

REPORT

HCLJ510-000356	Accident		
Aircraft:	Sikorsky S-61N	Registration:	OY-HGZ
Engine(s):	2 - CT58-140-2	Type of flight:	Charter, VFR
Crew:	3 – no injuries	Passengers:	24 – no injuries
Place:	Kangia, Greenland	Date and time:	18.4.2007 kl. 1715 UTC

All times are Coordinated Universal Time (UTC) unless otherwise noted.

Synopsis

The operator notified the Danish Accident Investigation Board (AIB) on April 18, 2007 at 1912 hrs. The Danish AIB notified the US National Transportation Safety Board (NTSB) on April 23, 2007.

A few seconds before landing engine number two did an uncommanded shut down. The flight crew was unable to make a go-around due to loss of power at low altitude. The helicopter impacted the terrain with a 2,76 g and was substantially damaged. The passengers and the crew evacuated the helicopter without any injuries.

The accident occurred in daylight and under visual meteorological conditions (VMC).

Summary of conclusion

The flight was uneventful and without any abnormal instrument indications until a few seconds before the accident.

Approximately five seconds before the estimated landing and close to the ground, the engine number two lost its power due to a Front Frame Accessory Drive (FFAD) failure.

It is the conclusion of the AIB that the engine number two stopped due to a loss of drive to the Accessory Drive Gear (ADG). The loss of drive to the ADG caused the fuel pump, the fuel control unit and the oil pump to stop, and due to fuel starvation the engine instantly shut down.

It is the assessment of the AIB that the failure of the input drive to the ADG might have been a result of an inadequate shimming of the FFAD. This inadequate shimming might have caused a substantial wear of the FFAD bevel gears. Subsequently, the bearings in the FFAD and ADG failed due to high load and metallic debris from the FFAD gear teeth and bearings. This led to a FFAD gear teeth slip and loss of drive to the ADG.

No safety recommendations were made during the course of this investigation.

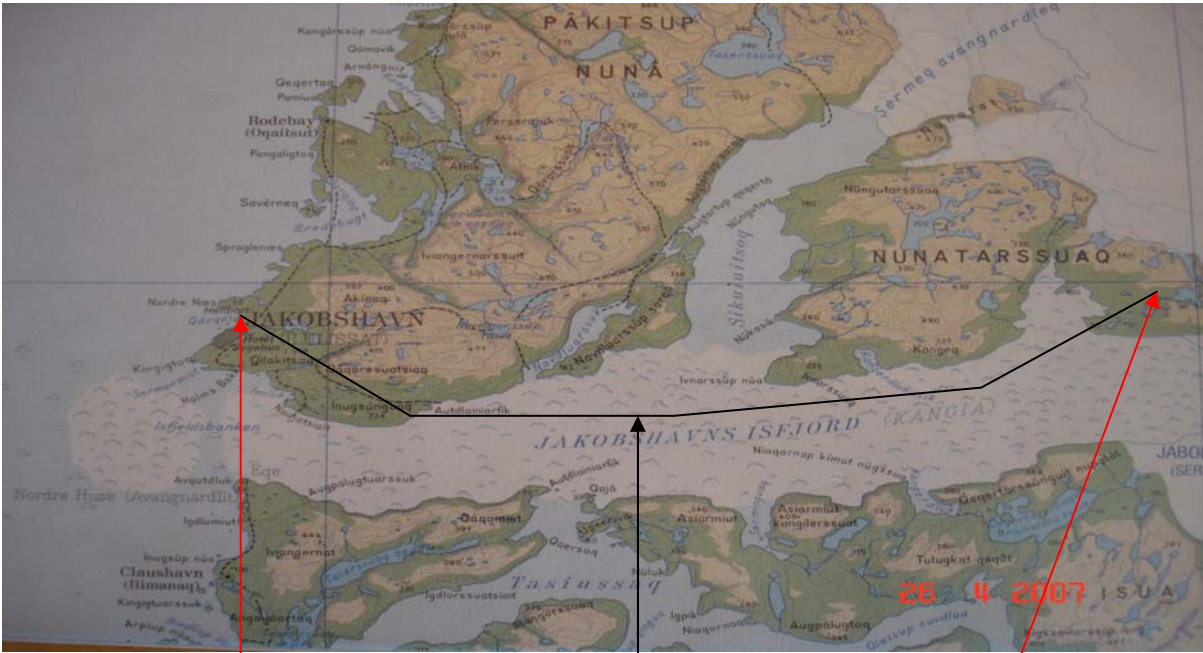
1. Factual information

1.1 History of flight

The accident flight was a charter VFR flight from Ilulissat (BGJN), Greenland carrying 24 passengers and three crew members. The planned destination was Kangia (KAG, 69 1350N 50 0005W) approximately 25 nm east of BGJN. During approach to KAG (sight-seeing point situated at 500 ft msl), and while the

helicopter was in a 36 ft hover in preparation for landing, the Pilot in Command heard a bang coming from the engine area. Instantly thereafter an engine in-flight shutdown occurred on engine number two. The subsequent high rate of descent resulted in a hard landing.

The helicopter impacted with the front fuselage followed by the main and the tail landing gear. The helicopter came to rest in a nose-up position on approximately 17 degree sloping ground adjacent to the landing area. After the flight crew completed an emergency shut down of engine number one, the passengers evacuated the helicopter using the air stair door.



BGJN

Route flown

Accident site



1.2 Injuries to persons

Injuries	Crew	Passenger	Other
Fatal			
Serious			
Minor/none	3	24	

1.3 Damage to aircraft

The lower fuselage, the sponsons and the landing gear were substantially damaged.

1.4 Other damage

None.

1.5 Personal information

1.5.1 Pilot in Command (PIC)

Personal Details: Male, aged 54 years.
Nationality: Danish.
Certificate: Helicopter Transport Pilot License (ATPL (H)).
Certificate valid until: October 9, 2008.
Total flight hours: 10,478 hrs.
Total flight hours on type: 6,336 hrs.
Medical class: 1
Medical valid until: July 1, 2007

1.5.2 First Officer

Personal Details: Male, aged 36 years.
Nationality: Danish.
Certificate: Helicopter Commercial Pilot License (CPL (H)).
Certificate valid until: March 30, 2012.
Total flight hours: 246 hrs.
Total flight hours on the type: 30 hrs.
Medical class: 1
Medical valid until: January 24, 2008

1.6 Aircraft information

1.6.1 General

The Sikorsky S-61N was a twin engine helicopter developed and manufactured by Sikorsky Aircraft Corporation. The cabin may seat up to 24 passengers.

The helicopter registration data were as follows:

Type:	Sikorsky
Model:	S-61N
Serial number:	61764
Registration No.:	OY-HGZ
Engines:	2 General Electric CT58-140-2
MTOW:	20,500 lbs
Minimum crew:	2
Airworthiness certificate:	No. E0145 valid until January 6, 2008

The aircraft data at time of the accident:

Aircraft total flight hours:	34,348:53
Aircraft cycles:	53,198

1.6.2 Maintenance

The helicopter's maintenance records were verified to be in compliance with the established maintenance program.

The last A-inspection was accomplished at 34,321 flight hours.

The last B-inspection was accomplished at 34,321 flight hours.

The last C-inspection was accomplished at 34,187 flight hours.

The last D-inspection was accomplished at 34,187 flight hours.

The last E-inspection was accomplished at 33,208 flight hours.

The last MI-inspection was accomplished at 26,271 flight hours.

MI (Major Inspection) had an interval of 13,200 flight hours.

On March 4, 2007 at a scheduled maintenance check, engine number two was replaced with a newly overhauled engine at aircraft flight hours of 34,293.

1.6.3 Engine

Engine data at the time of the accident:

Serial number 295235C was installed as engine number one:

Time between overhaul: 2,000 flight hours.

Time since overhaul: 706 flight hours.

Total time: 21,264 flight hours.

Remaining hours: 1,294 flight hours.

Serial number 295219C was installed as engine number two:

Time between overhaul: 2,000 flight hours.

Time since overhaul: 56 flight hours.

Total time: 22,886 flight hours.

Remaining time: 1,944 flight hours.

1.6.4 Aircraft mass

The helicopter was approved to a maximum takeoff mass of 9,300 kg. The last weighing was performed on April 4, 2006 and was due on April 3, 2010.

The load sheet showed that the actual take off mass was 9,294 kg.

Total traffic load *)	1,896 kg
Dry operating mass	6,536 kg
Zero fuel mass	8,432 kg
Take off fuel	862 kg
Take off mass	9,294 kg
Trip fuel	181 kg
Landing mass	9,113 kg

The Centre of Gravity was within the envelope.

*) Passenger and baggage.

1.7 Meteorological information

The weather during the day of the accident (BGJN = Ilulissat):

Metar: BGJN 181550Z 30004KT 270V020 9999 BKN082 M017M12 Q1020=
TAF 9 hours: BGJN 181550Z 181621 VRB08KT 9999 SCT070 BKN120 BECMG 1618 FEW040
BKN090 TEMPO 1821 10012KT 6000 -SN DRSN BKN0400=

Route forecast:

Valid: 1700-1920 UTC April 18, 2007
Route: BGJN-KAG-BGJN
Weather: NIL-After period snow approaches from west.
Surface vis: More than 10 km.
Clouds (MSL): BKN70VC AC7AS BASE ABV 6000FT. BLW FEW LATER POSS SCT SC BASE
2500-4000FT.
Freezing level: SFC
Icing: NIL/FBL IN SC
Turbulence: MAINLY FBL
Surface wind: VRB 06-12KT

1.8 Aids to navigation

Nil

1.9 Communication

The communication between OY-HGZ and Sonderstrom Flight Information Service on frequency 120.300 MHz was recorded and of good quality.

1.10 Landing area information

The landing area was situated at 500 ft msl and was a flat spot in a remote mountainous area, approximately 25 nm east of Ilulissat. The condition of the ground was five to ten centimeters light snow on top of 20 to 50 centimeters hard snow. There was a wind sock located in the eastern part of the landing area.



1.11 Flight recorders

1.11.1 The accident flight

The helicopter was equipped with a Health and Usage Monitoring System (HUMS) and with Penny+Giles Cockpit Voice & Flight Data Recorder (CVFDR) type 900/D51615. The CVFDR was in a good shape without any damage. The CVFDR was transported to the UK Air Accidents Investigation Branch, for read out and data examination. The data was of good quality and was used in the investigation.

The data from the FDR are shown in Appendix A. The aircraft operated normally until approximately five seconds before impact, and at that time the radio altimeter indicated 36 ft. The engine number two lost its torque very rapidly and at the same time the engine RPM, turbine stage 5 temperature (T5), main rotor speed and NG started to drop. The impact acceleration was equal to 2,76 g.

The CVR indicated normal operation communication between the flight crew and Sonderstrom Flight Information Service before and after the impact. The communication did not uncover the reason for the engine failure.

It was possible to hear an engine spooling down and approximately five seconds later, a “bang” was recorded on the tape (impact).

1.11.2 Previous flight

The investigation did not disclose any abnormal data (CVFDR read out) from the helicopter’s previous flight. The data were used to compare the engines and flight data with the accident flights data. (Appendix A.).

1.12 Wreckage and impact information

1.12.1 Impact

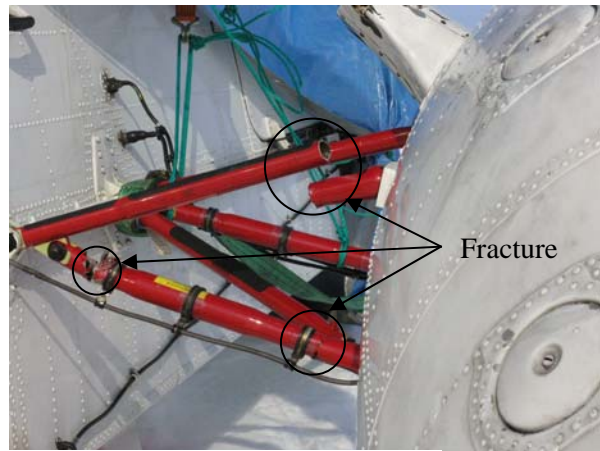
The helicopter impacted with 2.76 g and with the front lower fuselage first, followed by the main landing gear and the tail landing gear. The accident site was on the edge of the landing area with a down slope of 16.7°.

The landing gear was in its down and locked position and the helicopter had suffered substantial damage to the left gear, sponsons and support tubes. All support tubes on the left side were fractured due to overload and the absorption strut was separated from the sponson. Two of the sponson support tubes were fractured

due to overload on the right side. The lower forward and mid lower fuselage was substantially damaged.



Left sponson and support tubes.



Right sponson and support tubes.

The main landing gear supported the helicopter through the sponsons and the sponsons were supported by an energy absorption strut, which provides stability for the helicopter during water manoeuvres. The upper half of the strut contained three shear bolts and an aluminium honeycomb core within an upper tube. Should a hard landing occur, the shear bolts would fracture, and allowing the lower tube to compress the honeycomb core within the upper tube.

None of the three shear bolts in either the right- or left side were sheared.

1.12.2 Free wheel units and torque sensing unit transmitter

The main gearbox and the free wheel units were disassembled for a detailed inspection in a hangar facility in Greenland, without any findings.

The torque sensing unit transmitter (TX) for engine number two was found to have an external restrictor installed in the adjacent elbow fitting (pn. SS49PB833-4-22Y). The yellow dot on the fitting indicated that there was a restrictor installed (see photo). The number one engine did not have the external restrictor installed. Both the TX's were tested in a test cell and were found to operate correctly without the restrictor. With the restrictor installed the TX's had a tendency to lead and lag on the pressure gauge and had a little slower reaction time on the gauge needles, but they still showed the correct figures. If the elbow fitting

was screwed too far into the TX, which was possible, the restrictor in the fitting and the internal restrictor in the TX could more or less make contact against each other. The result was that the pressure gauge did not show the correct figures; even it was possible to make zero reading.

Furthermore, the position 2 TX data plate was missing and was replaced by an unauthorized label. The IPC prescribes that there should be installed an external restrictor in the elbow fitting.



TX pos. 1

TX pos. 2



TX pos. 1

TX pos. 2



Elbow fittings

Yellow dot.



Restrictor in elbow fitting pos. 2

1.12.3 Engine service history

As a result of the CVFDR read out, the investigation focused on number two engine, a CT58-140-2, serial number 295219C.

- The engine was removed from position #1 of another helicopter on September 10. 2006, with 22,830 flight hours since new.
- The engine had undergone a light overhaul, at 22,830 flight hours since new.
- The engine was installed in position #2 of the accident helicopter on March 3. 2007 at a helicopter total time of 34,293 flight hours.
- Three topping tests were performed before the engine complied with the requirements.
- Helicopter B-check, including check of all engine magnetic plugs, was performed at helicopter total time of 34,321 flight hours - 28 flight hours since installation of the engine.
- The accident occurred at 22,886 engine flight hours since new and 56 flight hours since light overhaul and at helicopter total time of 34,348 flight hours.

1.12.4 Engine investigation

The first part of the engine inspection took place in a hangar facility in Greenland. The external condition of the engine was good, with no evidence of uncontainment or fire.

There was no evidence of any foreign object damage at the compressor inlet, but there was evidence of a hot air leak at the 6 o'clock position between the mating flanges of the second stage turbine casing and the power turbine exhaust casing assemblies.

Based on the above mentioned preliminary investigation and the CVFDR read outs, the engine was shipped to a neutral overhaul facility for further disassembly and investigation by the AIB.

When the starter jaw was rotated to rotate the engine core, none of the accessories were observed to rotate. This indicated a loss of integrity within the accessory drive system.

The starter jaw is a part of the engine Forward Frame Accessory Drive (FFAD). The FFAD is mounted in front of the engine and is mainly a bevel gear arrangement which primary function is to transfer engine power to the Accessory Drive Gear (ADG). The ADG drives the accessories. Most of these accessories are essential for the operation and control of gas turbine engine such as fuel pump, oil pump, fuel control etc. when engine is running. The secondary function is to act as an input shaft from the engine starter during engine start.

The four magnetic drain plugs were removed and all found to be contaminated with fine metallic debris. The oil filter was found to be clogged with fine metallic debris. See figure below.

The four magnetic plugs and the oil filter were scanning electron microscope (SEM) analysed and the results revealed that the debris was consistent with cold section bearing material (copper alloy, iron and silver. Material match: AISI 52100) and gear tooth material (case hardened steel. Material match: AISI E9310). No other materials were found.



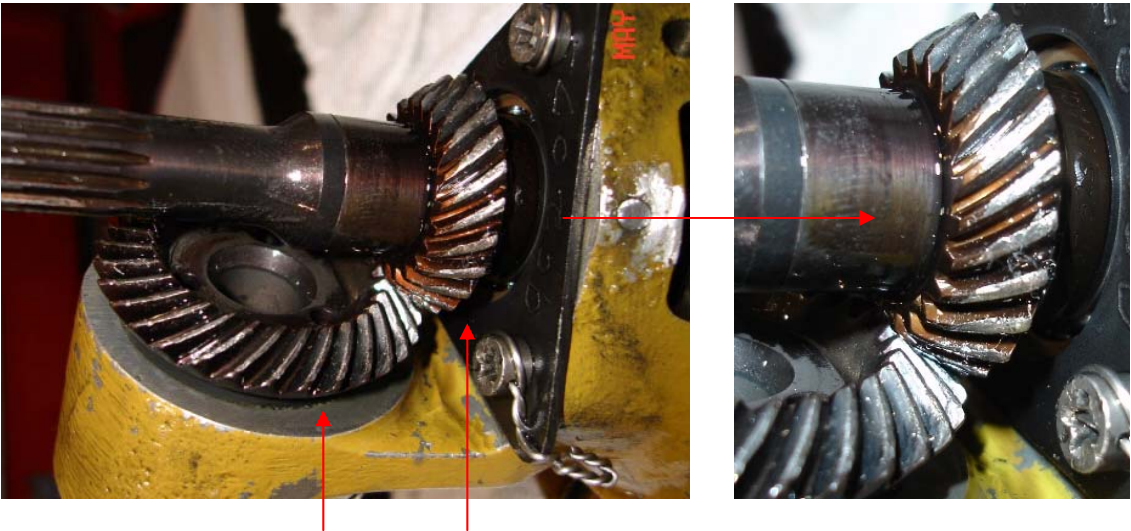
Magnetic plug for accessory drive gear box and main bearing number



Magnetic plugs for main bearing number two and three and power turbine.

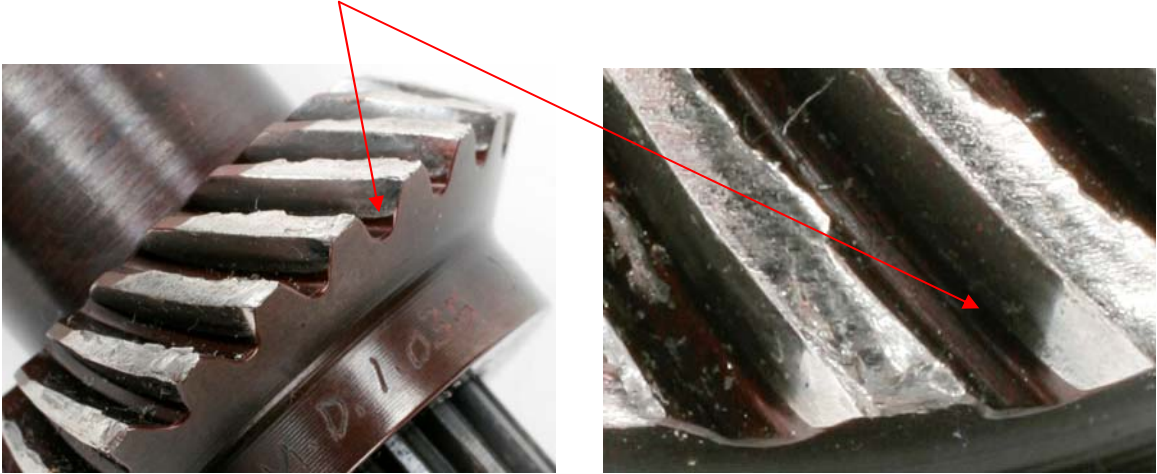
The tear down of the FFAD and the ADG revealed that this loss of drive to the ADG was due to disengagement of the pinion and bevel gears of the FFAD. Wear and damage was observed on the teeth on these gears. See figure below.

The FFAD pinion and bevel gear teeth had the most extensive wear and damage. The tooth contact pattern was inconsistent with the Overhaul Manual.



FFAD bevel and pinion gear.

The bevel gear teeth were found to have contact with the pinion gear teeth almost to the bottom of the roots as far as it was possible due to the design of the teeth.



FFAD pinion gear

The pinion gear was supported by a starter drive bearing. The bearing was found to be in a normal condition.

The bevel gear was supported by two bearings in the FFAD housing, s/n HPCRCS01046. Of the two bevel gear assembly bearings, the upper one showed evidence of wear and distress.



The ADG was equipped with Aircraft Recommended Practices (ARP) lock nut for the pinion gear. The ARP lock nut breakaway torque was measured to 183 inches/pound, the nut was found to have been tightened correctly. There was no evidence of that the pinion nut or bevel nut were loose. The key washer was in place.

The ADG pinion and bevel gear teeth were also worn with damage evident at the toe end of the pinion gear teeth. The tooth contact pattern was inconsistent with the Overhaul Manual. Both the ADG bevel pinion assembly bearings showed evidence of wear and distress. All other bearings in the ADG were found to be in a normal condition.



ADG bevel pinion assembly, bearings and teeth.

The FFAD and ADG were further disassembled to the piece-part level. The four shims required for proper alignment and loading of the pinion and bevel gears were removed and inspected.

According to the overhaul manual each pair of pinion and bevel gears should be shimmed axially and radially. Backlash and tooth contact pattern checks were required after shimming to confirm the correct shim thickness.

The investigation found the following:

1. FFAD axial shim part number 3030T59P04 is a solid, 0.024-0.025 inch thick shim (Appendix B, item 7), which requires machining at assembly to meet the shim thickness requirements for a particular FFAD assembly. This shim was found to be 0.025 inch thick with no evidence of machining.
2. FFAD radial shim part number 3030T71P11 is a solid, 0,045 inch thick shim, which requires machining at assembly to meet the shim thickness requirements for a particular FFAD assembly. (Appendix B. item 21.). This shim was found to be 0,036 inch thick.
3. ADG axial shim part number 324B174P003 is a laminated shim, which requires removal of layers to meet the shim thickness requirements for a particular AGB assembly. (Appendix B. item 53.). This shim was found to be 0.027 inch thick.
4. ADG radial shim part number 324B254P001 is a laminated shim, which requires removal of layers to meet the shim thickness requirements for particular ADG assembly. (Appendix B. item 15.). This shim was found to be 0.026 inch thick.

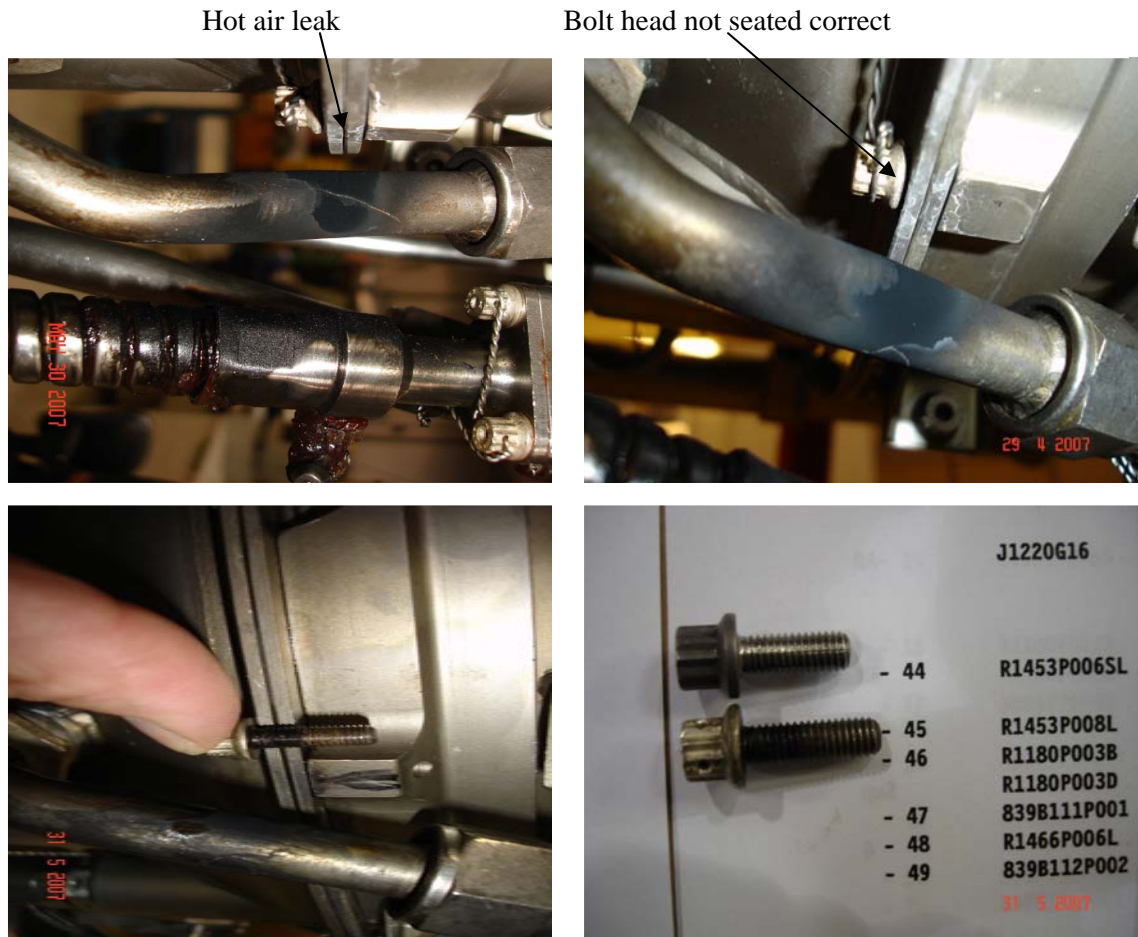
All five engine mainline bearings were removed for inspection and all found to be in normal condition. The outer races (Bearing Bore) for number one and number three bearing were found to be loose, allowing them to turn within their housings. A few small score marks were found on the number four bearing cage.

There was evidence of a hot air leak at the 6 o'clock position between the mating flanges of the second stage turbine casing and power turbine exhaust casing assemblies. This hot air leak caused some thermal distress to the fourth stage cooling air tube and flexible drive shaft casing, just forward of where they connect into the power turbine accessory drive assembly.

Disassembly of the flexible drive assembly revealed that almost all grease had disappeared from around the flexible shaft. An excessive axial play was found in the assembly.

The casing mating flanges are required to use a combination of P06 bolts (13 mm long) and P08 bolts (16 mm long). The bolts through every other flange hole also screw into blind holes in the blade guard behind the flanges. These bolts should be P06 to avoid the risk of 'bottoming-out' of the bolt in the blind hole. The P08 bolts are used in combination with nuts on 'open' flange holes and when there was also a bracket mounted to the casing flanges.

All the casing flange bolts on the accident engine were found to be P08 bolts, which increased the likelihood of insufficient clamping force on the casing flanges due to 'bottom-out' of the blade guard blind hole locations.



1.13 Medical and pathological information

There were no medical aspects to this accident.

1.14 Fire

There was no fire.

1.15 Survival aspects

The helicopter came to rest in a 16,7° nose-up position and an approximately 5° left bank. This type of aircraft was not fitted with evacuation slides because of the doorsill height. The helicopter was constructed with two cabin emergency escape hatches and two cockpit emergency escape hatches, one aft emergency door in the left side, one baggage door in the right front section and a passenger door at the aft right side.

The passengers and the crew evacuated the helicopter through the passenger door without any problems. An evacuation through the left cabin emergency escape hatch would have been difficult due to the exit being partially blocked by the left sponson.

The upper half of the landing gear strut contained three shear bolts and an aluminium honeycomb core within an upper tube. Should a hard landing occur, the shear bolts would fracture, and allowing the lower tube to compress the honeycomb core within the upper tube.

None of the shear bolts were sheared due to reduce G-force as it should. The AIB did not investigate in this issue, but simply note that the landing gear was a factor in keeping the helicopter from sliding down the slope on the snow.

1.16 Test and research

The FFAD pinion and bevel gear teeth had the most extensive wear and damage therefore the investigation was focused on the FFAD. The findings on the ADG also indicated that the investigation should be focused on the FFAD.

1.16.1 FFAD

During the engine investigation in Canada, the FFAD (drive housing s/n HPCRC01046) was rebuilt according to the Overhaul Manual using the same shims, but with other (refurbished) bevel gear assemblies. This demonstrated that the bevel gears were difficult to rotate by hand, with a noisy ratcheting sound heard. There was no backlash when the FFAD was handheld. The tooth contact pattern was incorrect and the pattern ran into the root of the gear tooth.

According to the Overhaul Manual the FFAD should have a backlash of 0.002 to 0.006 inch and the gear tooth pattern should have a contact length of minimum 0.15 inch starting from between 0.19 - 0.29 inch from the tooth outer end. The contact pattern must not run off the top or into the root of the gear tooth (Appendix B).

1.16.2 FFAD tests

The Accident Investigation Board Norway (AIBN) did perform the below following tests at the accident FFAD's overhaul facilities. The results was made available for AIBD and discussed (Appendix C).

Test 1: FFAD drive housing, s/n KPA3201 was removed serviceable from a serviceable engine. The FFAD was rotated by hand and it made "normal" noise. Backlash measured to 0.005 inch.

The FFAD was disassembled and shim where measured. Axial shim: 0.019 inch, radial shim 0.030 inch. Inspection in stereo microscope indicated that the wear on the gear teeth was minimal.

Test 2: The FFAD housing from test 1 (s/n KPA3201) was rebuilt with shims from the FFAD s/n HPCRC01046 involved in the accident. Axial shim: 0,025 inch, radial shim: 0.036 inch. The FFAD was now harder to turn and made more noise than in test 1. Backlash was measured to 0.

Test 3: FFAD housing s/n HPCRCS01046 was rebuilt with shims and radial retaining ring (Appendix B, item 13); all parts are from the FFAD involved in the accident. Gears and bearings came from FFAD s/n KPA3201. The FFAD was easy to turn by hand and made “normal” noise during numerous rotations. Wear pattern checked with pattern-marking compound revealed a normal wear pattern according to the Overhaul Manual. Backlash was measured to 0.003 inch.

Test 4: The FFAD was re-built as described in test 3, but with shims installed with thickness as following: axial 0.016 inch and radial 0.028 inch. The FFAD was easy to turn by hand and made “normal” noise during rotation. Backlash was measured to 0.008 inch.

These tests (Test 2: s/n KPA3201 versus test 3: s/n HPCRCS01046) could indicate that there are a difference between the two FFAD housings and that the difference is equivalent to a difference in backlash of 0.003 inch, however it is difficult to estimate that the differences in backlash was caused by wear on gear and bearings from S/N KPA3201 and/or from different housings.

1.16.3 Mathematical calculation

Dimension Y where shim P/N 3030T71P11 was installed (0.036 inch) determined the height of this gear to engage with Diameter X, where shim P/N 3030T59P04 was installed (0.025 inch).

From the mathematical calculation the maximum recommended shim thickness for the actual FFAD s/n HPCRCS01046 would have been:

- Bevel shim size 0.030 inch.
- Pinion shim size 0.015 inch.
- Backlash: 0.006 inch.

On the actual FFAD s/n HPCRCS01046 was found:

- Bevel shim size 0.036 inch -
- Pinion shim size 0.025 inch –
- Backlash: -0.005 inch.*)

The bevel shim difference between 0.030 and 0.036 is 0.006. The effect of the bevel shim being 0.006 inch too thick is to reduce the backlash by 0.006 inches (1:1 relationship).

The pinion shim difference between 0.015 and 0.025 is 0.010 inch The effect of the pinion shim being 0.010 inches too thick is to reduce the backlash by 0.005 inch (2:1 relationship).

The net effect is to reduce the backlash by 0.011 inch, going from a recommended backlash of 0.006 inch to minus 0.005 inch.

*) the backlash found on the FFAD is the mathematical calculation.

1.16.4 Component Maintenance Report (CMR)

The AIB received a copy of the CMR for the FFAD that was overhauled and installed on the accident engine (the component overhaul shop was not the same as the engine overhaul shop). The CMR did not document the calculations made to determine the shim thickness. Neither did the CMR mention any backlash or gear pattern check being performed.

1.17 Organizational and management information.

None

1.18 Additional information

1.18.1 ADG radial shaft bearings

Both of the bevel pinion assembly ball bearings showed evidence of wear and distress. A historical search on this bearing (part number 4002T02P02) revealed four previous events since 1995 - one in 1995, one in 1997, one in 1999 and one in 2004.

No documentation could be found for the 1995 and 1997 events. The root cause for the 1999 event was found to be hard particle contamination (aluminium oxide) in the cage pockets (source could not be found). Distress to the thrust bearing included raceway damage and rolling element wear, leading to disengagement of the pinion gear after 21 flight hours.

The 2004 event was an in flight shut down in Brunei, with 44 hours since overhaul. The exact cause of this bearing event could not be determined due to the significant wear of the rolling elements and transfer of worn material to the raceway. No hard particle contamination was found. The bearing manufacturer concluded that a manufacturing defect was improbable, and suggested that an abnormally high thrust load of unknown origin may have caused this bearing distress.

There was no record of ADG or FFAD shim thicknesses available for any of these events.

The above bearing failures could have been caused by a failure of the bearings themselves excluding the event in 2004, but there is also the possibility that the above bearing failures could have been caused by incorrect shimming.

1.19 Useful or effective investigation techniques

None

2. Analysis

2.1 CVFDR

The flight was normal until a few seconds before the accident. The read out of the CVFDR showed a drop in almost all engine number two parameters, approximately 4.5 seconds before impact. This indicated an engine failure (Appendix A).

2.2 Airworthiness

The AIB found that the flight crew was properly licensed. The helicopter had a valid Certificate of Airworthiness and the helicopter's maintenance records were verified to be in compliance with the established maintenance program.

2.3 Mass and balance

The mass and balance was within the Flight Manual envelope. The weather, the operation and the mass of the helicopter did not influence the sequence of events.

2.4 Engine torque sensing unit

The missing external restrictor in the elbow fitting on engine number one torque sensing unit, did not influence the sequence of events.

However, installation of the elbow fitting with the restrictor was not made in a failsafe manner as possibilities to screw the fitting against the torque sensing unit's restrictor needle existed.

2.5 Engine flanges

The wrong bolts installed, which caused the hot air leak at the 6 o'clock position from the engine flanges of the second stage turbine casing, did not influence the sequence of events.

2.6 Engine main bearings

The loose outer races (Bearing Bore) for number one and number three bearing did not influence the sequence of events.

2.7 Flexible drive shaft

The missing grease in the flexible drive shaft did not influence the sequence of events. It was most likely that the hot air leak from the 6 o'clock position from the engine flanges had dried-up the grease from the flexible drive shaft. This could have lead to an engine failure in the long term.

2.8 Engine magnetic plugs

All magnetic plugs and the oil filter were contaminated which indicated an internal failure in the engine. The oil filter was found to be clogged with fine metallic debris. This indicated that the oil filter had likely gone into bypass. The debris was consistent with cold section bearing material and gear tooth material.

2.9 FFAD - Component maintenance report (CMR)

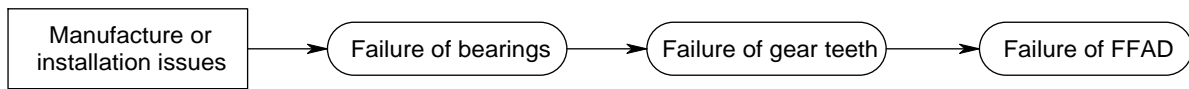
The CMR (overhaul) for the FFAD did not document the calculations made to determine the shim thickness. It was required to have a shim calculation between diameter X and Y of the FFAD in order to determine the thickness of the shim. Neither did the CMR document any backlash or gear pattern check being performed, which also was required.

The AIB found that the overhaul procedure for check of gear and pinion pattern limits and backlash for the FFAD during assembling was not followed in a correct manner and that the quality control was inadequate.

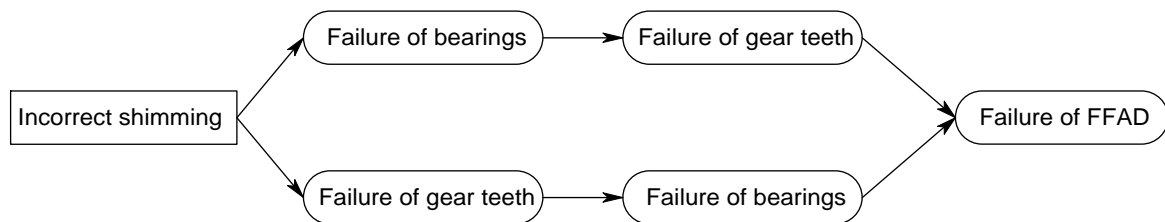
2.10 Failure of the FFAD and ADG

It is the opinion of the AIB that there could be two possible scenarios causing the failure of the FFAD.

Scenario 1:



Scenario 2:



2.10.1 Scenario 1

There is a possibility of a manufacture or installation issue. The bearings might not have fulfilled the manufacturers specifications. There is also the possibility of misalignment of the gear shafts causing an abnormal load of the bearings, which could lead to a failure of the bearings.

During the investigation and examination of the FFAD and ADG no indications supporting this scenario were found.

2.10.2 Scenario 2

During the investigation and examination of the FFAD and ADG it was revealed that the shimming of the FFAD was incorrect. This supported scenario 2.

The test and research of the FFAD showed that there was no backlash during two out of three tests and revealed that the tooth contact pattern was incorrect. The mathematical calculation showed minus 0.0005 inches backlash. This supported scenario 2.

In theory it would be possible to shim a new FFAD with the same over-size shims and having only about 0.001 inches of backlash; this would be the average of the three measured examples (0; .003 and 0 inches). This might explain why the FFAD bevel gears did not initially wear or produce metal debris during the test cell runs, or even at the 28 hours magnetic plug inspections, but were able to run for 56 hours before disengagement. (the pinion gear disengaged after 21 flight hours, at the 1999 event recalling that the shim s thicknesses were not recorded for this event).

The bevel gear tooth did run almost into the root of the pinion gear tooth which indicated that the shimming was incorrect. If a calculation between diameter X and Y of the FFAD and a gear pattern check had been available it might have indicated that the shimming was correct and therefore could have supported scenario 1.

But it is the AIB assessment that an over-sized FFAD axial and radial shim would have the effect of introducing undue stress and loads on the bevel gear teeth and bearings during normal engine operation. The undue stress and loads on the FFAD bevel gear teeth started to create metallic debris which caused the bearings to fail. Due to the self-perpetuating effect it finally ended up with a gear teeth slip and consequently the ADG lost its input; however again, it can not be totally excluded that the bearings in the FFAD failed before the bevel and pinion gear teeth due to an abnormally high thrust load caused by incorrect shimming.

The loss of input to the ADG caused the fuel pump, fuel control unit and oil pump to stop and the engine instantly shut down, due to fuel starvation.

2.11 Survivability

At the given mass weight (approximately 9,113 kg, equivalent to the estimated landing weight), ambient temperature and combination of height and velocity, the S-61 Height vs. Velocity diagram showed that the aircraft would have had insufficient velocity for the actual height to perform a go-around or make it to the elevated helipad (“pinnacle”) for an emergency landing. As a result of the snow covered terrain, the impact was cushioned which greatly improved the survivability (See Appendix D.).

The time and position – in terms of height and velocity – for the failure of the N_g governor to supply signal to the fuel control was from a survivability point of view very fortunate. Had the failure occurred at a higher altitude (Appendix E.), the survivability would most likely have been negatively affected – irrespective of the cushioning effect of the snow covered surface.

3. Conclusions

3.1 Findings

1. The flight crew was properly licensed.
2. The helicopter had a valid airworthiness certificate.
3. The centre of gravity was within the envelope.
4. The helicopter maintenance records were verified to be in compliance with the established maintenance program.
5. The weather did not influence the sequence of events.
6. The helicopter was close to the ground (36 ft.) when the engine number two did an uncommanded shut down.
7. Engine number two accessory drive gearbox failed and caused the engine to shut down due to fuel starvation.
8. CVFDR read outs showed an abnormal degree in almost all engine number two HUMS parameters approximately 4.5 seconds before impact.
9. The shear bolts for upper half of the landing gear struts were not fractured.
10. An external restrictor in number one engine torque TX elbow fitting was missing.
11. All magnetic plugs were contaminated.
12. Loss of integrity between the FFAD and the ADG.
13. The CMR for the FFAD did not document the calculations made to determine the shim thickness.
14. The CMR for the FFAD did not mention any backlash or gear pattern check being performed.

15. The FFAD had two over-sized shims.
16. The FFAD bevel gear top bearing showed evidence of wear and distress.
17. Both the ADG bevel pinion bearings showed evidence of wear and distress.
18. The ADG ARP lock nut was found to have been tightened correctly.
19. Main bearings number one and three were loose in outer races (Bearing Bore).
20. Wrong bolts were installed between the mating flanges of the second stage turbine casing and power turbine exhaust casing assemblies causing a hot air leak.
21. Flexible shaft was found dry and badly worn which might have lead to an engine failure in the long term.
22. Quality control was inadequate.

3.2 Causal factors

- Quality control was inadequate.
- Engine number two accessory drive gear box failed and caused the engine to shut down due to fuel starvation.
- The helicopter was close to the ground (36 ft) when the engine number two shut down.
- The FFAD was inadequate shimmed.

3.3 Summary

The flight was uneventful and without any abnormal instrument indications until a few seconds before the accident.

Approximately five seconds before the estimated landing and close to the ground, the engine number two lost its power due to a Front Frame Accessory Drive (FFAD) failure.

It is the conclusion of the AIB that the engine number two stopped due to a loss of drive to the Accessory Drive Gear (ADG). The loss of drive to the ADG caused the fuel pump, the fuel control unit and the oil pump to stop, and due to fuel starvation the engine instantly shut down.

It is the assessment of the AIB that the failure of the input drive to the ADG was a result of an inadequate shimming of the FFAD. This inadequate shimming might have caused a substantial wear of the FFAD bevel gears. Subsequently, the bearings in the FFAD and ADG failed due to high load and metallic debris from the FFAD gear teeth and bearings. This led to a FFAD gear teeth slip and loss of drive to the ADG.

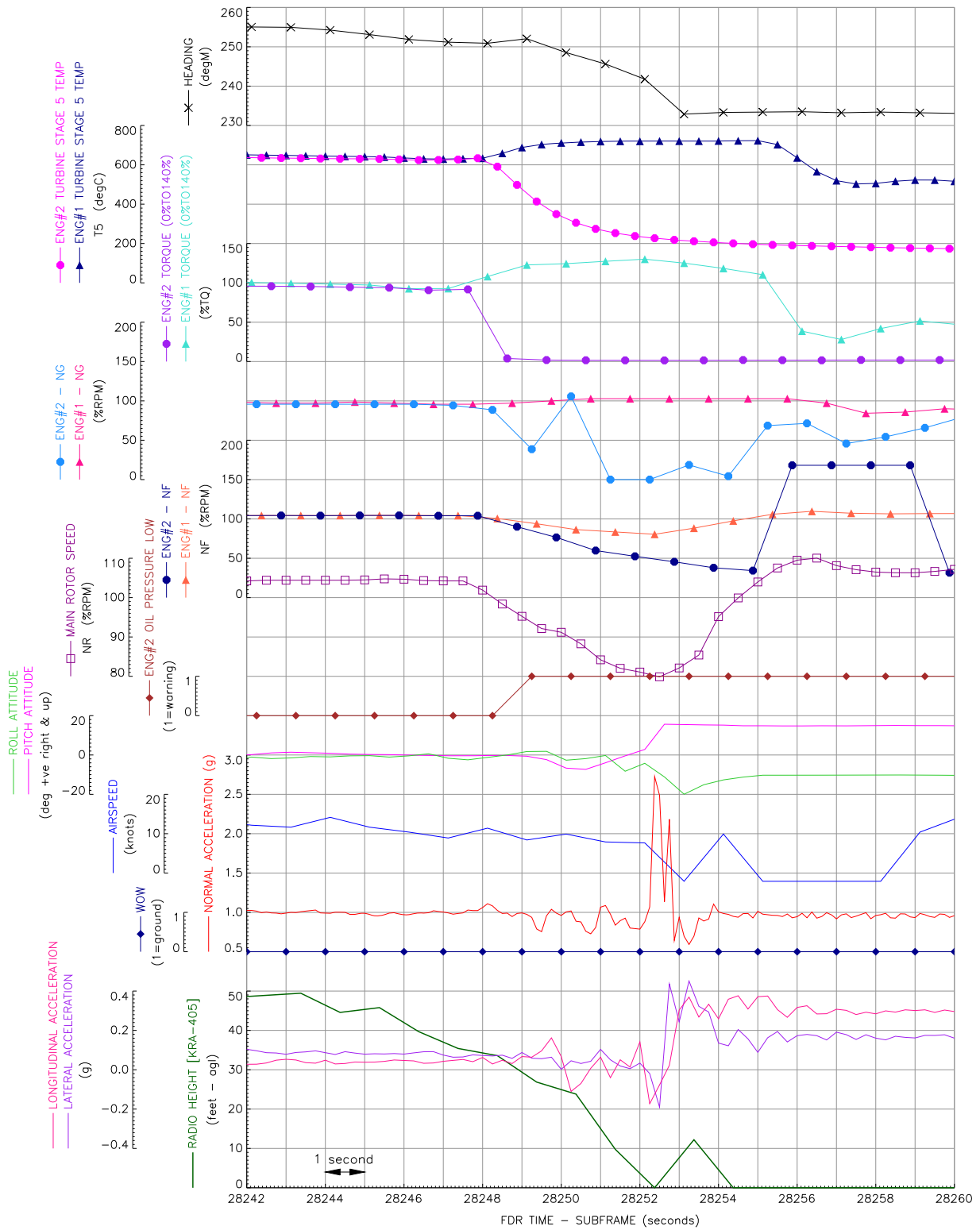
4. Safety recommendation

None

5. Appendix

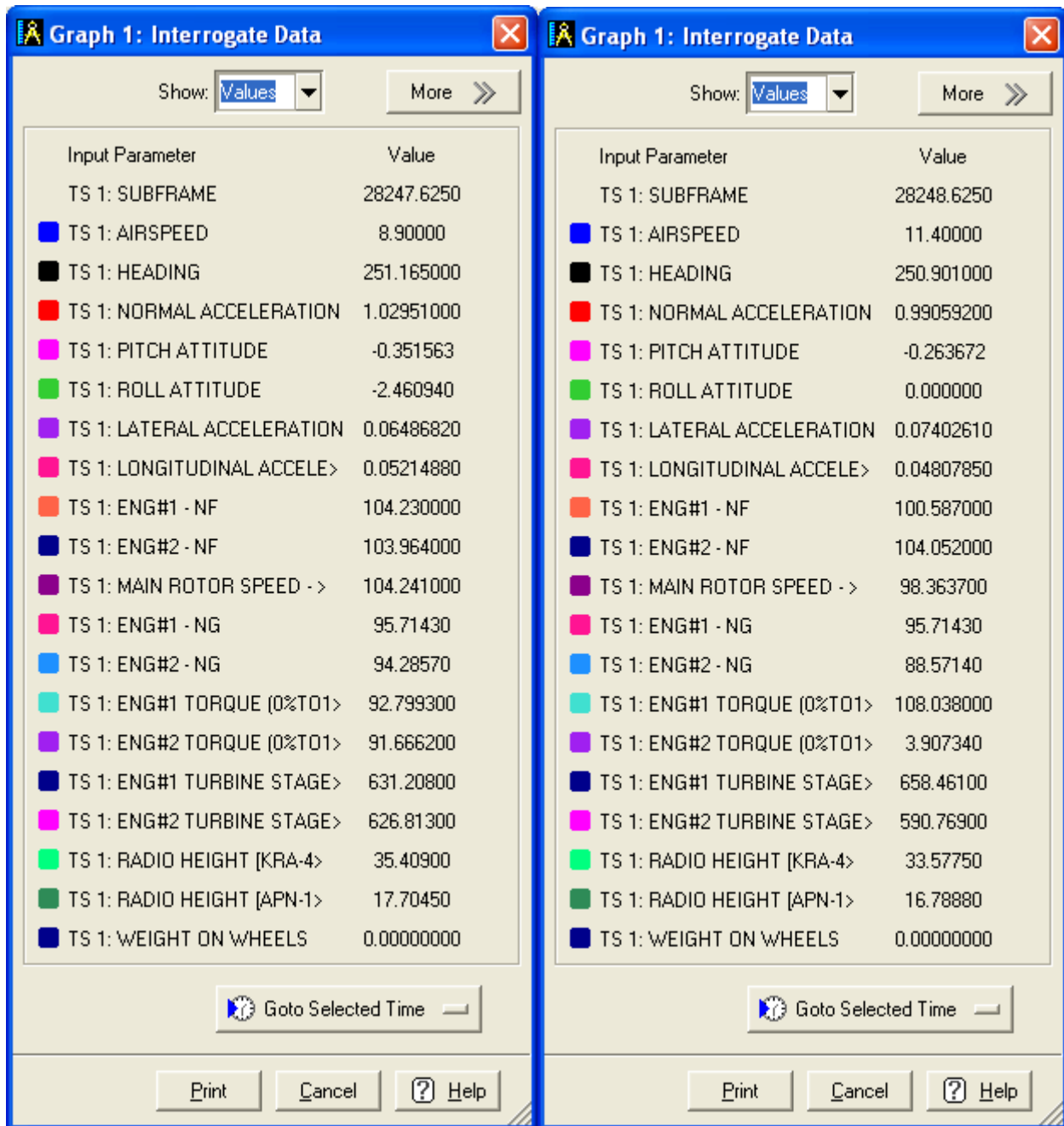
- Appendix A. / Read outs from CVFDR.
- Appendix B. / FFAD & ADG breakdowns and gear pattern limits.
- Appendix C. / FFAD bevel gear shimming tests.
- Appendix D. / Operating limitations.

Accident flight.

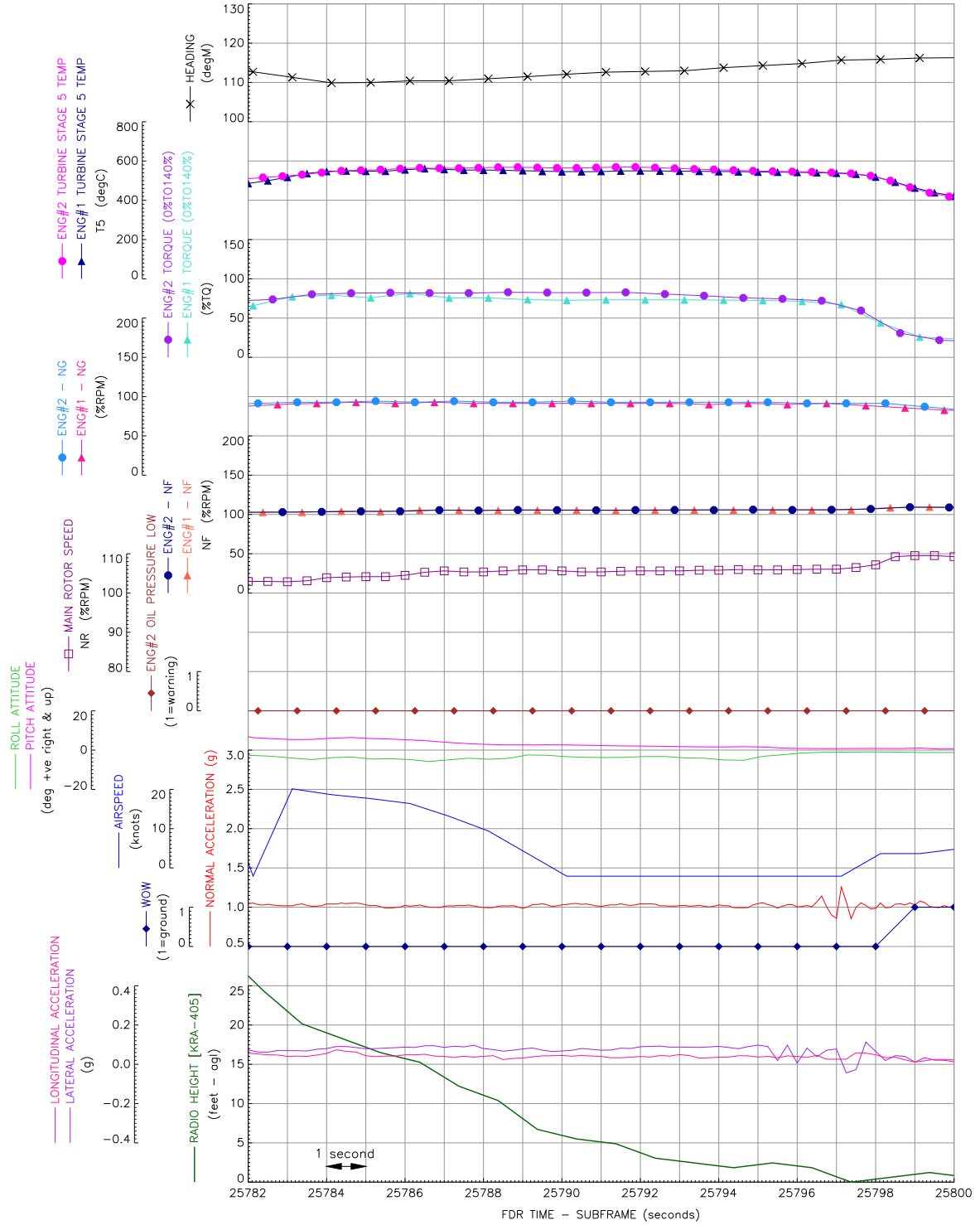


Note: The eng. 2 data at 28250 sec. is an error as well as some data after the impact.

Below data demonstrate the development from 28247.6250 seconds to 28248.6250 seconds (one second).

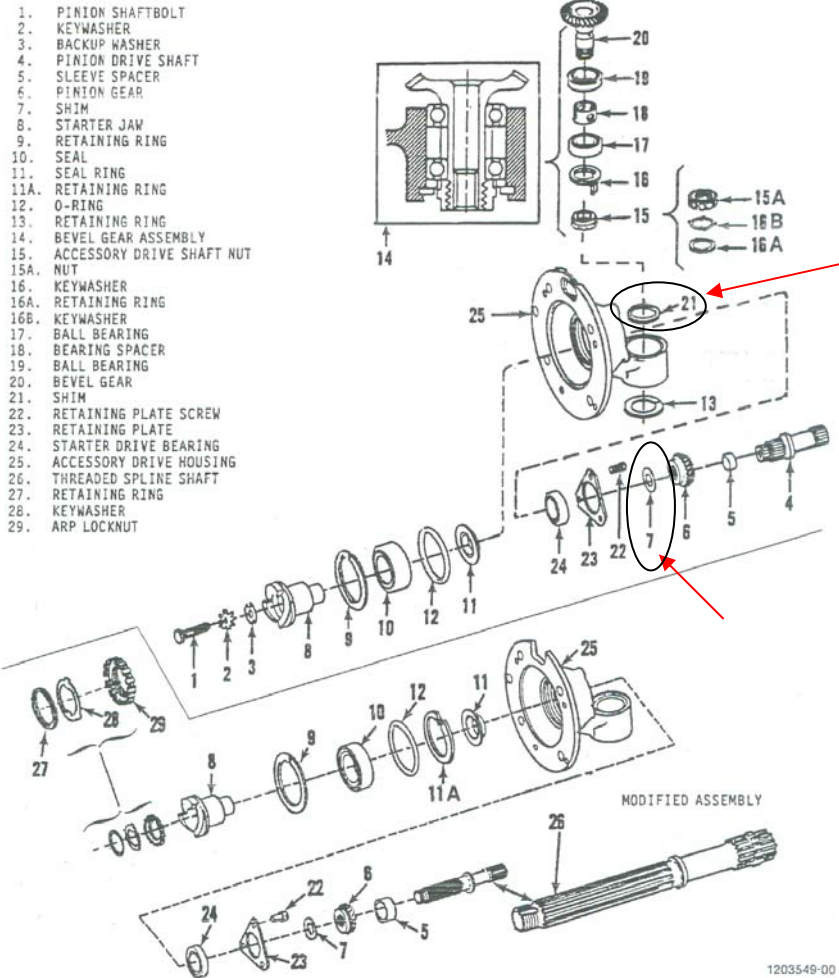


Previous flight data.





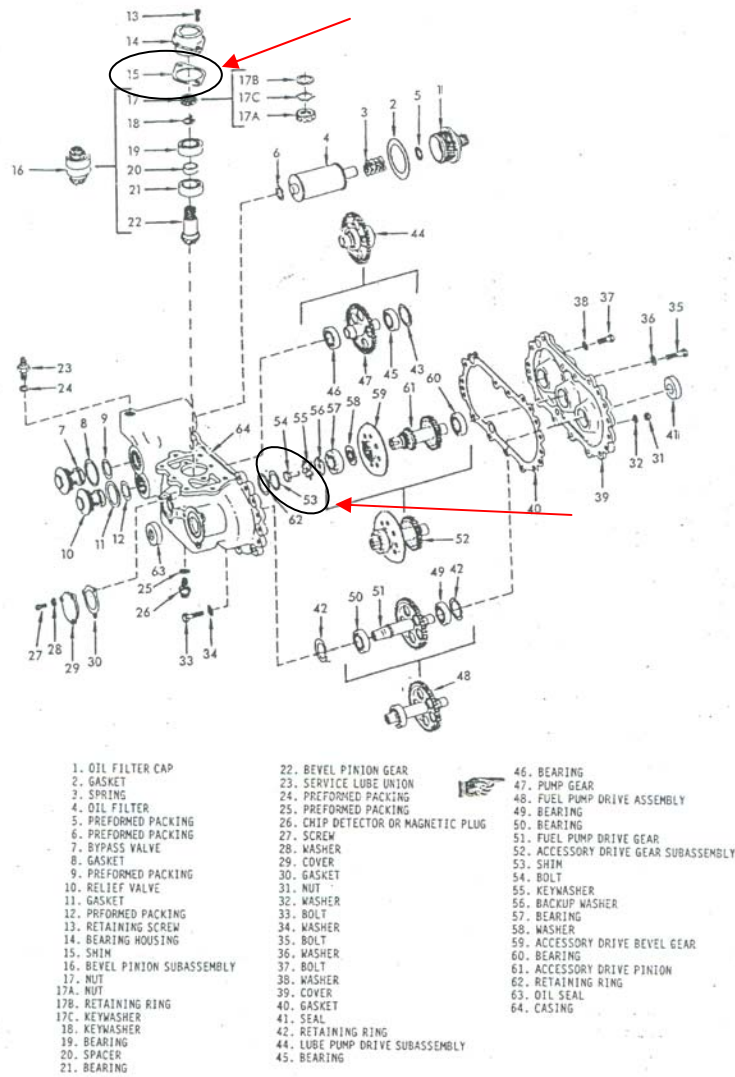
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SEI-183
OVERHAUL MANUAL



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Front Frame Accessory Drive Assembly - Disassembly
Figure 101

Accessory drive gear casing assembly.



1155288-01

Exploded View - Accessory Drive Gear Casing Assembly

FFAD - Gear and pinion pattern limits.

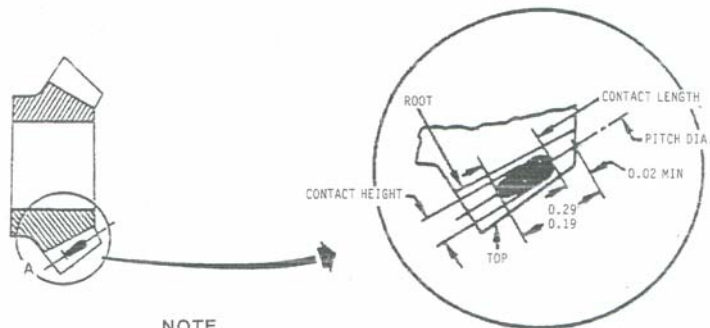


GE Aircraft Engines

CT58 TURBOSHAFT

SEI-183

OVERHAUL MANUAL



NOTE

CONTACT LENGTH MUST BE 0.15 INCH MINIMUM BETWEEN LIMITS SHOWN.
CONTACT HEIGHT MUST BE 0.04 INCH MINIMUM AND CENTRAL ABOUT THE PITCH LINE.
CONTACT PATTERN MUST NOT RUN OFF THE TOP OR INTO THE ROOT OF THE GEAR TOOTH.

DETAIL A

1188995/00

Front Frame Accessory Drive - Gear and Pinion Pattern Limits
Figure 506

- (5) Measure gear backlash. Attach an indicator (0.001 inch graduations with 0.035 inch diameter contact point) to a surface gage. Position contact point anywhere on tooth perpendicular to tooth surface. Carefully oscillate gear. Dial indicator displacement is the backlash of the bevel gears and must be 0.002 to 0.006 inch.
 - (6) Remove indicator.
- K. Check wear pattern on the bevel gears as follows:
- (1) Loosen thumbscrew on rear support clamp and raise clamp to position the V-surface against the spline. Tighten the thumbscrew.
- NOTE:** Do not overtighten the thumbscrew so as not to restrict rotation.
- (2) Coat teeth of pinion with pattern-marking compound.
 - (3) Rotate the starter jaw counterclockwise when viewed from the front, enough times to bring out the tooth-bearing pattern. Pattern must be within limits shown in figure 506. Tooth contact pattern must not run off the edge of the tooth. The pattern applies to the loaded side of the tooth only.

CT58 engine FFAD bevel gear shimming tests:

	<p>Normal shims:</p> <p>Axial: 0.016-0.019 inch. Radial: 0.028-0.030 inch.</p>	<p>Thicker shims:</p> <p>Shims used on FFAD s/n HPCRCS01046 Axial: 0.025 inch. Radial: 0.036 inch.</p>
<p>Serviceable FFAD s/n KAP3201</p>	<p>Test 1: Hand rotation easy Normal noise 0.005 inch backlash</p>	<p>Test 2: Hand rotation hard Noisy 0 backlash</p>
<p>"Hybrid FFAD" FFAD s/n HPCRCS01046 and serviceable gears & bearings.</p>	<p>Test 4: Hand rotation easy Normal noise 0.008 inch backlash</p>	<p>Test 3: Hand rotation easy Normal noise 0.003 inch backlash</p>
	<p>Canada demonstration: Hand rotation easy Normal Noise Backlash felt normal</p>	<p>Canada demonstration: Hand rotation hard Noisy; ratcheting 0 backlash</p>

Note: Backlash limits are 0.002 – 0.006 inch. The FFAD s/n HPCRCS01046 was installed on the accident engine.

Two out of three times that HPCRCS01046 thicker shims were used resulted in 0 backlash.

CATEGORY "B" LIMITING HEIGHTS AND CORRESPONDING SPEEDS FOR SAFE LANDING AFTER AN ENGINE SUDDENLY BECOMES INOPERATIVE ENGINE INLET ICE SHIELD INSTALLED

1. THE CURVES ARE APPLICABLE TO ALL ALTITUDES AND TEMPERATURES AT THE CORRESPONDING MAXIMUM ALLOWABLE TAKEOFF GROSS WEIGHT AS DETERMINED FROM FIGURES 1-11 AND 1-13.
2. AT GROSS WEIGHTS OR TEMPERATURES BELOW THE MAXIMUM ALLOWABLE AS DETERMINED FROM FIGURES 1-11 AND 1-13, REDUCE THE H / V DIAGRAM AT THE 100 FOOT HEIGHT 1 KNOT / 2°C FROM THE MAXIMUM ALLOWABLE TEMPERATURE FOR THE TAKEOFF GROSS WEIGHT AND ALTITUDE AND USE THE WEIGHT CURVE PASSING THROUGH THE CORRECTED SPEED.
3. DO NOT DECREASE BELOW 15 KNOTS IAS.
4. WHEN CONDUCTING CATEGORY "B" ROTORCRAFT EXTERNAL LOAD OPERATIONS, THIS CURVE DOES NOT CONSTITUTE A LIMITATION.

INFORMATION :
DIAGRAM BASED ON THE FOLLOWING TEST CONDITIONS:
1. HARD SURFACE RUNWAY OR WATER
2. NOMINAL WINDS 5 KNOTS OR LESS
3. STRAIGHT TAKEOFF AND CLIMB-OUT PATH

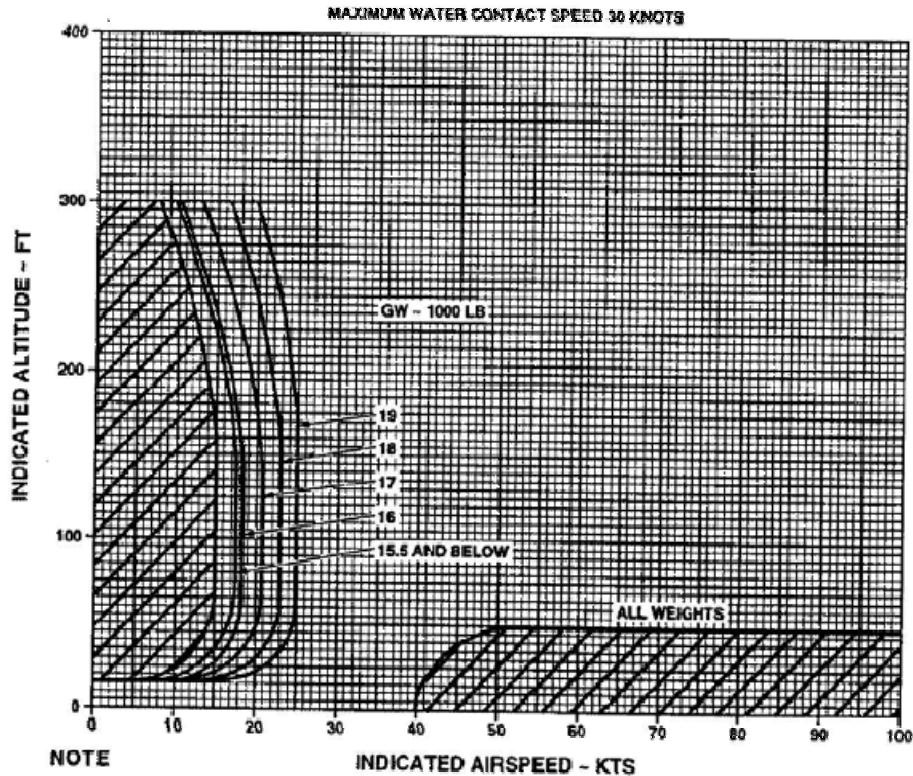


Figure 1-21

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