

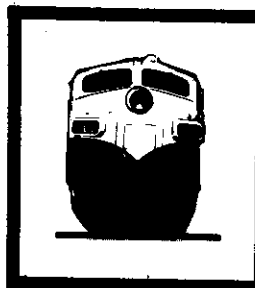
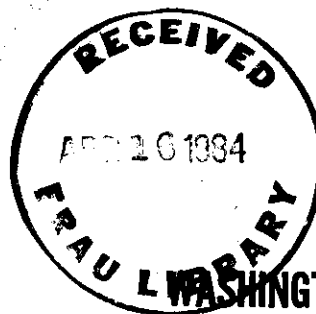
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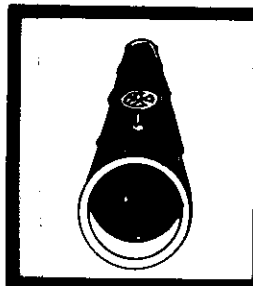


# NATIONAL TRANSPORTATION SAFETY BOARD



## AIRCRAFT ACCIDENT REPORT

WESTERN HELICOPTERS, INC.  
BELL UH-1B, N87701  
VALENCIA, CALIFORNIA  
JULY 23, 1982



NTSB/AAR-84/02 → SUPERSEDED BY AAR 84-14

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UNITED STATES GOVERNMENT

SEE ALSO: NTSB REPORTER - JUNE '84, p. 2

TECHNICAL REPORT DOCUMENTATION PAGE

1. Report No. NTSB/AAR-84/02		2. Government Accession No. PB84-910402		3. Recipient's Catalog No.	
4. Title and Subtitle Aircraft Accident Report -- Western Helicopters Bell UH-1B, N87701, Valencia, California, July 23, 1982.				5. Report Date March 6, 1984	
				6. Performing Organization Code	
7. Author(s)				8. Performing Organization Report No.	
9. Performing Organization Name and Address National Transportation Safety Board Bureau of Accident Investigation Washington, D.C. 20594				10. Work Unit No. 3876	
				11. Contract or Grant No.	
				13. Type of Report and Period Covered Aircraft Accident Report July 23, 1982	
12. Sponsoring Agency Name and Address  NATIONAL TRANSPORTATION SAFETY BOARD Washington, D. C. 20594				14. Sponsoring Agency Code	
15. Supplementary Notes					
16. Abstract On July 23, 1982, at 0220 Pacific daylight time, a Bell UH-1B, N87701, registered to Rocky Mountain Helicopter, Provo, Utah, and operated by Western Helicopters, Inc., Rialto, California, crashed during the filming of a movie at Indian Dunes, Valencia, California.  The helicopter was being used in conjunction with the filming of a motion picture scene depicting a village typical of villages in Viet Nam which was under attack from heavy ordnance. The helicopter was used as a camera platform as well as playing an active role in the movie sequence. The helicopter was hovered about 25 feet above the village and nearly directly above the location where special effects explosives were detonated to simulate the heavy ordnance. As the pilot turned his helicopter to the left to provide camera coverage, the helicopter's tail section was engulfed in a fireball created by the detonation of a special effects explosion. The tail rotor assembly separated and the helicopter descended out of control. The helicopter's main rotor blade struck and fatally injured three actors on the ground. The six occupants on the helicopter sustained minor injuries, and the aircraft was damaged substantially.					
17. Key Words <u>helicopter, separated tail rotor system, film production, special effects explosions.</u>  <u>Rotorcraft</u>				18. Distribution Statement This document is available to the public through the National Technical Information Service Springfield, Virginia 22161.	
19. Security Classification (of this report) UNCLASSIFIED		20. Security Classification (of this page) UNCLASSIFIED		21. No. of Pages 25	
				22. Price	

The National Transportation Safety Board determines that the probable cause of the accident was the detonation of a debris-laden special effects explosion too near to a low flying helicopter leading to damage to a rotor blade, the separation of the helicopter's tail rotor assembly, and the uncontrolled descent of the helicopter. The proximity of the helicopter to the special effects explosions was due to the failure to establish direct communications and coordination between the pilot, who was in command of the helicopter operation, and the film director, who was in charge of the filming operation.

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**NATIONAL TRANSPORTATION SAFETY BOARD  
WASHINGTON, D.C. 20594**

**AIRCRAFT ACCIDENT REPORT**

**Adopted: March 6, 1984**

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**WESTERN HELICOPTERS, INC.  
BELL UH-1B HELICOPTER, N87701  
VALENCIA, CALIFORNIA  
JULY 23, 1982**

**SYNOPSIS**

On July 23, 1982, at 0220 Pacific daylight time, a Bell UH-1B helicopter, N87701, registered to Rocky Mountain Helicopter, Provo, Utah, and operated by Western Helicopters, Inc., Rialto, California, crashed during the filming of a movie at Indian Dunes, Valencia, California.

The helicopter was being used in the filming of a motion picture scene depicting a village typical of villages in Viet Nam which was under attack from heavy ordnance. The helicopter was used as a camera platform as well as in an active role in the movie sequence. The helicopter was hovered about 25 feet above the village and nearly directly above the location where special effects explosives were detonated to simulate the heavy ordnance. As the pilot turned his helicopter to the left to facilitate camera coverage, the helicopter's tail section was engulfed in a fireball created by the detonation of a special effects explosion. The tail rotor assembly separated, and the helicopter descended out of control. The helicopter's main rotor blade struck and fatally injured three actors on the ground. The six occupants on the helicopter sustained minor injuries, and the aircraft was damaged substantially.

The National Transportation Safety Board determines that the probable cause of the accident was the detonation of a debris-laden special effects explosion too near to a low flying helicopter leading to damage to a rotor blade, the separation of the helicopter's tail rotor assembly, and the uncontrolled descent of the helicopter. The proximity of the helicopter to the special effects explosions was due to the failure to establish direct communications and coordination between the pilot, who was in command of the helicopter operation, and the film director, who was in charge of the filming operation.

**1. FACTUAL INFORMATION**

**1.1 History of the Flight**

On the afternoon and evening of July 22, and the early morning of July 23, 1982, a cast of actors and a movie production crew were filming a segment of a motion picture at Valencia, California. The segment of the movie was a Viet Nam war scene in which a village was under attack by heavy ordnance. The movie set consisted of 11 bamboo huts located along the shore of a shallow manmade river. The scenario included

a Bell UH-1B helicopter, N87701, which served as both a movie prop and a platform from which some of the ground action would be filmed. The movie production required the detonation of special effects explosive devices prepositioned on the ground to simulate the heavy ordnance attack.

The film director was in charge of the filming sequence. He determined the effects that he wanted to create on film and discussed these effects and the placement of explosives to produce them with the special effects coordinator. The special effects coordinator, in turn, instructed the special effects technicians about the placement of the explosive devices. During the filming sessions, the special effects technicians initiated the detonation of the devices in accordance with cues agreed upon in previous discussions with the special effects coordinator.

Three filming sessions were scheduled at the movie set on July 22 and 23. (See figure 1.) About 2100 P.d.t, <sup>1/</sup> the helicopter departed the takeoff/landing area for the first filming session and proceeded about 600 feet east to the movie set. The helicopter was used as a camera platform during this session, hovering above the set while the ground scene was filmed. The special effects devices were detonated to simulate the ordnance as specified in the script. When the scene was completed, the helicopter returned to the takeoff/landing area.

The helicopter returned to the movie set about 2330 for the second filming session. During this scene, the pilot hovered the helicopter over the set while more special effects explosive devices were detonated. One special effects device had been placed in the water and was detonated while the helicopter was nearly above it. The pilot noted afterward that the water which shot into the air as a result of the explosion was dispersed by the helicopter's rotor system and obscured the pilot's vision through the windscreen for several seconds. Witnesses who were on the ground estimated that the geyser and some of the fireballs which resulted from special effects detonations during this filming session rose as high as the 98-foot cliff behind the village. The two cameramen and one of the stuntmen aboard the helicopter stated during postaccident interviews that they had become concerned about the exposure of the helicopter to the heat generated by the special effects detonations during this filming session.

At the postflight debriefing following the 2330 filming session, the helicopter pilot expressed his aggravation to the director about the unexpected eruption of water, and he further related his concern to the unit production manager (UPM) regarding the potential hazard to the helicopter caused by debris produced by the special effects explosions. The UPM, who had been aboard the helicopter during the second filming session, assured the pilot that he would advise the film director of these concerns. The filming activity was suspended about 2345 for a 1-hour break. The UPM drove to the set and had lunch with the director. When he returned to the helicopter, he assured the pilot that during the third filming session the helicopter was to remain over the water and that there would be nothing to be concerned about.

Preparations for the third filming session resumed after the break. The script to be enacted during this session required that an adult actor carry two children from the village and wade across the river while special effects devices were detonated to simulate the heavy ordnance attack. The helicopter was to hover above the river as a part of the scenario and to make a 180° left hovering turn to provide appropriate camera vantage angles. The scene was to be filmed from cameras both on the ground and in the

1/ All times herein are Pacific daylight time based upon the 24-hour clock.

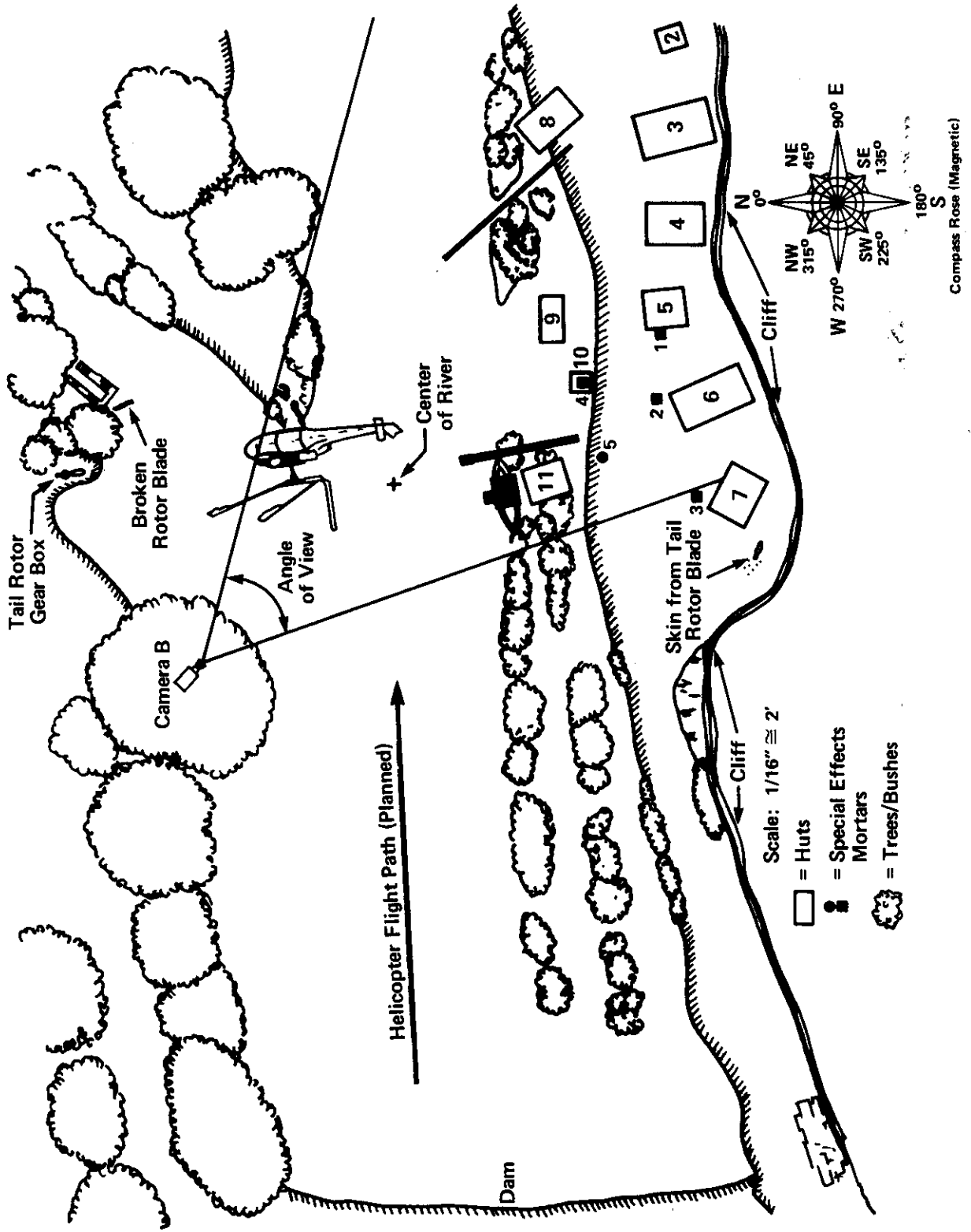


Figure 1.--Accident site.

helicopter. Two stuntmen aboard the helicopter were to fire blank rounds from machine guns on both sides of the craft. The script called for the total destruction of the village by the special effects explosives when the helicopter was over the north shore of the river. A rehearsal of the scene was scheduled before the final filming.

Before the rehearsal, the helicopter pilot walked through the movie set to review the scenario for the scheduled filming session. He personally checked the security of the cardboard and palm frond roofs of the village huts. He was concerned that the helicopter rotor downwash might dislodge these roofs, or portions thereof, and cause them to be swept up into the rotor system. The pilot did not receive, nor did he actively seek, any information from the special effects coordinator or the UPM regarding the sequence, timing, or positioning of the special effects explosions. He stated to the special effects coordinator that "as long as no debris is allowed to enter the rotor system, and nothing is set off under the helicopter, it doesn't matter which structures you have rigged for a firebomb." During interviews conducted by the Safety Board following the accident, the UPM indicated that he had assured the pilot that the helicopter would not be over any special effects explosive devices during the filming sequence.

About 0200, on the 23rd, the helicopter was flown to the movie set to participate in a rehearsal of the scene. The helicopter initially was positioned about 40 feet above the center of the river. There were no special effects devices detonated during the rehearsal. The turbulence generated by the helicopter rotor system during its left turn obscured visibility to the extent that one of the special effects technicians obtained a welder's hood to protect his eyes from the flying dirt. No other difficulties were apparent during the rehearsal.

About 0218, the helicopter took off again for the filming of the scene. In addition to the pilot and the two stuntmen who were to fire the machine guns, the UPM and two cameramen were on board the helicopter. The UPM was sitting in the left front seat to operate a spotlight, one of the cameramen was on the left side of the helicopter, and the two stuntmen with machine guns were positioned by the side doors, one on the left and one on the right. The other cameraman was standing in the passenger compartment. According to the cameraman on the left side, the helicopter initially appeared to follow the same route down the center of the river as it had during the rehearsal flight. (See figure 1.) When the helicopter passed over the dam, he climbed out on the left skid. He then realized that the helicopter was much lower than it had been during the rehearsal and that it was over the village on the south shore rather than near the center of the river. The cameraman on the north shore of the river stated that the helicopter arrived over the sampan area at a height of about 40 feet, and that while hovering there the director shouted commands through a megaphone, including the command for the helicopter to "get lower." The director later stated that he did not recall having given that command. According to the assistant director who had a VHF communications radio and who was standing near the director, the director asked for the helicopter to descend lower. The assistant director could not recall having transmitted the directions to descend to the UPM, and the UPM could not recall having received the directions. The pilot stated that after arriving over the set at 60 to 70 feet, he descended to align his main rotor with a strata line on the adjacent cliff at a height of about 35 feet above the set. He then heard directions over the VHF radio to descend lower. A review of the film from the camera on the north shore of the river showed that after the helicopter descended into view and stabilized in a hover, the special effects charges began to explode.



After three explosions, the helicopter began a level hovering left turn to permit the cameraman on the left skid to film the actors as they waded across the river. A fourth special effects device was detonated, followed less than 0.1 second later by a fifth detonation. As the fifth device was detonated, a column of gasoline/sawdust mixture which it had raised erupted into a fireball which engulfed the tail section of the helicopter.

The helicopter stopped turning to the left and stabilized on a magnetic heading of about 009° for less than 1 second. The helicopter began a right ascending turn until it left the film frame. About 2 seconds later the helicopter reappeared in the film frame in about a 20° tail down attitude, and was still turning to the right, but descending. The tail rotor assembly was missing. The helicopter crashed into the peninsula on the north side of the river in a noseup 45° left bank attitude, while the helicopter was still turning to the right. The helicopter's main rotor blades continued to turn to the left and struck the adult actor and the two children as they were crossing the river. This entire sequence of events, including the explosions resulting from the detonations of special effects devices and the subsequent crash of the helicopter, was recorded on film by the ground cameras. The accident occurred at night about 0220 hours at latitude 34° 25 feet north and longitude 118° 35 feet west. The elevation of the crash site was 1,000 feet m.s.l.

The special effects coordinator and special effects technicians stated after the accident that radio communication was provided only between the coordinator and the technician who was to detonate the first special effects device. The other technicians had been instructed to begin detonating their explosives when they heard the machine guns aboard the helicopter begin to fire. Although the special effects coordinator stated that each technician was responsible for ensuring that his area was clear before firing his explosives, the technician who detonated the explosives nearest to the helicopter stated that the safety of the helicopter had not been discussed nor had he been apprised of the helicopter's proposed flight pattern. The technician also observed that his vision had been restricted by the welder's hood he was wearing during the filming session.

**1.2 Injuries to Persons**

<u>Injuries</u>	<u>Helicopter Crew</u>	<u>Ground Personnel</u>	<u>Total</u>
Fatal	0	3	3
Serious	0	0	0
Minor/None	6	40	46
Total	6	43	49

**1.3 Damage to Aircraft**

The aircraft was destroyed.

**1.4 Other Damage**

Not applicable.

**1.5 Crew Information**

The pilot was certificated in accordance with applicable Federal Air Regulations (FAR). He had completed a biennial flight review 2 months before the accident, and

he had conducted six night landings in Bell UH-1B helicopters during the preceding 90 days. According to company and pilot records, he had accumulated 4,514 flight-hours, 4,408 of which were in rotorcraft, and 1,536 of which were in the Bell 204/205/UH-1B. This was the pilot's fourth employment in movie production work, but it was his first experience flying in the vicinity of special effects devices.

The pilot reported for duty about 1830 hours on the evening of July 22. After darkness, he began a series of short flights between the takeoff/landing area and the movie set before the 2100 filming segment. The pilot flew the helicopter for a total of about 20 minutes during the estimated 7 hours 50 minutes he was on duty.

#### **1.6 Aircraft Information**

Bell UH-1B helicopter, N87701, serial No. 64-14038, was owned by Rocky Mountain Helicopter, Inc., Provo, Utah, and was operated by Western Helicopters, Inc., Rialto, California. The helicopter was operating under a temporary experimental category airworthiness certificate because it had been modified for use in filming activity. The operating limitations portion of the certificate permitted the pilot to carry passengers for the purposes of film production and to operate at night in VFR conditions. The certificate imposed no altitude operational limits other than those in 14 CFR 91. A review of the maintenance records showed that the helicopter had flown 11 hours since the last annual inspection on April 20, 1982. At the time of the accident, the aircraft had accumulated 5,817 flight-hours. All maintenance inspections prescribed by current regulations had been completed.

#### **1.7 Meteorological Information**

The pilot and other witnesses at the scene reported that the skies were clear (moonlight bright), that the visibility was unrestricted, and that the wind was from the east at less than 5 knots. Burbank-Glendale-Pasadena Airport, Burbank, California, located about 23 miles southeast of the accident site, reported the 0145 hours surface weather observation as:

Scattered clouds at 20,000 feet; visibility--15 miles;  
temperature --75° F; dewpoint--60° F; wind--calm; altimeter  
setting--29.92 inches.

#### **1.8 Aids to Navigation**

Not applicable.

#### **1.9 Communications**

Communications between the helicopter and the ground were conducted by radio. There were no known mechanical difficulties with the communications equipment used to communicate between the helicopter and the ground.

#### **1.10 Aerodrome and Ground Facilities**

The helicopter was using an especially constructed takeoff/landing pad located about 600 feet west of the accident site.

**1.11 Flight Recorders**

Not applicable.

**1.12 Wreckage and Impact Information**

The helicopter came to rest on its left side on a magnetic heading of 345°. The helicopter's structure, flight controls, and rotating assemblies, except the tail rotor assembly, remained intact. The main rotor mast assembly, including the main rotor blades and their associated components, were heavily damaged as a result of impact. Damage to the main rotor blades was consistent with the damage which would be expected if the blades were rotating at impact. The preimpact integrity of the main rotor flight control system was established; all of the damage to the main rotor flight control system was determined to be the result of impact. There was no evidence of any pre-existing malfunction or failure.

The main transmission rotated freely and the free-wheeling unit operated normally. The right-hand rear and fifth mounts had separated from the transmission; the fracture surfaces were clean and typical of overload failure. The left beam was buckled; however, the left link remained attached. The nonrotating flight controls were damaged during impact. The tail boom attachment brackets remained intact and were not damaged. The left synchronized elevator showed evidence of extensive compression buckling. The right synchronized elevator was not damaged. Continuity of the flight control system for both synchronized elevators was established. Continuity of the antitorque control system from the cockpit rudder pedals to the 42° gearbox was established. The Nos. 1, 2, and 3 bearing housing for the tail rotor drive shaft hanger remained intact. The tail rotor drive shaft had separated from the transmission tail rotor drive quill assembly.

The vertical pylon drive shaft, located between the 42° gearbox and the 90° gearbox, had separated. The shaft was found near the wreckage in the center of the river. The spline teeth, male and female, showed no signs of damage. An impact mark was found on the right side of the vertical pylon drive shaft cover.

The tail rotor 90° gearbox, with one intact blade and the butt portion of the other blade attached to the hub assembly, was found about 41 feet north of the main wreckage. Tail rotor blade, serial No. A3-84197, had separated 18 1/4 inches outboard of its butt end. The outboard portion of the blade was found about 21 feet southwest of the tail rotor 90° gearbox. The broken tail rotor blade exhibited a semicircular indentation about 3 1/2 inches deep on its trailing edge; the indentation spanned the fracture line in the blade. (See figure 2.) The left side of the blade had two rectangular punctures just aft of its leading edge. Foreign particles were found on both fracture surfaces of the blade. Tail rotor blade serial No. A3-84164 remained attached to the hub assembly. About 33 1/4 inches of the blade skin was missing; the skin was found behind hut No. 7. (See figure 1.) Visual examination of the skin disclosed extensive curling at the butt end and extensive heat damage. Also, particles of a rubbery substance with wood embedded were found on the right side of the skin.

The engine was operated by use of its starter. There was no evidence that the rotating components had bound, and the engine rotated freely. After the engine was operated, the particle separator was removed; no foreign contaminants were found in the separator.

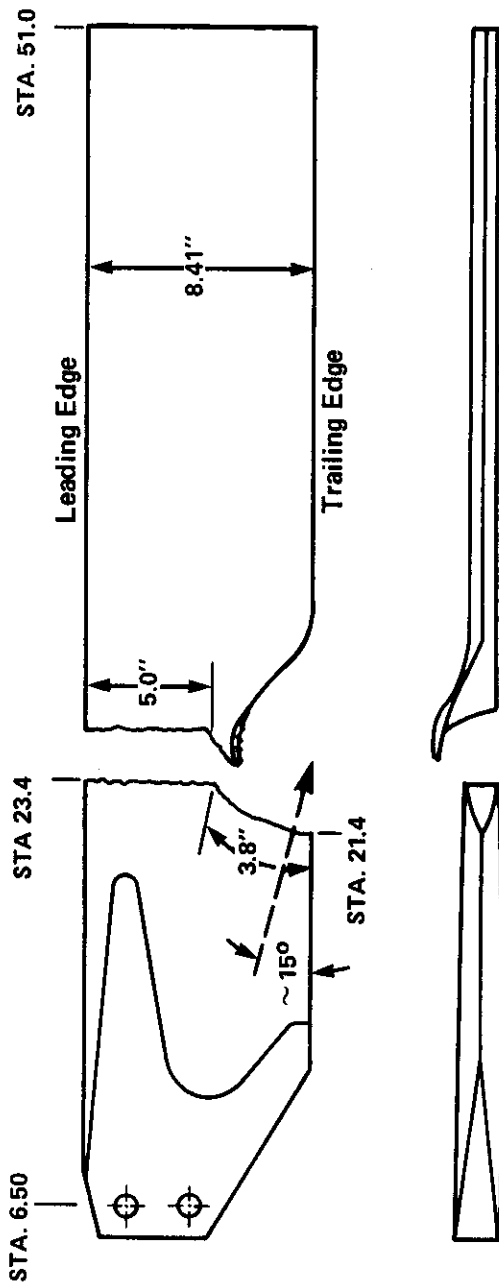


Figure 2.—Blade damage.

**1.13 Fire**

The helicopter did not catch fire either before or after impact.

**1.14 Medical and Pathological Information**

Postmortem examinations on the three actors were performed by the Los Angeles County Medical Examiner-Coroner's Office. The postmortem examination of the adult actor and male child actor disclosed that their deaths were attributed to injuries to the head, neck, and shoulder of each actor, inflicted by the main rotor blades of the helicopter. The cause of death to the female child actress was attributed to multiple traumatic injuries and blunt force trauma. Toxicological examinations were performed on the adult actor, and no evidence of drugs and/or alcohol was found. Toxicological examinations were not performed on the children.

The pilot and three of the other fire occupants of the helicopter were treated at Henry Mayo Memorial Hospital, Newhall, California, for minor injuries and were released. There was no evidence of any preimpact incapacitation or pre-existing physiological conditions which would have affected the pilot's judgment or performance. Toxicological examinations were not performed, because they were deemed not warranted. Since this aircraft was operating on an experimental airworthiness certificate, crashworthiness was not considered pertinent to this mishap.

**1.15 Tests and Research**

**1.15.1 Film Examination**

At the Safety Board's request, the Federal Bureau of Investigation (FBI) examined the film recorded during the accident sequence by one of the movie production cameras located on the north shore of the river and about 12 feet above the elevation of the ground to the rear of hut No. 11. (See figure 1.) The purpose of the examination was to determine the position and movement of the helicopter relative to the special effects devices when they were detonated. The examination included 228 frames of the film taken during an elapsed time of 9.5 seconds, beginning with the first of the five special effects explosions and terminating when the helicopter disappeared from the camera's view immediately before the helicopter crashed.

Table 1 shows the helicopter's height (measured above the camera), heading, rotational rate, and forward speed. Examination revealed that the helicopter's position at the instant of the fourth special effects explosion placed the center of the tail rotor about 34 feet above and 19 feet laterally displaced west-northwest from the source of the explosion. The helicopter's position at the time of the fifth special effects explosion placed the center of the tail rotor about 34 feet above and 13 feet laterally displaced west-northwest from the source of the explosion. (The center of the tail rotor is 10 feet, 4 inches above the skids.)

Table 1.--Helicopter Movements.

<u>Time <sup>1/</sup></u> <u>(Seconds)</u>	<u>Height of</u> <u>skid above</u> <u>camera</u> <u>(ft)</u>	<u>Heading</u> <u>(°)</u>	<u>Average yaw</u> <u>rate and</u> <u>direction</u> <u>(°/sec)</u>	<u>Forward speed</u> <u>(mph)</u>
0	12	078	None	None
4	12	078	None	None
6 (4th explosion)	12	033	23° left	3.6
6.0938 (5th explosion)				
7	15	008	None	3.6
7.5	16	008	None	5.6
9.025	19	046	25° right	Leaving frame

<sup>1/</sup> The times are seconds elapsed from the first special effects explosion.

### 1.15.2 FBI Explosive Tests

The FBI laboratory also assisted the Safety Board in the investigation by examining the characteristics of the explosions created by the detonation of devices such as those reportedly used by the special effects personnel at the time of the accident. The FBI conducted tests at the accident site and at its own test facilities.

To produce the illusion of a heavy ordnance attack on the movie set, the special effects personnel stated that they had detonated mortars (steel pots) of various shapes and sizes which contained black powder explosive charges and gasoline/sawdust mixtures. The primary black powder charge, which reportedly was 6, 8 or 12 ounces, was placed in the bottom of the mortar with the gasoline/sawdust mixture in the middle and a smaller 2-ounce black powder charge on top.

The purpose of the FBI tests at the accident site, which were performed on September 23, 1982, was to record the sounds of the detonation of different shaped mortars charged with various amounts of black powder. The same recording equipment used at the time of the accident was used to record these sounds. The frequency spectrum of the sounds recorded during the tests were compared with the frequency spectrum of the sounds of explosion recorded at the time of the accident.

The FBI tests disclosed that each mortar configuration produced a unique sound frequency spectrum which did not vary regardless of the amount of the charge. The test sound spectra of the detonation of charges in two of the special effects mortar configurations were similar in frequency content to the sounds of the two explosions which were recorded immediately before the accident. The amplitude of the recorded sounds can, under identical recording conditions, indicate the level of the black powder charge in the mortars. Although a determination of the amount of a charge through a comparison of the amplitude of sound recorded was precluded by the automatic gain control feature of the recorder, it was possible to conclude from these tests that special effects explosions were produced by black powder charges.

The purpose of the tests at the FBI's test facility was to measure the velocity imparted to several objects by the special effects explosions. Mortar charges identical to those used by the special effects technicians were detonated, and the speed of objects

propelled upward was measured about 20 feet above the ground. The tests showed that an object having a mass and geometry similar to the pieces of bamboo used to construct the village huts would reach vertical speeds of 200- to 300-feet per second. Portions of mortar casings were projected to heights of 50 feet and more. There was no attempt during these tests to replicate the placement of the mortar charges or the structures which surrounded them when the accident occurred.

### **1.15.3 Tail Rotor Sound Spectrum Study**

The frequency spectra of the sounds recorded during the filming sequence in which the helicopter crashed were also studied by the Los Angeles County Sheriff's Department. The purpose of the study was to identify the discrete sound of the tail rotor and to relate the changes in sound frequency to tail rotor transient movements and rotational speed changes.

The frequency spectrum study disclosed that before the last two explosions, and just before the accident, the helicopter's tail rotor began to move in a counterclockwise direction away from the recording microphone. About 0.5 seconds after the last explosion began, the sound frequency change correlated with a reversal of the tail rotor's movement toward the recording microphone. About 1.7 seconds later, a frequency change occurred which correlated with a deceleration in the tail rotor's rotational speed.

### **1.15.4 Examination of the Tail Rotor Component and Other Materials**

At the Safety Board's request and under its direction, the helicopter's tail rotor assembly was examined by the helicopter manufacturer and an independent laboratory.

The metallurgical examination by the helicopter manufacturer was conducted using a transmission electron microscope and plastic replication techniques to determine the characteristics of the fracture of the tail rotor blade, serial No. A3-84197. The examination indicated that the tail rotor blade skin had fractured from combined shear loading and tearing and that the fracture progressed from the trailing edge to the leading edge of the blade. The helicopter manufacturer concluded that:

A foreign object impacted the tail rotor blade trailing edge approximately 18.25 to 22.3 inches (463.55 - 566.42 mm) from the butt end. The impact of the foreign object deformed the aft 4 inches of the tail rotor blade trailing edge at station 25. This deformation created an out-of-track condition of the tail rotor blade that may have resulted in the separation of the 90° gearbox and blades from the aircraft.

The helicopter manufacturer observed that it was not possible to assess accurately the impact force required to produce the observed damage without the support of tests. However, based on certain assumptions, the manufacturer estimated that the required force would be at least 7,800 pounds.

The helicopter manufacturer's examination of the tail rotor blade which remained attached to the hub, serial No. A3-84164, showed that the aluminum skin had separated at the bonding surface as a result of exposure to excessively high temperatures. Tests of the adhesive qualities of the bonded areas with respect to temperature increases disclosed that the adhesive coefficient of the bond area diminished at increased

temperatures; e.g., at 300° F, the average peel strength of the bonded area was about 23 pounds per square inch (psi), which is about 2 percent of the average peel strength at room temperature (1,109 psi).

The tests conducted by the independent laboratory consisted of a visual examination of all the separated components of the helicopter's tail rotor assembly and an energy dispersive x-ray (EDX) microprobe-type chemical analysis of several samples from the tail rotor section, fuels, materials used in the special effects devices and movie set, and debris which was recovered from the vicinity of the explosions and crash.

The independent laboratory tests disclosed that elements typical of the fire fuel used to create the special effects were deposited on the large indentation on the trailing edge of both parts of the separated tail rotor blade and on the two rectangular indentations on the right side of the separated portion of the blade. A green substance found on the separated tail rotor blade skin was chemically similar to a green substance found on a special effects device mortar casing; a black tar-like substance found near the leading edge of the fractured tail rotor blade was foreign to the blade and appeared to have originated from the bombing debris.

A lid from a 5-gallon glue pot, typical of several which were found at the accident site, was examined. The lid was made of steel and had several sharp tangs around its circumference. Two tangs were found to match the size and shape of the rectangular indentations found on the left side of the outboard portion of the separated tail rotor blade.

Red and turquoise substances found in the indentations on the right side of the vertical pylon drive shaft cover were similar to paint found on the fractured tail rotor blade. Also, the shape of the indentation on the drive shaft cover matched the leading edge of the outboard portion of the fractured tail rotor blade.

The independent laboratory's report concluded that debris from a special effects explosion on the ground struck the helicopter tail rotor blade during flight, that the blade fractured, and that this ultimately caused the separation of the tail rotor assembly and the crash.

#### **1.15.5 Engineering Evaluation**

The Safety Board provided the reports of the studies conducted by the FBI, the helicopter manufacturer, and the independent laboratory to a professor from the University of California School of Engineering for further evaluation.

Upon examination of these documents, the professor concluded that the confinement of the special effects device beneath the floor of a hut might cause debris to accelerate to higher velocities than were evident in the detonating tests conducted by the FBI. He calculated that, under some conditions, projectiles might reach heights of between 800 and 1,500 feet. He also observed that an off-center impulse force to a bamboo stick, typical of those used in the floors of the movie set huts, would cause the stick to rotate and that the rotating tips would attain velocities higher than those at the center of gravity of the projectile.

The professor's report indicated that he believed it likely that a blow from a piece of the fire-fuel-coated bamboo floor caused the indentation at the trailing edge of the tail rotor blade and that the bent or fractured blade caused aerodynamic and dynamic imbalance which created forces great enough to separate the tail rotor gearbox.



## 1.16 Additional Information

### Director's Responsibilities

Testimony given at a California Assembly Labor and Employment Committee and California Senate Industrial Relations Committee Joint Hearing held in Los Angeles, California, on October 8, 1982, by the Directors Guild representative was to the effect that the director has the final word on production; that is, he has the authority to overrule the stunt coordinator if he is so inclined. However, more often than not, he accepts the advice of the stunt coordinator with respect to safety. Further, safety on the set is the director's responsibility.

The Directors Guild representative further testified, in part, with respect to handling a stunt or special effect, "...when one is in a picture, we as directors, discuss and plan it with the assistant director, who is the man in charge of the set, with the production manager, who is in charge of the overall production, with the camera operator, the art director, and the special effects man—all the various people. . . ."

### Federal Regulations

According to the flight rules of the FAR (14 CFR 91.79) helicopters can be operated below the minimum altitudes prescribed for aircraft without an express waiver "...if the operation is conducted without hazard to persons or property on the surface." Aircraft other than helicopters must be operated at or above the minimum altitudes specified in the regulations in the absence of an express FAA waiver of the minimum altitudes. Since March 1982, operators of aircraft, other than helicopters, to be operated below the minimum specified altitudes as camera platforms or stunt vehicles in motion picture and television film productions have had to obtain FAA approval of a Motion Picture and Television Flight Operations Manual in accordance with Chapter 14, Section 5, of FAA Order 8440.5A, General Aviation Operations Inspector's Handbook, dated March 19, 1975, as amended.

## 2. ANALYSIS

### General

The Safety Board's investigation of this accident concentrated on those aspects of the accident which directly related to the loss of control of the helicopter and its subsequent crash. The Safety Board's analysis also is limited to this issue. The Safety Board believes that comprehensive review and analysis of the practices of the motion picture industry and the safety considerations given to the filming of stunts or other hazardous activities on a movie set are beyond the Board's investigative purview. The Safety Board's investigation of the accident was necessary to ascertain whether the circumstances which led to the accident might have broader application to the safety of U.S. civil aviation transportation, such as inadequate pilot qualifications, regulatory deficiencies, or airworthiness problems with the helicopter.

The helicopter was properly certificated and maintained in accordance with the existing regulations and approved procedures. There was no evidence of preexisting deficiencies, malfunctions, or failures of the helicopter's systems or components which could have led to the crash.

The pilot was certificated and qualified in accordance with applicable regulations. While he had been employed before in film activity, he had not flown previously in proximity to special effects explosions. He was obligated to fly the helicopter in conformity with the operating limitations specified in the helicopter's experimental airworthiness certificate which was issued by the FAA specifically to permit the rigging of the helicopter as required for the film production. The movie production persons who were in the helicopter were not involved in the direct control of the aircraft but were on board to perform their duties in the making of the movie. Since helicopters may operate below the minimum safe altitudes specified by regulation without an express waiver, it has not been the practice to seek waivers in connection with motion picture production activity. Moreover, there was no requirement enforced by the FAA that Western Helicopters, Inc., prepare for FAA approval a Motion Picture and Television Flight Operations Manual. However, the pilot was constrained by regulation to operate the helicopter "without hazard to persons or property on the surface."

The investigation of the accident revealed evidence to support strongly a conclusion that the loss of control of the helicopter was initiated by foreign object damage inflicted to the tail rotor. The visual examination of components recovered after the accident and the examination of both film and audio tape recordings substantiate this finding.

The separated portion of the one tail rotor blade was found 21 feet away from the tail rotor gearbox to which the blade hub with the mating fracture surface was still attached. This evidence indicates that the fracture occurred during flight. A matching semicircular indentation existed on the trailing edges of both portions of the fractured tail rotor blade. The matching indentations are conclusive evidence that the blade was struck by an object before the blade fractured and that the fracture was precipitated by the damage inflicted by the object.

The tail rotor assembly completely separated from the helicopter when the casing on the tail rotor's 90° gearbox mounting flange fractured. The fracture resulted from the excessive forces applied through the structure from the aerodynamic and dynamic imbalance that occurred after the tail rotor blade was damaged by the foreign object. The separation of the assembly was evident on the sound frequency spectrum analysis of the audio tape which had been recorded during the accident sequence. The sound frequency spectrum analysis distinctly showed a speed decay of the tail rotor rpms about 1.7 seconds after reversal of the helicopter's rotational left turn. This speed decay can only be associated with separation of the tail rotor assembly because there was no concurrent decay in main rotor rpm or engine rpm.

Damage to or separation of a portion of a tail rotor blade creates severe control problems for a helicopter pilot. If tail rotor damage occurs at a high enough altitude, a pilot may be able to reduce engine speed and enter an autorotative descent, which will significantly reduce the dynamic and aerodynamic imbalance in the tail rotor, and land upright from an autorotative descent with some measure of control. However, in this accident, the pilot had neither the time nor the altitude to establish an autorotative descent. Consequently, when the tail rotor assembly separated, the helicopter was not controllable.

#### Source of Tail Rotor Damage

The Safety Board cannot identify with certainty the specific object which struck the tail rotor blade or the direction from which the object came. The mass of the object and the relative velocity at which the object and tail rotor blade came together

had to have been sufficient to produce the impulse force needed to dent the trailing edge of the blade. Although the deformation of the fracture in the outboard portion of the blade tends to indicate that the blade was struck from the right side and from the trailing edge, the Safety Board does not believe that any of the objects propelled upward by the special effects explosions would have had sufficient mass and speed to have struck the blade from behind, in its direction of rotation, and inflict the evident damage. However, the Safety Board believes it is possible that the object was traveling essentially perpendicular to the tail rotor blades' plane of rotation when it struck the blade, just forward of its trailing edge. Under such conditions, the impulse force related to such an impact would have been very high because of the rotational speed of the blade. Consequently, the damage could have been inflicted by an object of relatively low mass. Furthermore, this type of impact would have been consistent with the pressure differential across the blades (deflected to produce a left turn) and the movement of debris through the blades' rotational plane. The peculiar deformation of the fracture surface of the outboard portion of the blade could be explained by the twisting of the blade by the aerodynamic and dynamic forces which caused its fracture and by the impact of the blade against the drive shaft cover of the vertical pylon.

Although the identity of the object that collided with the tail rotor blade during the helicopter's hovering left turn was not positively established, the exact time of the collision was established from examination of the film and audio tapes of the accident sequence. During a level hover, the helicopter tail rotor blade produces an essentially horizontal thrust vector to offset the rotational torque from the main rotor system which tends to rotate the helicopter to the right. The tail rotor blade must be structurally and aerodynamically sound in order to prevent the helicopter from rotating to the right in response to the torque and to produce the even higher thrust required to execute a hovering left turn. A disruption of the aerodynamic integrity of the tail rotor blade was evidenced by the helicopter's abrupt reversal from a left turn to a right turn -- both the video and audio film recording studies show that the helicopter's rotational direction reversed within about 2 seconds of the fourth and fifth special effects explosions. Therefore, the Safety Board concludes that the object which damaged the tail rotor blade was from debris propelled upward from the ground by the explosion. The findings from the chemical analysis of the tail rotor blade fracture surfaces, which indicated contamination from elements similar to the elements in the fire fuel that had been applied to some of the bamboo of the village huts, further support this conclusion.

The Safety Board also concludes that the two rectangular punctures found on the separated portion of the tail rotor blade near its leading edge were not significant to the fracture of the blade. These punctures matched closely the tangs on the steel lids of the 5-gallon glue pots found in the vicinity of the crash. However, since the punctures were not elongated and the surrounding damage was limited, the Safety Board concludes that the blade was not operating at high rotational speeds when the damage was inflicted. Consequently, the Safety Board concludes that the lid struck the blade after the tail rotor blade had fractured.

The Safety Board considered the possibility that the object which damaged the helicopter's tail rotor blade may have been ejected from the helicopter instead of projected upward from the ground. The object specifically considered was a 0.30 caliber blank casing, such as those from the blanks being fired from the machine guns on each side of the helicopter. Normally, objects from a hovering helicopter would descend rapidly as a result of the downwash force generated by the main rotor system. Although the downwash forces from the helicopter's main rotor possibly might have been offset for an instant by the upward force generated by the explosion, the Safety Board

believes that the evidence does not support this possibility because the near 1/2-inch diameter size of the 0.30 caliber blank casing is not consistent with the approximate 3 1/2-inch diameter size of the semicircular indentation on the trailing edge of the fractured tail rotor blade.

The Safety Board believes that the condition of the full tail rotor blade that remained attached to the rotor hub further illustrates the hazardous conditions to which the helicopter was exposed. The skin of part of this blade had separated from internal structure because the bonding had been exposed to high temperatures from the special effects explosions. However, the skin probably separated after the fracture of the other blade, and therefore, was not a significant factor in the loss of the tail rotor assembly.

### Safety of the Operation

Although the Safety Board considers the safety precautions taken by the motion picture industry during the filming of stunts, combat scenes, or other dangerous activities beyond its investigative purview, it is concerned by the events which led to the exposure of the helicopter to the hazards of the special effects explosions because of the frequent use of aircraft in film production. The concerns expressed by the pilot and other personnel following the filming of the second sequence in which special effects were detonated and following the rehearsal verified that the hazards of the operation were recognized by the pilot as well as by some of the film production personnel. It must be recognized that the pilot in command is ultimately responsible for the safety of flight. Since none of the personnel involved except the pilot had knowledge of helicopters and their vulnerability to damage from debris and heat from special effects explosions, this recognition should have prompted the pilot, who was responsible for the operation of the helicopter in a manner that would not pose a hazard to persons or property on the surface, to initiate the measures necessary to insure that the helicopter would be separated safely from the prepositioned special effects mortars when the mortars were detonated. These measures should have included, at a minimum, an insistence on a joint briefing among the director, the pilot, and the special effects technicians as to the exact maneuver the helicopter was to perform, the timing of the maneuver, and a keying of the detonation of the huts to the helicopter's completing the left turn and moving across the river. Further, as an added precaution, the pilot should have insisted on direct radio communication with the technicians to keep them apprised of his progress in the maneuver and to warn them in the event that alterations of the intended maneuver became necessary. In this case, however, no specific measures were agreed upon. Instead, the pilot relied on assurances from the UPM and special effects coordinator that nothing would be exploded beneath the helicopter. Additionally, apparently in response to commands from the director, he modified the maneuver and flew lower over the surface of the river and closer to the huts than had been intended originally, as established by the observations of the cameraman on the left skid and the cameramen on the north shore of the river. Consequently, it is evident that the operation lacked the precise planning and coordination needed to conduct it safely, particularly if changes in the scenario were made.

On the other hand, the Safety Board also recognizes that in the motion picture and television film industry, the director has full responsibility for safety on the set of a filming operation. Consequently, it is incumbent upon the director to take cognizance of visible and reported hazards and to take the measures needed to either eliminate the hazards or to cope with the hazards in a manner that will insure the safety of the personnel involved. In this accident, the director did not conduct preproduction meetings with the principals concerned—the pilot, the UPM, the assistant director, and the special effects coordinator—regarding the hazards related to operation of the helicopter in

proximity to the special effects explosions. Further, after conclusion of the 2330 filming session, when apprised of the hazards by the UPM and the pilot, the director took no positive measures to insure the precise coordination needed among all concerned to eliminate the hazards. Consequently, the Safety Board concludes that the director failed to fulfill his responsibility of insuring safety on the film set.

The FAA has recognized that significant precautions must be taken to assure safety of persons and property when civil airplanes are used in the production of movie and television films. Since March 1982, operators of airplanes (but not helicopters) used in film productions have been required to prepare a Flight Operations Manual detailing the safety precautions that must be taken before the operators are permitted to fly the aircraft at altitudes below minimum safe altitudes established by regulations. The Safety Board recognizes that the flight rules for helicopters allow pilot-initiated deviations from the minimum safe altitudes prescribed by regulation and that practically speaking requiring an express waiver for each operator would degrade the utility and value of the helicopter, which is its ability to hover and fly slowly at very low altitudes above the surface. Film production helicopter operators have not been required to obtain a specific waiver of the flight rules to operate at very low altitudes and have not been required to prepare a Motion Picture and Television Flight Operations Manual. However, the Safety Board believes that the facts, conditions, and circumstances of this accident amply demonstrate the need for a requirement that helicopter operators prepare such a manual and carry out its provisions as a prerequisite to the use of a helicopter in movie and television film production. At a minimum, the manuals should contain provisions for pilot qualifications, including any special qualifications, mandatory briefings of film production personnel on the risks involved, the safeguards needed during operations, emergency procedures, a communications plan for all participating personnel, and a provision confirming the pilot-in-command's ultimate authority to control all flight regimes relative to this type of operation.

### 3. CONCLUSIONS

#### 3.1

#### Findings

1. The aircraft was properly maintained in accordance with existing regulations, and there was no evidence of pre-existing malfunction or failure of the helicopter's systems or components that could have led to the crash.
2. The pilot was certificated and qualified for the flight in accordance with the existing regulations, and he was obligated to fly the helicopter in accordance with the operating limitations of its experimental airworthiness certificate.
3. The helicopter pilot was ultimately responsible for operation of the helicopter in a manner that did not pose a hazard to occupants of the helicopter and to persons or property on the surface.
4. The helicopter pilot and film production personnel were aware that the flight involved operating in very hazardous conditions.
5. There was no direct discussion among the director, the helicopter pilot, and the special effects personnel to insure that there was a common understanding of the intended positioning of the helicopter throughout the left hovering turn and to insure that the special effects charges would not be detonated prematurely.

6. No provision was made for direct radio communication between the pilot and the special effects technicians to insure that the technicians did not detonate the special effects charges in such a manner as to endanger the helicopter operation.
7. The helicopter flight including the left hovering turn maneuver was not conducted at a sufficient height above the river or at a sufficient distance from the huts to insure that the helicopter would not be struck by debris from a special effects explosion detonated under or near the helicopter.
8. Personnel involved in the filming operation other than the pilot did not have knowledge regarding the vulnerability of the helicopter to high temperatures and debris.
9. The director of the filming operation did not conduct a preproduction meeting of the principals involved in a known hazardous operation to insure the safety of the personnel on the film set.
10. The pilot was assured by the unit production manager that explosives would not be detonated beneath his helicopter.
11. An object, propelled upward by a special effects explosion, struck the trailing edge of one of the helicopter's tail rotor blades. The indentation caused by the impact created a dynamic and aerodynamic imbalance in the tail rotor system which generated sufficient loads to cause separation of the 90° tail rotor gearbox and the rotor assembly.
12. The object which hit the blade probably was not ejected from the helicopter.
13. The helicopter was not controllable after loss of its tail rotor assembly.
14. The aluminum skin of the other tail rotor blade separated because of its exposure to excessively high temperatures from the fire which engulfed the helicopter's tail section during the special effects explosion.
15. There was no requirement enforced by the FAA that the helicopter operator submit a Motion Picture and Television Flight Operations Manual to the FAA for approval as a prerequisite to use of the helicopter in the film production.

### **3.2 Probable Cause**

The National Transportation Safety Board determines that the probable cause of the accident was the detonation of a debris-laden special effects explosion too near to a low flying helicopter leading to damage to a rotor blade, the separation of the helicopter's tail rotor assembly, and the uncontrolled descent of the helicopter. The proximity of the helicopter to the special effects explosions was due to the failure to establish direct communications and coordination between the pilot, who was in command of the helicopter operation, and the film director, who was in charge of the filming operation.

#### 4. RECOMMENDATION

As a result of this accident, the National Transportation Safety Board recommended that the Federal Aviation Administration:

Extend the terms of FAA Order 8440.5A Section 5, Waiver of Section 91.79(a) and (c), Motion Picture and Television Flight Operations Manual, to require an FAA-approved flight operations manual for all types of aircraft. (Class III, Longer Term Action) (A-84-16)

#### BY THE NATIONAL TRANSPORTATION SAFETY BOARD

/s/ JIM BURNETT  
Chairman

/s/ PATRICIA A. GOLDMAN  
Vice Chairman

/s/ G.H. PATRICK BURSLEY  
Member

/s/ DONALD D. ENGEN  
Member

VERNON L. GROSE, Member, did not participate.

March 6, 1984

## 5. APPENDIXES

### APPENDIX A

#### INVESTIGATION AND HEARING

1. Investigation

The National Transportation Safety Board's Los Angeles Field Office was notified of the accident about 0300 on July 23, 1982, by the FAA Western Region Duty Officer. An investigator was dispatched to Valencia, California, from the Los Angeles Field Office and arrived at the scene of the accident about 0530 July 23, 1983.

Parties to the investigation were the Federal Aviation Administration, Western Helicopters, Inc., Los Angeles County Fire Department, The Screen Actors Guild, Bell Helicopters, California State Fire Marshalls, and Burbank Studios. Representatives of these parties assisted in the investigation.

2. Public Hearing

No public hearing was held and no depositions were taken.

Testimony of 34 witnesses was recorded and transcribed, one of which was taken under oath at the request of the witness.



**APPENDIX B**  
**CREW INFORMATION**

Pilot Dorcey A. Wingo

Pilot Wingo, 35, held commercial certificate No. 2032217 with a rotorcraft rating. He also possessed a certificate for private privileges in single engine land airplanes. He completed a biennial flight review in a Bell 206 helicopter 2 months prior to the date of this accident. Pilot Wingo held a valid second class medical issued in March of 1982, with no waivers or limitations.

According to company and pilot records, pilot Wingo had a total of 4,514 hours. Of this time 4,408 hours was rotorcraft time and 1,536 hours were in the Bell 204/205/UH-1B type aircraft. He had flown 60 hours in the last 90 days. Six of those hours were in the Bell 204/205/UH-1B type aircraft. During the 30 days preceding the accident he accumulated 42 flight-hours. During the 24-hour period prior to the accident, he had about 2 hours of flight time. Pilot Wingo received his flight training in the U.S. Army and served as a rotorwing pilot in Viet Nam. His military experience totaled about 1,200 hours of flying time. Of that time, about 900 hours was in helicopters similar to the one used in the movie filming. This was the pilot's fourth experience in movie work but this was the first film production in which he had flown near special effects explosions.

## APPENDIX C

### AIRCRAFT INFORMATION

The aircraft, a Bell UH-1B, serial No. 64-14038, was acquired by Rocky Mountain Helicopter, Inc., from Southern Helicopters, Inc., Sarasota, Florida, on September 2, 1980. On March 4, 1980, the aircraft received a restricted category airworthiness certificate. Prior to receiving the airworthiness certificate, the aircraft was operated by the U.S. Army, the Department of Health, Education and Welfare, and the Maryland State Police. These public agencies are exempt from obtaining an appropriate airworthiness certificate. On August 10, 1981, Rocky Mountain Helicopter, Inc., relinquished operational control of the subject aircraft to its subsidiary, Western Helicopters, Inc.

On July 21, 1982, the FAA General Aviation District Office, Riverside, California, issued a temporary experimental airworthiness certificate for the helicopter at the operator's request. The helicopter's gross takeoff weight was 6,205 pounds; the maximum authorized takeoff weight was 8,500 pounds. The helicopter was fueled with 600 pounds of jet-A fuel. The helicopter's center of gravity was well within prescribed limits. The maintenance records examination disclosed that the last annual/100-hour inspection was performed on April 20, 1982. The aircraft had accumulated 5,806 flight-hours at the time of the inspection.