

AIRCRAFT ACCIDENT REPORT

Adopted: August 27, 1969

LOS ANGELES AIRWAYS, INC.

S-61L HELICOPTER. N300Y

COMPTON, CALIFORNIA

AUGUST 14, 1968

NATIONAL TRANSPORTATION SAFETY BOARD
DEPARTMENT OF TRANSPORTATION
WASHINGTON D.C. 20591

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TABLE OF CONTENTS

	<u>Page</u>
Synopsis	1
Probable Cause	1
1.1 History of the Flight	2
1.2 Injuries to Persons	2
1.3 Damage to Aircraft	3
1.4 Other Damage	3
1.5 Crew Information	3
1.6 Aircraft Information	3
1.7 Meteorological Information	3
1.8 Aids to Navigation	3
1.9 Communications	3
1.10 Aerodrome and Ground Facilities	3
1.11 Flight Recorder	3
1.12 Wreckage	3
1.13 Fire	4
1.14 Survival Aspects	4
1.15 Tests and Research	4
1.16 Other	5
2.1 Analysis	8
2.2 Conclusions	11
(a) Findings	11
(b) Probable Cause	12
3 Recommendations	13

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SYNOPSIS

Los Angeles Airways, Inc., S-61L helicopter, N300Y, crashed at Compton, California, on August 14, 1968, at approximately 1035 P.d.t. All 18 passengers and three crewmembers were fatally injured, and the aircraft was destroyed by impact and fire.

The flight was en route from Los Angeles International Airport to the heliport at Anaheim, California, when the yellow blade, one of five main rotor blades, separated at the spindle which attached the blade to the rotor head. Following the failure, the helicopter was uncontrollable and it fell to the ground.

The Safety Board determines that the probable cause of this accident was the fatigue failure of the yellow main rotor blade spindle, causing separation of the blade which made the aircraft uncontrollable. The fatigue crack originated in an area of substandard hardness and inadequate shot peening.

1. INVESTIGATION

1.1 History of the Flight

Los Angeles Airways, Inc., (LAA) Flight 417, was a regularly scheduled passenger flight from Los Angeles International Airport to Anaheim, California. The aircraft and crew had completed three round trips to various destinations in the Greater Los Angeles Metropolitan area beginning at 0607, ^{1/} and departed the ramp at Los Angeles for Flight 417 at 1026. The flight, operating under Visual Flight Rules (VFR), was cleared by Los Angeles Helicopter Control to take off and proceed eastbound at 1028:15. For the next few minutes, traffic coordination was accomplished on both the Helicopter Control and Hawthorne Tower frequencies. The captain also checked an alternate transmitter with Helicopter Control which reported difficulty hearing the flight. At 1029:30, the flight reported to Hawthorne Tower that it was departing Los Angeles eastbound along Imperial Boulevard at 1,200 feet. At 1032:55, Helicopter Control advised, "LA four seventeen, seven miles east, radar service terminated." The flight acknowledged, "Four seventeen thank you." This was the last known radio contact with the flight.

Statements were obtained from 91 witnesses. A consensus of their observations indicates that the helicopter was proceeding along a normal flightpath when a loud noise or unusual sound was heard. A main rotor blade was either observed to separate or was seen separated in the vicinity of the main rotor disc. As the helicopter fell in variously described gyrations, the tail cone either folded or separated. In order to establish an approximate altitude for the flight, several simulated flights were conducted in a similar helicopter. Most witnesses indicated that the flights at 1,200 to 1,500 feet appeared to be most accurate.

The crash site coordinates were approximately 33°54'N latitude and 118°12'W longitude, and the elevation 97 feet m.s.l.

1.2 Injuries to Persons

<u>Injuries</u>	<u>Crew</u>	<u>Passengers</u>	<u>Others</u>
Fatal	3	18	0
Nonfatal	0	0	0
None	0	0	

^{1/} All times herein are Pacific daylight, based on the 24-hour clock.

1.3 Damage to Aircraft

The aircraft was destroyed by impact and fire.

1.4 Other Damage

None.

1.5 Crew Information

All crewmembers were properly qualified for their respective assignments. (See Appendix A for details.)

1.6 Aircraft Information

The aircraft had been maintained in accordance with Federal Aviation Administration (FAA) requirements, and was properly loaded for the flight. (See Appendix B for details.)

1.7 Meteorological Information

Witnesses in the area described the weather as very good, with clear visibility below a layer of clouds which were higher than the helicopter was flying. The wind was light, generally from the southwest.

1.8 Aids to Navigation

Not applicable.

1.9 Communications

Los Angeles Helicopter Control advised that it was having difficulty reading Flight 417 shortly after takeoff, but subsequently reported another transmitter as "loud and clear."

1.10 Aerodrome and Ground Facilities

Not applicable.

1.11 Flight Recorders

No flight recorders were installed or required.

1.12 Wreckage

The aircraft crashed in a recreation park located in a residential industrial area. The entire fuselage, both engines, main rotor head assembly, four main rotor blades, and the pylon

assembly were located in the main impact area. The fifth main rotor blade (yellow) including the sleeve and part of the spindle, was located approximately one quarter of a mile northwest of the main wreckage site. Minor parts associated with this rotor blade were scattered over a three-block area northwest of the park. Examination of the yellow blade spindle (S/N AJ19) revealed a fatigue fracture in the shank of the spindle adjacent to the shoulder at the inboard end of the shank. (See Attachment 1.)

1.13 Fire

There was no evidence of in-flight fire; however, an intense ground fire occurred at impact. The fire was extinguished by the Compton Fire Department.

1.14 Survival Aspects

This was a nonsurvivable accident.

1.15 Tests and Research

A stereomicroscope examination of spindle AJ-19 revealed that the nucleus of the fatigue fracture was on the trailing side of the spindle, one-eighth of an inch below the centerline, approximately at the shank tangency point, with the 0.125 inch radius at the shank/fork junction. The crack had originated in the base metal surface at the interface with the nickel plating, and propagated through approximately 72 percent of the shank cross-section prior to the failure. Additional laboratory studies revealed the following factors associated with the development of the fatigue crack:

- (1) Incomplete shot peening of the spindle shank before plating. Adequate shot peening would have increased the fatigue strength of the spindle and reduced the detrimental effect of the three following factors.
- (2) Low hardness of the steel in the area of the shank/fork junction where the fracture occurred. The general hardness was below the minimum specified for the spindle and, in addition, there were localized variations in hardness associated with a banded microstructure in the steel. The fatigue nucleus was in one of the softer bands.
- (3) A small surface flaw, similar to a corrosion pit, may have been present at the fatigue nucleus. Such a pit would increase the stress concentration normally present in the shank/fork fillet.

- (4) The nickel plating may have had a detrimental effect on the fatigue strength of the unpeened base metal.

1.16 Other

The spindle is part of the assembly which attaches the main rotor blade to the main rotor head, and about which the blade rotates to provide pitch control. The spindles are forged by independent contractors whose quality control of the parts includes chemical analysis, magnetic particle inspection, and hardness testing. One forging selected from each "heat batch" is subjected to 35 separate Brinell hardness checks along the longitudinal axis. Each remaining spindle is checked through use of a standard Brinell hardness tester. The receiving inspection at Sikorsky consists of (1) comparison of the chemical and physical properties listed on the certification sheets with the procurement specifications; (2) verifying that necessary inspections have been conducted by the contractor; (3) testing of a sample of the forging lot to verify that the chemical and physical properties meet specifications; and (4) on the basis of statistical sampling dimensional inspection, nondestructive testing (magnaflux), and hardness checks.

Prior to the accident, the hardness test on the basic forging sample at Sikorsky was accomplished on the shank end. If the sample failed to meet the hardness, magnaflux, or certain dimensional checks, the entire lot of forgings would be rejected. During the manufacturing process, each spindle was magnetic particle inspected, and tested for hardness and dimension following each operation. The hardness check after the machining operation was made at the fork end of the spindle. Normally only one reading per spindle was made unless the value was near the acceptable tolerance. In this instance, additional readings would be taken to insure that the hardness was acceptable.

Subsequent to the accident, Sikorsky instituted a new procedure requiring that a standard Rockwell hardness test be accomplished in the transition area adjacent to the radius at the shank/fork junction.

As part of the main rotor head, the spindles are overhauled every 1,200 hours to inspect the bores in the ears and the outside diameter of the shank for scoring, scratches, fretting, corrosion, gouges, or other damage. They are also magnetic particle inspected at every overhaul. 2/ The initial three overhauls of spindle AJ-19 were routine and completed in December 1963, October 1964, and August 1965. During the fourth overhaul in June 1966, the magnaflux inspection indicated the presence of

2/ The magnetic particle inspection includes either magnaflux or magnaglo.

nonmetallic inclusions 3/ on spindles AJ-19 and AL-82. They were sent to Sikorsky Aircraft for determination of their airworthiness, and were returned with the notation, ". . . no evidence of nonmetallic inclusions which could impair the serviceability of the parts." LAA then sent both spindles along with three others to Modern Plating Company (MPC) for salvage. 4/

The LAA purchase order for the salvage of the five spindles was accompanied by a drawing which set forth the following procedure:

- (1) Grind bearing journal to 4.523/4.524
- (2) Magnaflux inspect after grind
- (3) Shot peen reworked area
 - (a) No. 170 Shot per MIL-S-13165
 - (b) Intensity - .010/.012A
 - (c) Mask retention nut threads and washer land
- (4) Nickel Sulfamate plate to 4.530 diameter
- (5) Finish grind to 4.5271/4.5281
- (6) Mask spindle ear bores and threads, Cadmium plate per QQ-P-416 CL II type II

These instructions were in accordance with the salvage procedure recommended by Sikorsky Aircraft except that LAA did not specify hardness criteria or amplifying instructions for the Nickel Sulfamate plating. The Sikorsky procedure assigned a plating process (SS 8414) which requires a minimum hardness of Rockwell C 47.

The Quality Control Manager for MPC testified at the public hearing that his company subcontracted for the shot peening of the spindles with Astro-Peen Company. Following this operation they are given a visual inspection for peening and then plated. He advised that his plating procedure would produce a hardness in the range of Rockwell C 30 to 35.

3/ Nonmetallic inclusions - Particles of nonmetallic impurities, such as oxides, sulphides, and silicates, in a steel.

4/ Sikorsky overhaul instructions refer to the herein described rework procedure as salvage.

The owner of Astro-Peen Company reported that he had shot peened the spindles on a manual machine because it was loaded with 170 shot, whereas the automatic machine big enough to accommodate the spindle was loaded with smaller shot. He performed the work in accordance with Mil-S-13165.

During the fifth overhaul (November 1966), spindle AJ-19 was examined, along with three other spindles from the same rotor head, by representatives from Sikorsky. They determined that the fretting of nickel plate was due to insufficient hardness of the plating, and recommended that the spindles be reworked in accordance with previously provided engineering instructions. On May 9, 1967, these four spindles and the fifth, which had not been plated as yet, were shipped to Sikorsky for salvage. Instructions on the LAA purchase order, the shipping document, Sikorsky's RMA (Return Materials Authorization) document, customer checkoff list, and overhaul and repair order relating to the shipment and subsequent processing of the five spindles specifically outlined each operation to be accomplished, as follows:

- (1) Strip previous nickel plate
- (2) Replate and grind
- (3) Nickel Sulfamate plate per SS 8414
- (4) Shop peen per MIL-S-13165, No. 170 shot intensity 10-12A.

The work order operation sheet disclosed that the requirement to shot peen was deleted, and therefore not accomplished during this salvage of the five spindles. The operator who performed the plating of the spindles stated that since they appeared to have been shot peened, he did not shot peen them at that time. The Supervisor of Planning and Production Control testified that, ". . . it was not called out as a separate step on the operation sheet since it is covered in the standards for plating, and at that time when the part was stripped it would be checked." He also reported that as a result of this inspection it was determined that spindle AJ-19 had previously been shot peened, and therefore that step of the procedure was deleted.

The Chief, Quality Assurance and Reliability for Sikorsky Aircraft stated, "As the original manufacturer and designer of the helicopter, we possess technical capabilities. It is not

uncommon to get an order in from a customer with requirements that are not required. Since we do possess this technical capability, we would place the items in proper perspective. In this instance, the inspector in this area, and the operator, are well acquainted with (SS 8414). They are working with it all the time, and the document is in the area. There are many, many parts which we process through our system after having been shot peened once. Since there is no requirement to re-shot peen, upon examination that a shot peening operation had been completed at one point in time, they would proceed to induct the part into the nickel sulfamate process. However, before they would permit the part to go into the plating operation, they would have satisfied themselves that the part had in fact been shot peened."

The sixth overhaul of spindle AJ-19 was completed by Los Angeles Airways in June 1968, at which time it had been operated for 6,910.83 hours. No cracks were detected during the magnaglo inspection conducted at this time. The spindle was then reinstalled on N300Y, and remained there until the time of the accident. The spindle had a total time of 7,379.85 hours prior to the estimated 3.17 flight hours on the day of the accident.

2. ANALYSIS AND CONCLUSIONS

2.1 Analysis

Examination of the wreckage early in the investigation revealed that a fatigue fracture in the shank of the yellow blade spindle resulted in separation of the yellow main rotor blade, and caused loss of control of the aircraft. It was subsequently determined that no other factors related to the operation of the flight were involved. Consequently, the main thrust of the investigation focused on the circumstances surrounding the cause of the fatigue crack and the failure to detect it.

The fracture was of a type generally described as a high-cycle, low-stress fatigue fracture. A crack was initiated by stresses well below the gross yield strength of the steel and propagated by many thousands of load cycles before the spindle failed completely. It is believed that this crack was present and large enough to be detected during the magnaglo inspection

that was conducted at the last overhaul of the spindle. The magnaglo equipment operated by LAA should be capable of detecting cracks as small as 0.010 inch in length under plating of the thickness on spindle AJ-19. It is not known why the crack was not detected.

Regarding the cause of the fatigue crack, as previously noted, the basic metal stock of the spindle had a banded microstructure, indicating lack of uniformity in the distribution of certain constituents of the steel. The segregation of these elements in the ingot from which the spindle was manufactured affected its response to heat treatment and resulted in hardness readings as low as 28 on the Rockwell C scale. Microhardness tests indicated that the local hardness in the softer bands was even lower.

Thus, the hardness of the steel at the point where the fatigue crack initiated was well below the range of 34 to 38 Rockwell C specified on the spindle manufacturing drawing. The rough correlation between the hardness and fatigue strength of the steel indicates that the fatigue strength of spindle AJ-19 was considerably lower than that of others complying with all of the specification requirements. In addition, if the slight pitting observed at the fatigue nucleus was present prior to the initiation of the crack, it would have tended to further reduce the resistance of the spindle to fatigue failure. The effect of the plating itself is difficult to evaluate, but nickel plating normally produces some residual tensile stress in the steel surface which would tend to reduce the fatigue strength of the spindle and thus increase the detrimental effect of the other factors mentioned above. However, it should be noted that the SS 8414 plating process was selected to minimize the detrimental effects of nickel plating.

Incomplete shot peening undoubtedly was an important factor because the peening had not been effective in the critical area of the shank/fork fillet where the fatigue crack originated. Adequate shot peening of the fillet would have extended the fatigue life of the spindle by increasing the fatigue strength in the area where the general hardness was low and where localized soft spots were present. It probably would have eliminated any detrimental effect of small pits or other small surface defects that might have been present.

Some information on the effect of shot peening was obtained from two spindles that had been salvaged, but not shot peened, simulating the condition of AJ-19. These were included in a fatigue test program conducted by Sikorsky after the accident. Results were that the fatigue life of these two spindles was only about one-fifth to one-tenth of the mean life of spindles that had been shot peened during the salvage operation.

Finally, though virtually impossible to either assess or explain, is the overall effect of the salvage procedure on the part. It is apparent from the fatigue testing conducted by Sikorsky that there is extremely wide scatter in the relative fatigue strength of salvaged spindles. The failure pattern of reworked samples ranged from those with the shortest fatigue life to those that were retired without failing (two of which were from N300Y). The following possibilities, individually or in combination could explain this anomaly:

- (1) Fretting or other service damage to the base metal which is not eliminated prior to plating.
- (2) Variations in degree of shot peening
- (3) Differences in tensile stress from the plating
- (4) Coincidental normal variation in the fatigue properties of the base metal.

There were two items of corollary interest discovered during the investigation. The first was the apparent failure of LAA to insure that plating of the proper hardness was used in the initial salvage of AJ-19. However, inasmuch as this plating was replaced with proper plating, presumably before initiation of the crack, it had no bearing on the accident.

The second area is more difficult to accurately assess, but conceivably did have a direct effect on the accident. Sikorsky, based on their unique expertise, elected to deviate from the specific instructions of their customer and their own written procedure in that they did not shot peen spindle AJ-19 during their salvage of that part. Inasmuch as inadequate shot peening in the shank/fork radius area of the spindle contributed to the initiation of the fatigue crack, it must be concluded that this omission had a direct bearing on the accident.

2.2 Conclusions

(a) Findings

1. The aircraft gross weight and center of gravity were within limits.
2. The crewmembers were qualified for the flight.
3. The yellow main rotor blade separated in flight rendering the aircraft uncontrollable.
4. Blade separation was due to fatigue failure of the spindle.
5. The fatigue crack was a high-cycle, low-stress type which propagated over a long period of time.
6. The crack initiated because of a combination of the following factors:
 - (a) Metal hardness below specifications associated with a banded microstructure.
 - (b) Improper peening of the base metal surface.
 - (c) Possible detrimental effect of residual tensile stress from the plating.
 - (d) Pitting which may have been present in the base metal surface.
7. It is believed that the crack was present at the last magnaglo inspection of the part, and it is not known why it was not detected.

(b) Probable Cause

The Safety Board determines that the probable cause of this accident was the fatigue failure of the yellow main rotor blade spindle, causing separation of the blade which made the aircraft uncontrollable. The fatigue crack originated in an area of substandard hardness and inadequate shot peening.

3. RECOMMENDATIONS

Initial findings of the investigation revealed that there was strong evidence of a metal fatigue type failure in the rotor blade spindle assembly. Accordingly on August 16, 1968, the following recommendations were made to the FAA:

"Based on its preliminary findings in the Compton crash investigation, the Safety Board today is recommending to the Federal Aviation Administrator that he (1) require an immediate fleet inspection of all Sikorsky S-61 helicopter spindle units; (2) adopt a more precise and frequent inspection to preclude future spindle unit failures; and (3) study the need for establishing a retirement life for this vital part."

On the same date the FAA issued a telegraphic Airworthiness Directive which required the following action:

- (a) Before further flight, remove main rotor blade spindles P/Ns S6110-23325-1, S6110-23325-2 and S6112-23025-1 that either have been "salvaged" . . . or have accumulated 2,400 or more hours time in service on the effective date of this AD, and replace with blade spindles of the same part number that have not been "salvaged" and that have less than 2,400 hours time in service.
- (b) Replace main rotor blade spindles P/Ns S6110-23325-1, S6110-23325-2, and S6112-23025-1, that have not been "salvaged" and have less than 2,400 hours time in service on the effective date of this AD, before the accumulation of 2,400 hours time in service with main rotor blade spindles of the same part number that have not been "salvaged" and have less than 2,400 hours time in service.

On February 27, 1969, the Safety Board forwarded a recommendation to the FAA which stated in part:

"The spindle, as originally designed and tested, was certificated as an unlimited life item by the FAA. As testified to at the recent hearing held in connection with this accident, this certification was based on data submitted by the Sikorsky Aircraft Corporation and approved by the FAA. No such data were submitted in regard to reworking a spindle. Further, it appeared, from

testimony given at the hearing by FAA personnel, that the FAA was not aware of the rework procedure until after the accidents."

"At the time spindle rework was developed by Sikorsky, it is apparent that the criteria for determining what constituted a major or a minor change, allowed the rework to be classified a minor change. Under such a classification, no notification to the FAA by the manufacturer was necessary and no substantiating and descriptive data were required."

Under these circumstances the spindles continued to be considered as unlimited life items. Although it is quite possible that the FAA may have accepted a Sikorsky proposal indicating the rework would not appreciably affect the service life of the spindle, the recommendation pointed out that the FAA should have been made aware of a change to such a critical part.

Accordingly, the letter of recommendation concluded:

". . . the Safety Board recommends a re-evaluation of the FAA procedures and criteria involved in carrying out the intent of FAR Part 21, Subpart D (changes to type certificates). The procedures and criteria should insure that all changes affecting a part critical to the safe operation of the aircraft come to the attention of the appropriate FAA inspector so that proper action may be taken."

The reply to this recommendation was received from the FAA on March 26, 1969, and stated in part:

"Subsequent to the accident, we reviewed the procedures and criteria internally and with the manufacturers. It is our opinion that, when properly followed, the requirements will assure that an appropriate evaluation is made of any changes to type design. However, we have requested that our regions review the procedures used by the manufacturers, operators, repair stations, and the FAA in categorizing and evaluating major and minor repairs and design changes, and recommend any changes needed in procedures.

As a result of a quality assurance audit in January 1968, the Sikorsky Quality Control Manual 1101 was revised to make it clear that any Materials Review Board (MRB)

disposition in which there is any doubt that the non-conforming production part involves other than a minor change must be referred to FAA Engineering for evaluation. MRB dispositions are spot checked by the FAA to determine whether FAA approval has been obtained for major changes. In addition, we have reviewed with Sikorsky repair station personnel the criteria for categorizing repairs as major or minor and procedures for evaluating these repairs. They have instituted procedures to insure that Sikorsky Engineering continues to evaluate instructions for all repairs processed through their repair station."

BY THE NATIONAL TRANSPORTATION SAFETY BOARD:

/s/ JOHN H. REED
Chairman

/s/ OSCAR M. LAUREL
Member

/s/ FRANCIS H. McADAMS
Member

/s/ LOUIS M. THAYER
Member

APPENDIX A

Crew Information

Captain Kenneth L. Waggoner, aged 32, held airline transport pilot certificate No. 1486141 with ratings in rotocraft-helicopter, S-55 (VFR only), S-61L (unrestricted) and commercial privileges airplane multi-engine land, S-58, and instruments. He had accumulated 5,877:23 total flying hours, of which 4,300:27 hours were in the S-61L. He satisfactorily completed IFR and VFR proficiency checks on February 15, 1968, and March 8, 1968, respectively. His last FAA first-class medical certificate was issued July 10, 1968, with no limitations.

Copilot F. Charles Fracker, Jr., aged 27, held commercial pilot certificate No. 1628290 with ratings in rotorcraft-helicopter, V-107 II and instruments. He had accumulated 1,661:18 total flying hours, of which 634:18 hours were in the S61L. He satisfactorily completed his last proficiency check on May 22, 1968. His FAA first-class medical certificate was issued on August 1, 1968, with no limitations.

Flight Attendant James A. Black, aged 30, was employed by LAA on May 2, 1958, and had served on S-61L aircraft since March, 1962, when they were first placed in service with the company. His last check as a flight attendant was satisfactorily completed on March 6, 1968.

APPENDIX B

Aircraft Information

N300Y, a Sikorsky S-61L helicopter, serial No. 61031, was the prototype for the S-61L, and had accumulated 11,863.64 total flying hours prior to the day of the accident. It is estimated that approximately 3.17 hours were flown on August 14, 1968. The aircraft was equipped with two General Electric CT58-140-1 turboshaft engines installed as follows:

<u>Position</u>	<u>Serial No.</u>	<u>Time Since Overhaul</u>	<u>Total Time</u>
No. 1	280-131MA	1,231:52	5,762:49
No. 2	280-139MA	732:04	6,641:76

The aircraft was serviced with 1,000 pounds of JP-4 fuel and had a takeoff gross weight of 17,185 pounds, which was below the maximum allowable takeoff weight of 19,000 pounds. The computed center of gravity at the time of the accident was 260.111 inches from datum, which is 267.4 inches forward of the main rotor hub centerline. The allowable limits are from 256.0 to 278.7 for a gross weight of 17,000 pounds. The estimated gross weight at the time of the accident was 17,118 pounds.

APPENDIX C

Investigation and Hearing

1. Investigation

The Board received notification of the accident at approximately 1100 on August 14, 1968 from the Federal Aviation Administration. An investigating team was immediately dispatched to the scene of the accident. Working groups were established for operations, witnesses, human factors, structures, systems, powerplants and maintenance records. Interested parties included the Federal Aviation Administration, Los Angeles Airways, Inc., Sikorsky Aircraft, Air Line Pilots Association, and General Electric. The on-scene investigation was completed on August 24, 1968.

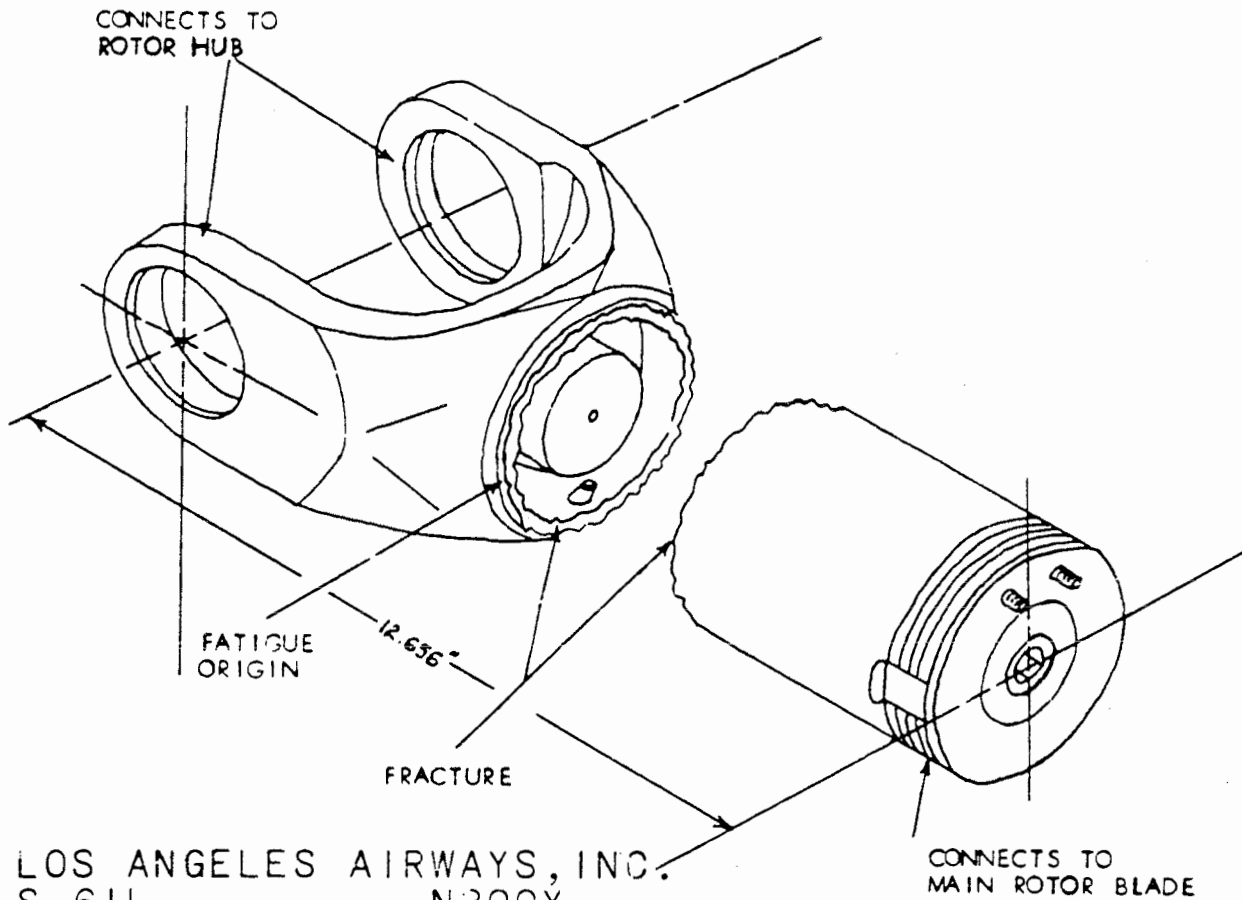
2. Hearing

A public hearing was held at Marina Del Rey, California on December 11-12, 1968. Parties to the Investigation included the Federal Aviation Administration, Los Angeles Airways, Inc., Sikorsky Aircraft, and the Air Line Pilots Association.

3. Preliminary Reports

A summary of the testimony which was taken at the public hearing was published by the Board on January 16, 1969.

ATTACHMENT 1
MAIN ROTOR SPINDLE
PART NO. S6110-23325-2B



LOS ANGELES AIRWAYS, INC.
S-61L N300Y
COMPTON, CALIFORNIA
AUGUST 14, 1968