The 5th isolation mount was disconnected from the cross beam. The 5th mount beam was disconnected by unbolting the left side, the right-side bolts had been sheared. The transmission aft left retaining bolt was disconnected, separating the left and right isolation mounts from the transmission. The forward isolation mounts were removed from the pylon structure. The aft isolation mounts remained in the pylon structure and were separated from the transmission by disconnecting the retaining bolts. The isolation mounts and 5th mount beam were packaged for shipment to the NTSB materials lab for further examination.

The NTSB Materials Laboratory examination determined that the transmission case was fractured on the right side near the aft support. The forward pylon support legs were fractured through the rivets attaching the isolation mount pad to the vertical faces of the legs. The aft left support leg was fractured at the lower attachment bracket for the friction damper, and the aft right support leg was fractured at its lower end. The main transmission and pylon structure likely separated due to overstress fracture. The aft isolation mounts and friction dampers showed evidence of substantial overtravel in the upward direction.

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