Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Swiss Confederation

Schweizerische Unfalluntersuchungsstelle SUST
Service d'enquête suisse sur les accidents SESA
Servizio d'inchiesta svizzero sugli infortuni SISI
Swiss Accident Investigation Board SAIB

Aviation Division

Final Report No. 2142 by the Swiss Accident Investigation Board SAIB

concerning the accident involving the K-1200 K-MAX helicopter, registration HB-ZEH

on 2 October 2007

in Strit, municipality of Illgau/SZ

Aéropole 1, Route de Morens, 1530 Payerne
Tel. +41 26 662 33 00, Fax +41 26 662 33 01
info@sust.admin.ch
www.saib.admin.ch

Ursachen

Der Unfall ist auf ein Versagen des Triebwerks auf einer Flughöhe, bei welcher eine erfolgreiche Autorotation nicht möglich war, zurückzuführen.

Die deutlichen Anzeichen eines Defektes am Triebwerk wurden nicht konsequent angegangen.

General information on this report

This report contains the Swiss Accident Investigation Board's (SAIB) conclusions on the circumstances and causes of the accident which is the subject of the investigation.

In accordance with Art 3.1 of the 10th edition, applicable from 18th November 2010, of Annex 13 to the Convention on International Civil Aviation of 7 December 1944 and Article 24 of the Federal Air Navigation Act, the sole purpose of the investigation of an aircraft accident or serious incident is to prevent accidents or serious incidents. The legal assessment of accident/incident causes and circumstances is expressly no concern of the accident investigation. It is therefore not the purpose of this investigation to determine blame or clarify questions of liability.

If this report is used for purposes other than accident prevention, due consideration shall be given to this circumstance.

The definitive version of this report is the original in the German language.

All times in this report, unless otherwise indicated, are stated in local time (LT). At the time of the accident, Central European Summer Time (CEST) applied as local time in Switzerland. The relation between LT, CEST and UTC is: LT = CEST = UTC + 2 hours.

Contents

Final Report

Synopsis

Owner	Fortis Lease Suisse SA, Avenue Gratta-Paille 1, CH-1018 Lausanne, Switzerland
Operator	Eagle Helicopter AG, Eggstrasse 17, Postfach 244, CH- 3770 Zweisimmen, Switzerland
Manufacturer	Kaman Aerospace Corporation, Bloomfield, CT, USA
Aircraft type	Kaman Aerospace K-1200 KMAX
State of registration	Switzerland
Registration	HB-ZEH
Location	Strit, municipality of Illgau/SZ
Date and time	2 October 2007, 12:40

Investigation

The accident occurred at approx. 12:40 UTC. The notification was received by the Aircraft Accident Investigation Bureau (AAIB) at 12:50 UTC. The investigation was opened in cooperation with the Schwyz cantonal police. The AAIB informed the investigation authority of the United States of America of the accident.

This report is published by the Swiss Accident Investigation Board (SAIB).

Synopsis

On Tuesday, 2 October 2007 a helicopter organization was engaged in logging operations in the Ibergeregg area (Schwyz). Tree trunks were transported by helicopter from a pick-up point to a central unloading point. On the approach to the pick-up point, the pilot noticed a distinct "RPM drop". The pilot used the emergency jettison to release the longline and initiated an emergency landing. The pilot, who was wearing a helmet, was slightly injured and was able to escape without assistance from the destroyed helicopter. The investigation revealed that the engine had shut down in flight.

Causes

The accident is attributable to an engine failure at an altitude at which a successful autorotation was not possible.

The clear indications of a fault in the engine were not appropriately addressed.

1 Factual information

1.1 History of the flight

1.1.1 General

The statements of the pilot, the aircraft mechanic and the flight assistant were used for the following description of the history of the flight.

The flight took place under visual flight rules. The flight was a commercial flight.

1.1.2 Previous events

For more than the four months preceding the accident, the ENG CHIP warning lamp in the cockpit illuminated repeatedly and metallic chips were found in the engine of helicopter HB-ZEH. This situation did not change after the installation of a loaner engine on 23 May 2007. According to the pilot's statement, the warning light could be extinguished in approximately 95% of the cases by applying the FUZZ BURN procedure.

On the morning of 2 October 2007, the helicopter, a type KAMAN K-1200 K-MAX, registration HB-ZEH, made a ferry flight from Ruhpolding/Germany to Switzerland and landed after a flying time of approx. 2 hours on the Ibergeregg, in the canton of Schwyz.

During the subsequent waiting time of approximately 35 minutes, an interim flight check was carried out by the operator’s technical director and the aircraft was found to be airworthy.

1.1.3 History of the flight

At approx. 12:10 the pilot started the engine of helicopter HB-ZEH in order to carry out logging operations in the Strit area, Ibergeregg Schwyz. During the starting procedure, the pilot noticed an anomaly in the form of an unknown noise, which was no longer audible on completion of engine start-up.

The technical director of the operator provided the following statement: *"When the pilot started the K-Max, we both heard an unusual noise. I immediately thought of the starter/generator. My thoughts:*

1. *If the starter/generator is not OK, the generator caption will come on*
2. *There is a rated break point on the starter/generator*
3. *After the Ibergeregg assignment, we are going to Alpnach RUAG"*

During engine acceleration to "Flight" RPM, the ENG CHIP caption illuminated. The chip detector was then removed and checked by the technical director. According to his testimony, it did not reveal any disconcerting chips. The pilot stated that after this intervention the ENG CHIP warning light illuminated once or twice more and that he was able to extinguish it by applying the FUZZ BURN procedure.

After consultation with the technical director, the pilot decided to carry out the envisaged work flight.

The pilot took off on his first rotation from the unloading point to the pick-up point, which was at an elevation of approximately 550 metres higher to the north-west. Over the next 30 minutes timber was transported between these two locations. During this time, the pilot twice noticed that the ENG CHIP warning caption illuminated again. It was possible to clear the two warnings by applying the FUZZ BURN procedure.

During the last approach in the direction of the timber unloading point, the pilot noticed that the ENG CHIP warning caption had illuminated again. He deposited the load and flew back towards the pick-up point. On subsequent application of the FUZZ BURN procedure it was not possible to clear the warning. During the approach to the pick-up point, the pilot noticed a distinct "RPM drop". The low altitude of approx. 60 feet above ground level forced the pilot to immediately perform an emergency release of the line, in order to make an emergency landing in the direction of flight. After recognising the emergency situation, the pilot concentrated on the emergency landing and no longer looked inside the cockpit.

The helicopter collided with the terrain approx. 100 metres west of the pick-up point on a sloping hillside and was destroyed. The pilot, who was wearing a helmet, was slightly injured and was able to escape from the destroyed helicopter without assistance.

The investigation revealed that the engine had shut down in flight.

1.1.4 Accident location

Accident location	Strit, Illgau/SZ municipality
Date and time	2 October 2007, 12:40
Lighting conditions	Daylight
Coordinates	698 891/206 653 (Swiss grid 1903) N 47° 00’ 12.8’’/ E 008° 44’ 20.4’’ (WGS 84)
Elevation	1320 m AMSL 4331 ft AMSL
Map of Switzerland	Sheet no. 1152, Sheet name Ibergeregg, Scale 1:25 000

1.2 Injuries to persons

1.2.1 Injured persons

Injuries	Crew	Passengers	Total number of occupants	Others
Fatal	-	-	-	-
Serious	-	-	-	-
Minor	1	-	1	-
None	-	-	-	Not applicable
Total	1	-	1	-

1.3 Damage to aircraft

The helicopter was destroyed.

1.4 Other damage

There was minor damage to farmland.

1.5 Personnel information

1.5.1 Flight crew

1.5.1.1 Pilot/commander

Person	Swiss citizen, born 1969
Licence	Commercial pilot licence helicopter – CPL(A) ICAO, issued by the Federal Office of Civil Aviation (FOCA) on 28 February 1994, valid till 8 January 2008 Commercial pilot licence – CPL(A) JAR, issued by the FOCA on 4 June 2002, valid till 29 December 2011
Helicopter ratings	AL III, AS350 Types, B206/206L, B407, B47 Types, BELL222/230/430, EC120B, K-1200 MD900/902, R22, BH06/ST/LT International radiotelephony for visual and instrument flight rules RTI (VFR/IFR) Mountain landing Helicopter flying instructor
K-1200ratinginitial issue	23 March 2006
Medical certificate	First class, no restrictions 20 December 2006 till 4 January 2008
Last aeromedical examination	20 December 2006
Commencement of pilot training	8 August 1988

1.5.1.1.1 Flying experience

Total helicopter	5153 hours
On the accident type	977 hours
During the last 90 days	207 hours
Of which on the accident type	207 hours
During the last 24 hours	5 hours
Of which on the accident type	5 hours
Helicopter landings	22 357
Landings during the last 90 days	233
Landings, total, on the accident type	1244
Landings during the last 90 days on the accident type	233

1.5.1.1.2 Crew duty times

Start of duty in the 48 hours before the accident	on 1 October 2007, at 07:15 on 2 October 2007, at 07:40
End of duty in the 48 hours before the accident	1 October 2007 at 18:45
Flight duty times in the 48 hours before the accident	11:30 hours
Rest times in the 48 hours before the accident	12:45 hours
Flight duty time at the time of the accident	05:00 hours

1.5.2 Maintenance personnel/technical director of the operator

Swiss citizen, born 1965

Licence	Licence for maintenance personnel, issued by the FOCA on 9 January 1992, valid till 9 January 2009
Ratings	M for aircraft: Eurocopter SA313/315/316/318/319/3160 Series Kaman K-1200 Series

1.5.3 Flight assistant on the ground

Swiss citizen, born 1978

1.6 Aircraft information

1.6.1 General information

Registration	HB-ZEH
Aircraft type	Kaman K-1200 K-MAX
Characteristics	Single-seat, single-engine transport helicopter with intermesher rotor system and turbine engine. Metal airframe with three-leg fixed landing gear. The K-1200 has two rotors, which are mounted laterally next to each other on separate masts forming a V-shape. The counter-rotating intermeshing rotors each have two rotor blades and are synchronised via the main transmission with a phase shift of 90°. The pitch of the rotor blades is controlled by one Flettner flap on the trailing edge of each rotor blade. Since the counter-rotating rotors cancel out their torques, this helicopter does not require a tail rotor.
Manufacturer	Kaman Aerospace Corporation, Bloomfield, CT, USA
Year of manufacture	1995
Serial number	A94-0014

Owner	Fortis Lease Suisse SA, Avenue Gratta-Paille 1, CH-1018 Lausanne, Switzerland
Operator	Eagle Helicopter AG, Eggstrasse 17, Postfach 244, CH- 3770 Zweisimmen, Switzerland
Engine	Honeywell (Textron Lycoming) T5317A-1 P/N 1-000-060-29; S/N LE07103C; max. power 1500 SHP/ 1119 kW Year of manufacture: 1969 as T5313 Modified to T5317B status in June 1999 Modified to T5317A-1 status in September 2004
Equipment	Cargo hook with weighing system, primary cargo hook K931204-001, mounted on the helicopter airframe. Hook mounted on a longline approx. 50 m long.
Operating hours	According to Hobbs Meter (operating hours counter): Airframe: 9440.9 hours TSN[1] Engine: 12 737.9 hours TSN 3344.7 hours TSO[2]
Engine operating cycles	Gas producer 13322 cycles Compressor 4400 cycles Power turbine 2779 cycles
Number of landings	Not documented
Max. permitted take-off mass	No external load: 6500 lb (2948 kg) With jettisonable external load: 12 000 lb (5443 kg) Max. load on hook: 6000 lb (2721 kg)
Mass and centre of gravity	At the time of the accident, the mass of the helicopter was approx. 2780 kg (6130 lb). Both the mass and centre of gravity were within the permitted limits in accordance with the rotorcraft flight manual (RFM).
Technical limitations	No open items were entered in the flight log or the hold item list.
Permitted fuel grade	Kerosene MIL–T–5624, grade JP–4/Jet B and JP–5/Jet A, or equivalent.
Fuel load	At the time of the accident, according to the pilot, there was approx. 500 lb of fuel on board, corresponding to a flying time reserve of approximately ¾ hour.

1 TSN – time since new
2 TSO – time since overhaul

Certificate of registration	Issued by the FOCA on 17 November 2003/no. 2
Certificate of airworthiness	Issued by the FOCA on 12 September 2002/no. 1, valid until revoked
Last condition check	Performed on 27 December 2006
Scope of utilization	In private and commercial operation: VFR by day

1.6.2 Maintenance

1.6.2.1 Engine T5317A-1 P/N 1-000-060-29; S/N LE07103C

An engine overhaul in accordance with ASE T53-13 overhaul manual, including an overhaul of the N1 accessory drive gearbox was signed-off on 9 December 1998 at 9393.2 hours TSN.

On 12 December 2006, SB T5313B/17-0122 was incorporated and thus the TBO[3] was increased from 3000 to 5000 operating hours, subject to the condition that at 2500 operating hours a so-called midpoint inspection is performed. In this context, the N1 accessory drive gearbox is considered part of the engine.

McTurbine INC., Corpus Christi, TX, United States, performed a post-rental inspection which was signed-off on 2 May 2005 at 11258.1 hours TSN. Due to wear which exceeded the allowable limit of 50%, the internally splined bevel gear P/N 1-080-310-01, was replaced with a new part S/N 040137402196. During this work, as required by the maintenance manual 330.2 section 72-00-00, the new ball bearing P/N91547-SOCN-2-300-013-03 CDA 99193; S/N 021991421878 was installed in the N1 accessory drive gearbox P/N 1-080-250-25; S/N 1353. The condition of the removed ball bearing was not documented in the work report.

On 12 December 2006, at 11787.3 hours TSN, a 2500-hour midpoint inspection was signed-off by Airborne Engines Ltd., Richmond, BC, Canada. The corresponding comment in the inspection report is:

"Starter drive gear spline inspection. No discrepancies noted. Starter drive seal no leaks noted."

This engine was subjected to a post-rental inspection by Airborne Engines Ltd., Richmond, BC, Canada, and on 16 May 2007 an authorised release certificate was issued at 12029.6 hours TSN, LCF1: 9816; LCF2: 3864; LCF3 2412 and 2636.4 hours TSO.

[3]TBO - time between overhaul

1.6.2.2 Helicopter HB-ZEH

On 16 May 2007 at Hobbs 8730.7 hours:

Engine installed at the time S/N LE81014

"*Performed oil contamination check after ENG.CHIP warning light on. Inspected the eng. Oil filter, replaced the airframe oil filter and performed oil change found several magnetic and non magnetic shining chips. After 15' ground run with no further chip detection released for ferry flight to maintenance base."*

The corresponding comment in the inspection report is:

"…

- *pinion outer liner light wear on inner bearing bore – replaced*
- *starter generator gearshaft drive spline wear – replaced*
- *oil pump drive gearshaft tooth pitting – replaced*

…"

On 23 May 2007 at Hobbs 8732.5 hours, the engine S/N LE81014 was removed and the loaner engine S/N LE07103C was installed in helicopter HB-ZEH[4].The starter generator spline lubrication/inspection was signed-off.

On 28 June 2007 at Hobbs 8978.5 hours, a 100/300-hour inspection was signed-off. The starter generator spline lubrication/inspection was marked "N/A"[5].

For the checks on 14 July 2007 and on 30 July 2007, the maintenance organization stated in a report that it had carried out the starter generator spline lubrication/inspection. This is not evident from the technical documents.

On 30 July 2007 a spectroscopic analysis of the engine oil was performed. The results were, among others: copper 1.0 ppm, iron 1.1 ppm and magnesium 0.2 ppm.

On 19 August 2007 at Hobbs 9267.5 hours, a 100/600-hour inspection was signed-off. The starter generator spline lubrication/inspection was marked "N/A – *see component list, separate tracking"*.

On 24 August 2007 at Hobbs 9281.8 hours the fuel control unit was replaced because of a fault.

On 27 August 2007 "*engine oil leak"* was entered as point 193 in the hold item list and on 28 August 2007 the action "*starter/generator seal changed*" was signed-off in the hold item list. The seal was new.

On 18 September 2007 at Hobbs 9377.1 hours a 100-hour inspection was signed-off and the starter/generator was replaced on the basis of its operating time.

On 27 September 2007 at Hobbs 9420.4 hours a 50-hour inspection was signed-off.

On 29 September 2007 at Hobbs 9432.4hours "*engine oil leak*" was entered as item 195 in the hold item list and on 30 August 2007 the action "starter/generator seal changed" was signed-off in the hold item list. The date is incorrect and

[4]The installation of the engine was not entered in the aircraft maintenance log.
[5]N/A - not applicable

should read 30 September 2007. On this occasion the seal which was removed on 28 August 2007 was re-fitted and the spring was shortened by approx. 8 mm.

On the day of the accident, the AD 2004 - 269 M/R grip inspection SB 109 and AD 1999/643 clutch inspection AFM 3-7 were signed-off.

Some of the maintenance work was poorly and incompletely documented.

1.6.3 Design features and certification basis of helicopter K-1200

The K-1200 helicopter was developed by the Kaman company as a transport helicopter. The rotorcraft flight manual (RFM) states in this regard: *"The K-1200 is built specifically for repetitive lifting operations. The simplified design uses traditional aircraft materials engineered for maximum load bearing strength. The single-seat configuration offers maximum pilot visibility in all directions. Controls and instruments are arranged to be compatible with vertical reference flight requirements. The pilot's seat is a high-energy absorbing unit supported by reinforced structure."*

Type certification according to FAR 21 and FAR 27 was granted by the Federal Aviation Administration (FAA) on 30 August 1994.

1.6.4 Engine

1.6.4.1 Description of the system

The K-MAX helicopter is equipped with a "Honeywell T5317A-1" twin-shaft turbine engine. The engine consists of a two-stage free power turbine (N2) and a two-stage gas producer turbine (N1) which drives a combined axial and centrifugal compressor.

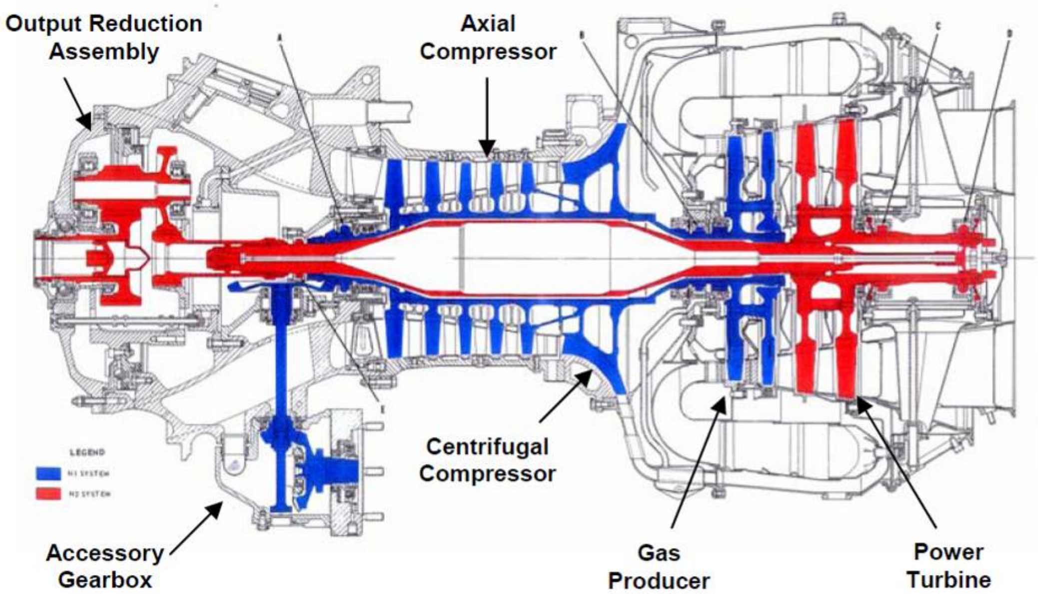


Figure 1 – Cross-sectional view of a T53 engine

N1 is controlled by the pilot's twist-grip throttle on the collective via various control linkages to the fuel control unit – FCU.

A constant N2 RPM is achieved by means of a varying N1 RPM depending on the load.

1.6.4.2 Description and function of the N1 accessory drive gearbox

The N1 accessory drive gearbox is mounted at the six o'clock position of the air inlet housing. It is driven via the accessory drive shaft, which connects the N1 stage of the engine via the outer pinion gearshaft assembly to the accessory drive gear assembly (see Figures 1 and 2).

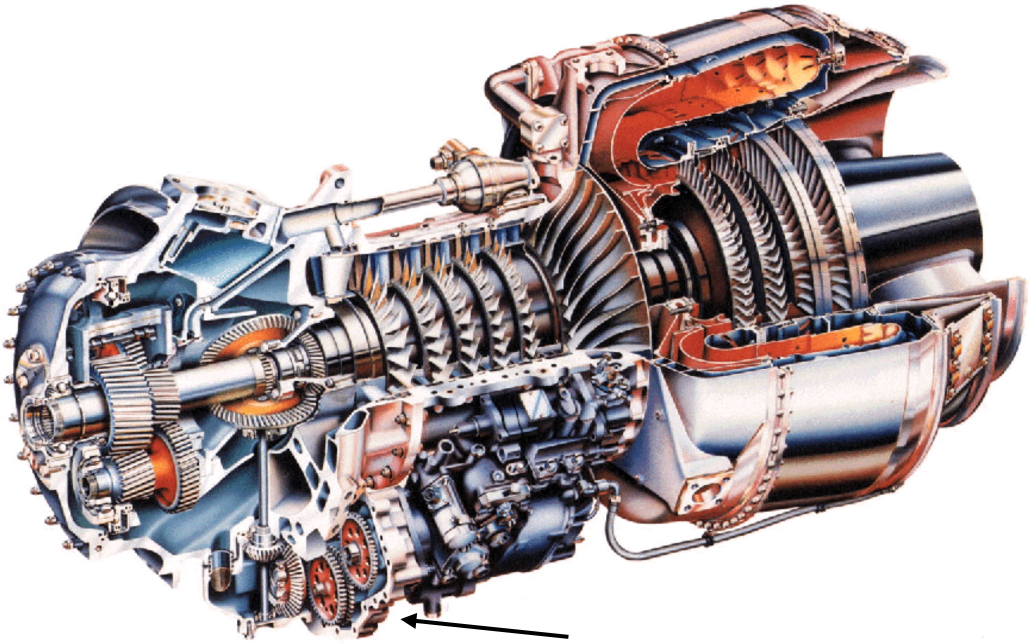


Figure 2 – Depiction of the T53 engine and the position of the N1 accessory drive gearbox(see arrow)

The oil pump, fuel control unit, gas producer tachometer and starter/generator are connected to the N1accessory drive gearbox. These accessory drives are driven by the accessory drive gear assembly.

At the bottom of the housing, a magnetic chip detector is installed.

A detailed description of the components is provided in the Annex.

1.6.5 Information in the Rotorcraft Flight Manual

1.6.5.1 General information on emergency procedures:

“General

The procedures outlined in this section deal with the common types of emergencies; however, the actions taken in each actual emergency must relate to the complete situation. Extraordinary circumstances such as compound emergencies may require departures from the normal corrective procedures used for any specific emergency.

Throughout this section, the terms “land immediately,” “land as soon as possible,” and “land as soon as practical” are used to reflect the degree of urgency with which a landing must be made.

1. *LAND IMMEDIATELY – Self explanatory.*
2. *LAND AS SOON AS POSSIBLE – Land at the nearest site at which a safe landing can be made.*
3. *LAND AS SOON AS PRACTICAL – Extended flight is not recommended. The landing site and duration of the flight are at the discretion of the pilot.*

Many of the malfunctions described in this section will be indicated by the lighting of warning or caution lights, the master caution light, and in some cases, a tone in the headset. Whenever a caution light goes on, the RESET pushbutton should be depressed to turn the master caution light off and reset it for another condition. An audio tone can be eliminated and reset for another condition by pressing the RESET pushbutton.

Any unusual change in aircraft noise, vibrations, or flight characteristics should be investigated immediately to determine an appropriate course of action. If the cause and procedure are not immediately obvious, a power–on landing should be made as soon as possible. External load operations should be discontinued, including jettison as required, until the aircraft has been thoroughly inspected and returned to normal service."

1.6.5.2 Cockpit indicating lights

"The following tables provide cockpit indicating light definitions and scenarios:

1. Cockpit master warning and caution lights – Table 4–1.

2. Cockpit indicating lights requiring landing as soon as possible – Table 4–2.

3. Cockpit indicating lights requiring landing as soon as practical – Table 4–3.

4. Cockpit indicating lights requiring immediate pilot action – Table 4–4.

5. Cockpit advisory lights – Table 4–5.

(….)

Table 4–2: Cockpit indicating lights requiring landing as soon as possible

Legend	*Meaning*
XMSN CHIP	*Possible transmission deterioration. Press FUZZ BURN. If light continues, land and inspect.*
XMSN PRESS	*Low transmission oil pressure. Land and inspect.*
XMSN TEMP	*High transmission oil temperature. Reduce transmission load; land and inspect.*
XMSN BYPASS	*Impending oil filter bypass. Land and inspect.*
XMSN LOW	*Transmission oil level low. Land and inspect.*
ENG CHIP	*Possible engine deterioration. Press FUZZ BURN. If light continues, land and inspect.*
ENG PRESS	*Low engine oil pressure. Land and inspect.*

(….)"

1.6.5.3 Chip Detection System

"Chip detection systems are installed in the engine and transmission lubricating systems to provide early detection and a visual warning of possible component deterioration/failure.

The engine oil system employs a quick–disconnect type chip detector at the base of the engine oil tank and a threaded type chip detector on the lower part of the engine. Detection of metal particles by either of these detectors results in illumination of the MAST CAUT and ENG CHIP warning lights.

The transmission oil system employs a quick–disconnect type chip detector at the base of the transmission oil tank and two quick–disconnect type chip detectors located on the left and right sumps of the transmission. Detection of metal particles by any of the three detectors will result in illumination of the MAST CAUT and XMSN CHIP warning lights.

A chip burn–off system is installed to remove fuzz or small ferrous particles caused by normal wear that have caused illumination of the chip warning lights. A momentary–type switch labelled FUZZ BURN is located on the lower left part of the main instrument panel to activate this system. When the fuzz–burn switch is depressed a short–duration pulse of current is provided to all chip detectors. This will normally cause the MAST CAUT and appropriate CHIP WARNING lights to extinguish if the fault was only fuzz or small ferrous particles caused by normal wear."

1.6.5.4 Height-Velocity Diagram

"The Height–Velocity diagram (….) uses factors of airspeed and height above ground to represent areas where aircraft damage or injury may occur in the event that an autorotation has to be accomplished. The clear areas shown represent regions where extended operations should be avoided. They do not represent limitations. The aircraft gross weight used to define the diagram was 6500 lbs."

The corresponding diagram is shown in Annex 4.

1.6.6 Information in the engine maintenance manual

1.6.6.1 Procedures in the event of lubrication oil contamination

The engine maintenance manual, section 79-30-01, describes the following with regard to inspection of the chip detector:

„*Inspection/Check*

A. *Inspect chip detector for build-up of metallic particles.*

   (1) *A small amount of metallic powder is normal and acceptable.*

   (2) *Course chips or an excessive amount of metallic powder are symptoms of possible failure. This condition requires a lubrication system contamination trouble shooting procedure (72-00-00[6]).*

B. *Inspect chip detector and threaded hole in gearbox for damaged threads. Replace chip detector if stripped or damaged beyond repair."*

[6]Maintenance Manual T5313B and T5317 Series 72-00-00 Page 120 -122 (see Annex 3)

1.7 Meteorological information

1.7.1 General information

The information in sections 1.7.2 and 1.7.3 was provided by MeteoSwiss.

The information in section 1.7.5 is based on eyewitness observations.

1.7.2 General meteorological situation

A zone of high pressure centred over central Europe was moving slowly eastward. In the process, somewhat milder but more humid air was being conveyed by a high-altitude south-westerly airflow towards the area of the Alps.

1.7.3 Weather at the time and location of the accident

The following information on the weather at the time and location of the accident is based on a spatial and chronological interpolation of the observations of several weather stations.

Weather/clouds	*5/8 at approx. 30 000 ft AMSL (Cirrus spissatus)*
Visibility	*Approx. 25 km*
Wind	*South-west at 2-4 kt*
Temperature/dewpoint	*14 °C/08 °C*
Atmospheric pressure	*QNH LSZH 1021 hPa; LSZC 1021 hPa; LSZA 1021 hPa*
Hazards	*None detectable*

1.7.4 Astronomical information

Position of the sun	*Azimuth:* 166 °	*Elevation:* 39 °
Lighting conditions	daylight	

1.7.5 Weather according to eyewitness reports

Both the flight assistant on the ground and the aircraft mechanic confirmed very good visibility, scattered cloud and a light wind.

1.8 Aids to navigation

Not applicable.

1.9 Communication

Radio communications between the pilot and the flight assistant on the ground took place in an orderly fashion and without difficulties up to the time of the accident.

1.10 Aerodrome information

Not applicable.

1.11 Flight recorders

The helicopter was fitted neither with a flight data recorder nor a cockpit voice recorder. These were not prescribed.

The exceedance flag was black for torque, NG, EGT and load indicators, i.e. in a normal state.

1.12 Wreckage and impact information

1.12.1 Accident site

The site of the accident was in hilly, sparsely wooded and steep terrain at approx. 1320 m AMSL (see figures 3 and 4).

Figure 3 – Aerial photograph of the accident site with wreckage and load pick-up area

1.12.2 Impact

The impact of the helicopter was violent. This is evident from the deformation of the robust frontal structure. Part of the left section of the main gear dug into the earth and stabilised the wreckage. The rotor blades were destroyed on impact with the ground.

Figure 4– Final position of the wreckage

1.12.3 Wreckage

1.12.3.1 General findings

The lap and shoulder belts were worn and withstood the stress.

A general visual examination of the helicopter gave no indications of pre-existing defects.

The following findings were made on the wreckage:

Battery	OFF
Fuel/oil switch	ON
Generator switch	ON
Particle separator switch	OFF
Emergency governor guard down	OFF

- The twist grip was in the FLY detent position.

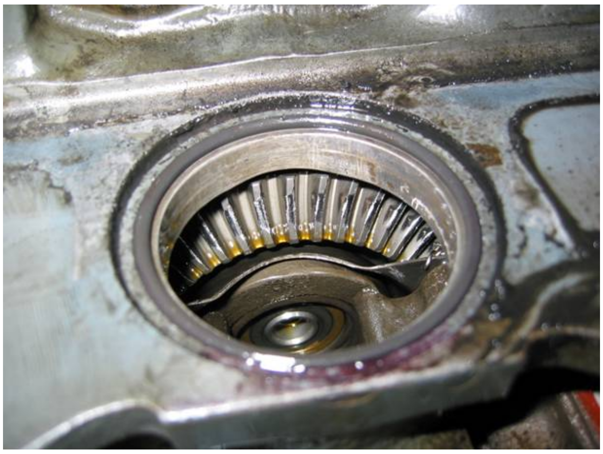
- The KAflex drive shaft coupling and the clutch assembly were intact.

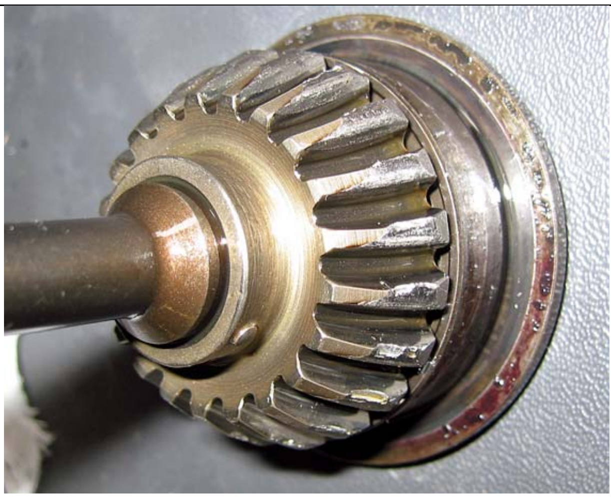
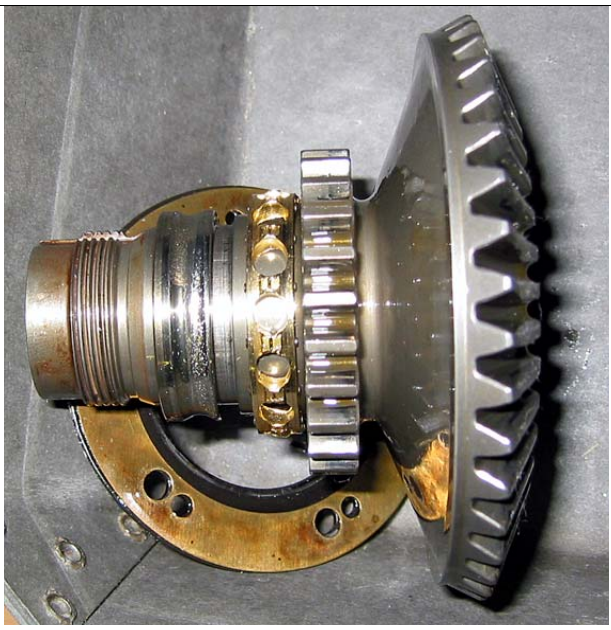
1.12.3.2 Initial examinations of the engine

The engine was removed from the helicopter and initial examinations gave the following findings:

- The power turbine could be rotated freely by hand.

- The N1 accessory drive gearbox was removed. It was found that the accessory drives could not be driven by turning the accessory drive shaft. In particular, axial play in the accessory drive gear assembly was found.

<table>
<tr><td>
Figure 5 – Engine chip detector with chips</td><td>The engine chip detector was removed and revealed a large quantity of metallic chips.</td></tr>
<tr><td>
Figure 6 – Starter/generator drive pad on the N1 accessory drive gearbox</td><td>The internal splines of the starter/generator drive in the accessory drive gearbox exhibited wear and traces of oil.</td></tr>
<tr><td>
Figure 7 – View of damaged accessory drive gear assembly</td><td>After removal of the outer pinion gearshaft assembly, the accessory drive gear assembly was visible. The bevel gear is severely damaged and shows plastic deformation.</td></tr>
</table>

 **Figure 8** – Outer pinion gearshaft assembly (counterpart to Figure 7)	The bevel pinion of the outer pinion gearshaft assembly exhibited pronounced damage and plastic deformation.
 **Figure 9**–Bevel gear accessory drive gear assembly in disassembled state with damaged bearing and grooves on the inner race of the bearing	After removal of the accessory drive gear assembly from the accessory drive gearbox, the damaged ball bearing (P/N 91547-SOCN-2-300-013-03 CDA-99193; S/N 021991421878) was visible. Evident are the grooves and elongated, oval boreholes in the bearing cage.
 **Figure10** – Outer race of the bearing with grooves	The outer bearing race also has grooves.

1.13 Medical and pathological information

The pilot suffered minor injuries to his upper and lower extremities.

1.14 Fire

Fire did not break out.

1.15 Survival aspects

The accident was survivable thanks to the robust construction of the helicopter.

1.16 Tests and research

1.16.1 Forensic investigations

The forensic investigation of the instruments and displays yielded the following results:

- The gas producer RPM (N_G) indicator was slightly above 30%.
- The ammeter exhibited a smeared mark from approx. 75 A down to just below 0 A.
- The engine oil pressure gauge exhibited a smeared mark from approximately 40 psi to just below 0.
- The main gearbox oil pressure indicator exhibited a mark at approx. 31 psi.
- The "MASTER CAUTION" and "MAST CAUT" warning lamps were activated.
- On the caution panel, the "XMSN PRESS" and "GENERATOR" lamps were activated. The coiled filaments of the "ENG PRESS" warning light were still located in the guides of the filament supports, but are changed slightly compared to new lamps. The "ENG CHIP" lamp showed no marks.

1.16.2 Dismantling of the engine for inspection

Due to the large amount of metal chips found in the N1 accessory drive gearbox, the engine was disassembled for inspection and examined.

“Summary of inspection:

The engine was disassembled into its main subassemblies and visually inspected in “dirty condition”. The oil wetted parts of the engine were in a good and healthy condition. Neither in the reduction gearbox and the front bearing housing nor in the hot section bearing areas was any abnormal wear or damage discovered. The main bearings and the reduction gearbox gears and bearings were found without visual damage. No oil leakages could be recognized at any sealing. Several parts in the hot section were severely burned and damaged. Particularly the combustion chamber, the 1st stage gas producer nozzle, 1st stage turbine blades and 2nd stage gas producer nozzle were exposed to excessive heat. Although the above mentioned hot section components were severely damaged all those damages are not uncommon for a T53-17A1 engine used in a K-MAX operation. The worn combustion chamber deflector flange as well as the worn combustion chamber liner flange indicate (or may even have caused) an increased level of engine vibrations. The type of wear at these parts is known but not very common.

(….)

The test assembly of the accessory drive gearbox was done with the mixture of new and original parts. A statement regarding the correct shimming during last repair or overhaul is not possible."

1.16.3 Examination of the FCU

A functional test of the fuel control unit (FCU p/n: 1-170-240-93; S/N: 32AS11619) and the overspeed governor (p/n: 1-160-850-25; S/N: 9A0Y1833) was carried out.

"The test result can be summarized as follows. The "as received" FCU settings were out of limits i.a.w. the valid Overhaul Manual. The discovered discrepancies are typical for installed FCU's and related to minor adjustments that have to be done during the engine test or after engine installation into the helicopter."

1.16.4 Examination of the oil pump

The oil pump installed on the engine of the helicopter involved in the accident was a Lear Romec RG17350D vane pump.

First, the static breakaway torque and the un-loaded torque were measured.

The pump was then disassembled and examined for wear, internal damage and residues or foreign objects.

Findings:

- The measured values were consistently below the limits.
- Neither wear nor residues were detected.

1.16.5 Examination of the starter/generator

The starter/generator was examined after the accident. The following findings were made:

- The concentricity of the drive shaft was 0.05 mm.
- The test as a generator was successful and showed that the unit runs very quietly.
- The unit was internally covered with oil and was in a functional condition.

The input/output end of the starter/generator drive shaft was measured. The splined shaft exhibited no wear; the measured values were within the permissible limits.

1.16.6 Examination of components of the N1 accessory drive gearbox

The damaged bevel pinion, bevel gear and the ball bearing of the accessory drive gearbox N1 were examined in detail. Those parts which are important for mounting the damaged components were also examined.

1.16.6.1 Conformity of the components

On the damaged lower bevel gear P/N 1-080-310-01 the diameters of the bearing seat and the intermediate shoulder distance were measured. The gearbox housing in the area of the bevel gear bearing, the shimming of the ball bearing and the width of the bearing races were also measured. Taking into account the maximum permissible dimensional variation according to the drawing with regard to the outer and inner race of the bearing, it can be ruled out that the bearing of the lower bevel gear shaft was fitted axially braced.

All the measured dimensions are in conformity with the drawing. Because of the damage to the teeth it was not possible to determine whether the tooth contact pattern was correct before the accident.

The material composition of the bevel gear P/N 1-080-310-01, bevel pinion P/N 1-080-320-01 and ball bearing P/N 2-300-013.03 were examined in detail. According to the material analysis, the material of the bevel pinion can be classified as A304 (9310 H) ASTM, and that of the bevel gear as 6263 H (AMS). Both are high-performance steels which are often used for the production of gears.

From the examination of the material of the inner race, the outer race, the balls and the cage of the damaged bearing, it is evident that all these components are composed of standard material of the appropriate quality. The hardness measurements on the inner race, outer race and balls yielded values of 61 HRC to 63 HRC. These values are also in conformity.

The chips found on the chip detector in the N1 accessory drive gearbox and in the oil sump were also examined. The chips consist of the same material as the gears – so they are presumably fragments of these gears.

1.16.6.2 Damage

On the bevel pinion, it was primarily the teeth which were damaged. The material of the tooth tip exhibited plastic deformation across its entirety and had partially broken off; the base and the flanks of the teeth in the area of the root were not damaged.

No damage could be found on the bevel pinion shaft bearing.

On the bevel gear, the teeth and the internal splines on the output side of the shaft – which transfers torque to the starter/generator – were damaged.

The smaller of the two bearings by which the bevel gear shaft is supported – a roller bearing which does not carry axial loads – did not exhibit any damage. The larger bearing – a ball bearing which supports the bevel gear shaft in the radial and axial direction – was severely damaged.

The most pronounced damage was exhibited by the raceway of the inner race of the bearing, the balls and the cage. The wear of the raceway of the outer race was less pronounced. The SEM[7] examination of the ball bearing raceways and the balls revealed evidence of pitting[8] and fatigue, i.e. the damage and wear on the ball bearing is due to fatigue.

1.17 Organisational and management information

1.17.1 The operator – Eagle Helicopter AG

Eagle Helicopter AG is an aerial work operator and employed some 30 employees. The company was active in the areas of logging, specialist logging, construction and transport. A Kaman K-1200 and a Eurocopter AS350 were used for these purposes.

---

[7] SEM - scanning electron microscope

[8] pitting - break-out of material and micro-fissures near to the surface

1.17.2 Maintenance Organization – RUAG Aviation

RUAG Aviation is a company in the aviation industry based in Emmen, with ten other locations in Switzerland and two in Germany. Its main activities include the maintenance and modification of aircraft, helicopters, drones, guided missiles and air defence systems.

1.17.3 Organisation of the maintenance of helicopter HB-ZEH

Since the operator did not have a JAR-145 Maintenance Organization for the type K-1200 helicopter, a corresponding contract was agreed with RUAG Aviation.

The aircraft mechanic referred to in section 1.5.2 was listed in the MOE[9] of RUAG Aviation.

[9] MOE - maintenance organisation exposition

2 Analysis

2.1 Technical aspects

2.1.1 Damage to the teeth of the bevel gear

As a result of the damage to the ball bearing the bevel gear shaft was no longer supported axially and was displaced axially as force was transferred by the bevel pinion. As a result of this displacement, there was a reduction in the tooth engagement, plastic deformation of the tips of the teeth and broken-off material particals. The progressive wear of the ball bearing race meant that the two gears were no longer engaged, resulting in a loss of function of the FCU and shut-off of the engine; this subsequently led to the helicopter accident.

2.1.2 Bearing wear

The bearing wear which was found is a classic example of fatigue of the races and balls as a result of pitting – a form of fatigue wear.

Such wear is typical when a bearing is at the end of its life. This is affected by the operating conditions, such as for example the load on the bearing, the lubricant, the amount of contaminants in the lubricant, the bearing material, etc.

According to the results of the investigation, it must be assumed that the load on the bearing was too high and/or the lubricant had an excessively high amount of foreign particles.

It is evident from the maintenance records that 1480 operating hours before the accident, the N1 accessory drive gearbox was repaired, and the ball bearing as well as the internally splined bevel gear shaft were fitted as new parts. This took place 1865 operating hours after an overhaul of the N1 accessory drive gearbox. This means that, the installed ball bearing was well short of the required service life of 5000 hours.

Any existing minor concentricity misalignment in the splined shaft end with respect to the centring spigot assembly of the starter/generator will cause a considerable increase in the load on the ball bearing of the bevel gear, which could lead to premature failure of the bearing.

It could not be determined whether the starter/generator installed until 64 hours before the accident occured had a concentricity misalignment.

2.1.2.1 Bevel gear shaft bearings

The bevel gear shaft is retained by a roller bearing and a ball bearing. The roller bearing is subjected to radial loading and the ball bearing is subjected to a radial and an axial load. The ball bearing is a single-row radial bearing which according to its designation is designed primarily for radial loads. Axial loads on this type of bearing are permissible to a limited extent. From the available data, it was not possible to assess whether the bevel gear shaft ball bearing was sufficiently dimensioned to cope with the service loads.

2.1.3 Internal spline

The internal spline of the bevel gear shaft was worn. The transfer of power to and from the starter/generator was assured, despite the wear.

From the type of wear it can be concluded that it developed over a fairly long period. It must remain an open question as to whether the cause of this wear was a concentricity misalignment of the starter/generator or due to the bearing failure.

2.1.4 Accessory units

All of the accessory units driven by the accessory drive gearbox were inspected and their serviceability was tested. No anomalies or malfunctions were found.

2.1.5 Maintenance

The engine manufacturer prescribes the procedure described in Annex 3 if chips are found. This procedure was not complied with.

According to the information from the maintenance organization, since the installation of the loaner engine 708.4 hours before the accident the internal spline teeth were visually inspected for wear several times based on the maintenance manuals – the last time 64 hours before the accident. On the occasion of the engine and starter/generator replacement and the two interventions in connection with the identified oil losses, the area would have been accessible for a more accurate assessment of the internal splines. The maintenance organization did not find anything out of the ordinary when this work was performed.

It must be mentioned that the performance of this inspection is extremely problematic and it is only possible to determine and quantify any wear with great difficulty.

Although the internal state of a mechanical assembly can be assessed by periodically carrying out a spectrometric oil analysis, no analysis was carried out since 30 July 2007.

The helicopter was often maintained in the field. This may be one of the reasons why the technical documentation was in part incomplete and inaccurately maintained.

2.2 Human and operational aspects

During more than four months preceding the accident the ENG CHIP warning lamp in the cockpit illuminated repeatedly and metallic chips were found in the engine of helicopter HB-ZEH. This situation did not change, even after the installation of a loaner engine on 23 May 2007.

The Rotorcraft Flight Manual describes the procedure in the event of an engine chip detector warning, which indicates to the pilot that there are metallic deposits in the oil circuit:

1. Press the FUZZ BURN button.
2. If the warning light stays on, land at the nearest safe place and examine the engine.

According to the pilot's statement, it was possible to extinguish the warning light in an estimated 95% of cases by applying the FUZZ BURN procedure. The Rotorcraft Flight Manual unfortunately does not describe any measure in the event of a recurrent warning. It must be assumed however, that the FUZZ BURN system was not intended and installed for continuous use.

The recurring loss of oil in the immediate vicinity of the worn bevel gear shaft bearing, the abnormal noise during the engine starting procedure and the repeated illumination of the ENG CHIP warning lamp were indicators of a mechanical problem in the N1 accessory drive gearbox. Insufficient attention was paid to these indications. Instead, top priority was placed on the fulfilment of the work assignment. The evident indications of a defect in the engine were not appropriately addressed, apparently as a result of previous experience with regard to CHIP ENG warnings. This appears to be incomprehensible, particularly in the light of the exposed situation of the helicopter during the cargo flight.

This becomes clearly evident when the main envelope of the helicopter's operation on cargo flights is compared with the H/V diagram (Annex). The operation of the helicopter on cargo flights is located almost exclusively within the zones to be avoided, shown shaded in white on the graph.

An engine failure in such a flight phase makes it impossible to carry out a successful autorotation and inevitably leads to serious consequences.

3 Conclusions

3.1 Findings

3.1.1 Technical aspects

- The aircraft was licensed for VFR flight.
- Both the mass and centre of gravity of the rotorcraft at the time of the accident were within the permitted limits according to the RFM.
- The investigation produced indications of pre-existing technical faults which caused the incident.
- On 18 September 2007 at Hobbs 9377.1 hours, a 100-hour inspection was signed-off and the starter/generator was replaced on the basis of its operating time.
- The last condition check by the FOCA took place on 27 December 2006.
- On 23 May 2007 at Hobbs 8732.5 hours, engine S/N LE81014 was removed and the loaner engine S/N LE07103C was installed in helicopter HB-ZEH. The starter generator spline lubrication/inspection was signed-off.
- For more than the four months preceding the accident, chips were repeatedly found in the engine and were also indicated to the pilot by means of the ENG CHIP warning lamp in the cockpit. The pilot repeatedly applied the FUZZ BURN procedure.
- After the accident it was possible to rotate the power turbine freely by hand.
- The N1 accessory drive gearbox was disassembled. Subsequently it was found that the accessory gears could not be driven by rotating the accessory drive shaft. In particular, axial play was detected in the accessory drive gear assembly.
- On the bevel pinion, it was primarily the teeth which were damaged. The material of the tooth tip exhibited plastic deformation across their entirety and had partially broken off; the base and the flanks of the teeth in the area of the root were not damaged.
- On the bevel gear, the teeth and the internal splines on the output side of the shaft – which transfers power to the starter/generator – were damaged.
- The smaller of the two bearings which support the bevel gear shaft– a roller bearing with no load transfer in the axial direction – did not exhibit any damage.
- The larger bevel gear shaft bearing – a ball bearing which transfers loads in the radial and axial direction – was severely damaged. The most pronounced damage was exhibited by the raceway of the inner bearing race, the balls and the cage. The wear of raceway of the outer race was less pronounced. The examination of the raceways and the balls indicated pitting and fatigue, i.e. the wear on the ball bearing is attributable to fatigue.
- 1480 operating hours before the accident, the N1 accessory drive gearbox was repaired, and the ball bearing as well as the internally splined bevel gear shaft were fitted as new parts. This took place 1865 operating hours after an overhaul of the N1 accessory drive gearbox. This means that the installed ball bearing was well short of the required service life of 5000 hours.

- The recurring loss of oil in the immediate vicinity of the worn bevel gear shaft bearing, the abnormal noise during the engine starting procedure and the repeated illumination of the ENG CHIP warning lamp were indicators of a mechanical problem in the N1 accessory drive gearbox.
- The evident indications of a defect in the engine were not appropriately addressed, apparently as a result of previous experience with regard to CHIP ENG warnings.
- The procedure prescribed by the engine manufacturer in the event that chips are found was not observed.
- The maintenance work was in part inaccurately and incompletely documented.

3.1.2 Crew

- The pilot held the necessary licences for the flight.
- The lap and shoulder belts were worn and withstood the stress.
- There are no indications of the pilot suffering health problems during the flight involved in the accident.

3.1.3 History of the flight

- During the starting procedure before the flight involved in the accident, the pilot and the technical director noticed an anomaly in the form of an unknown noise.
- During engine acceleration up to "Flight" RPM, the ENG CHIP lamp illuminated. The chip detector was then removed and checked by the technical director. The pilot stated that after this intervention the ENG CHIP warning light illuminated once or twice and that he was able to extinguish it by applying the FUZZ BURN procedure.
- After consultation with the technical director, the pilot decided to carry out the envisaged working flight.
- Over the next 30 minutes timber was transported. During this time, the pilot twice noticed that the ENG CHIP warning lamp illuminated. It was possible to clear the two warnings by applying the FUZZ BURN procedure.
- During the last approach in the direction of the timber unloading area, the pilot noticed that the ENG CHIP warning lamp illuminated again. He set down the load and flew back towards the pick-up point.
- In the approach to the pick-up point, a distinct loss of RPM was noticed.
- The pilot activated the longline emergency release in order to make an emergency landing in the direction of flight.
- The helicopter collided with the terrain approx. 100 metres west of the pick-up point on a sloping hillside and was destroyed.

3.1.4 General conditions

- The emergency procedure if the ENG CHIP warning occurs as defined in the Rotorcraft Flight Manual reads:

  "*Possible engine deterioration. Press FUZZ BURN. If light continues, land and inspect.”*

3.2 Causes

The accident is attributable to a failure of the engine at an altitude from which a successful autorotation was not possible.

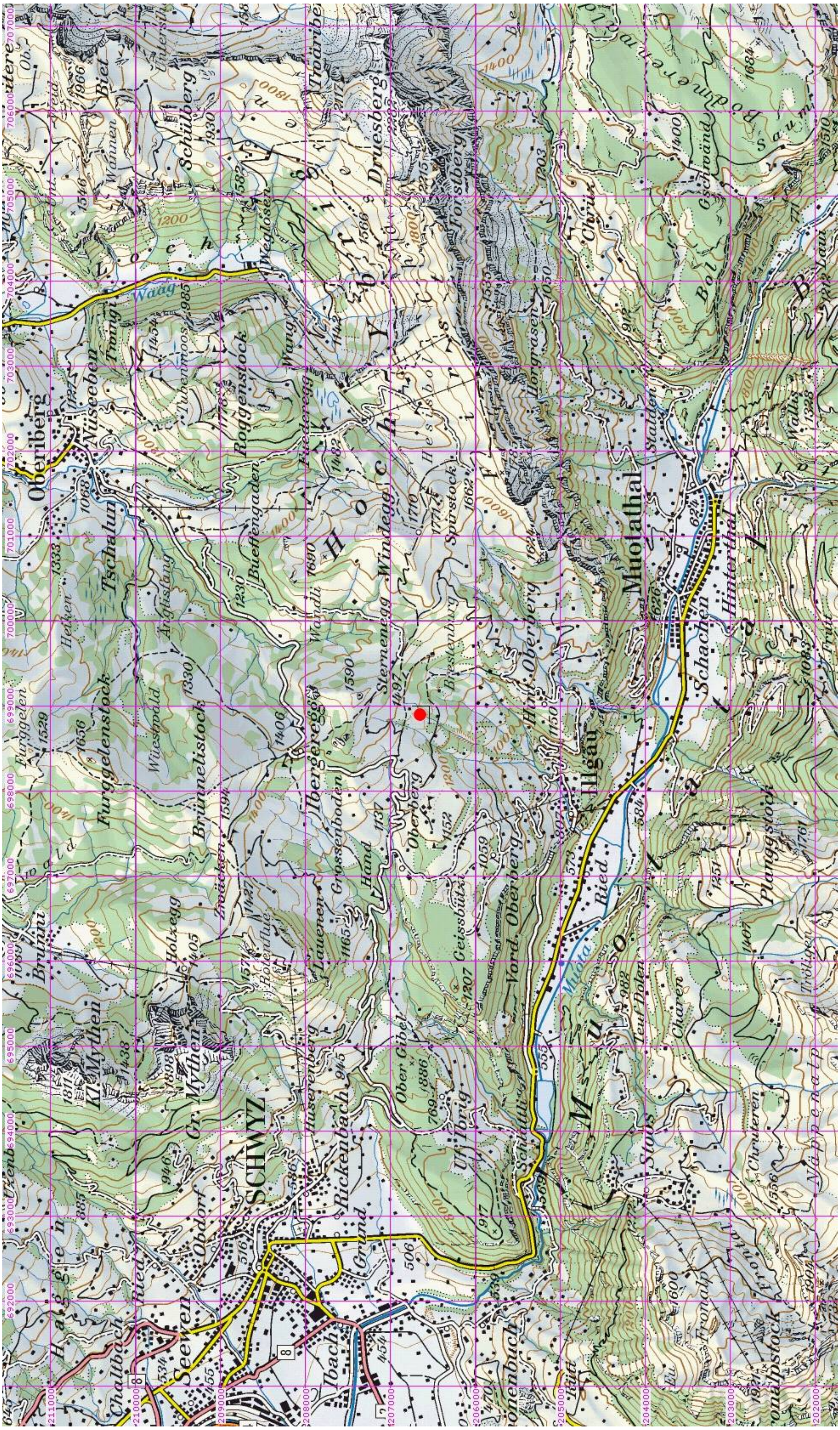
The clear indications of a fault in the engine were not appropriately addressed.

Payerne, 3 October 2012 Swiss Accident Investigation Board

This final report was approved by the management of the Swiss Accident Investigation Board SAIB (Art. 3 para. 4g of the Ordinance on the Organisation of the Swiss Accident Investigation Board of 23 March 2011).

Berne, 25 September 2012

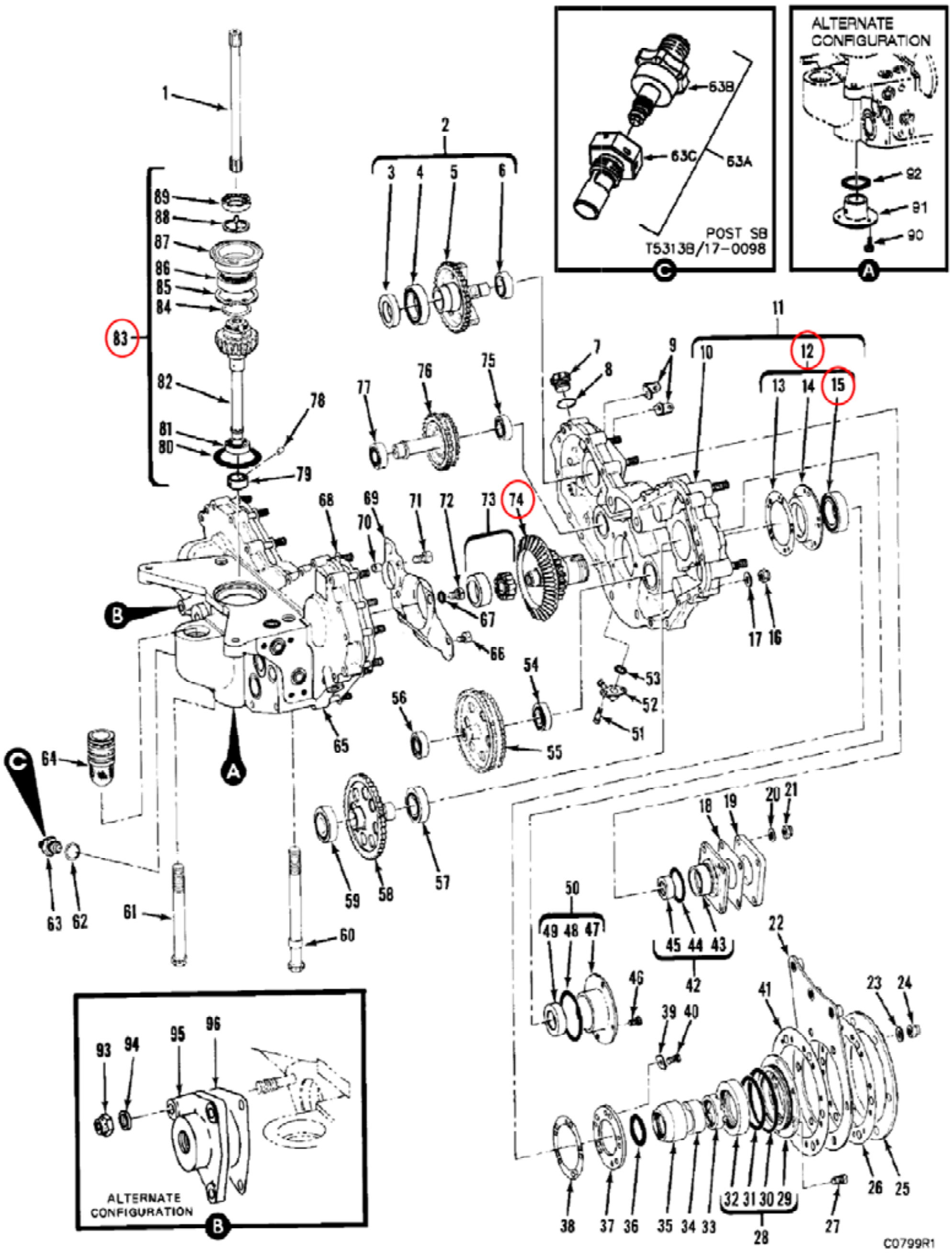
Annex 1



Annex 2 – Overhaul Manual 72-60-01 Accessory Drive Gearbox

Honeywell

OVERHAUL MANUAL
T5313B AND T5317 SERIES



Accessory Drive Gearbox
Figure 101

72-60-01

Page 102
Oct 1/05

KEY TO FIGURE 101

1. ACCESSORY DRIVE SHAFT
2. GEARSHAFT AND BEARING ASSEMBLY
3. PLAIN ENCASED SEAL
4. BALL BEARING
5. TACHOMETER DRIVE GEARSHAFT ASSEMBLY
6. BALL BEARING
7. STRAIGHT THREAD PLUG
8. PREFORMED PACKING
9. BRACKET
10. ACCESSORY GEARBOX COVER ASSEMBLY
11. GEARBOX COVER ASSEMBLY
12. THRUST BEARING LINER ASSEMBLY
13. THRUST BEARING SHIM
14. THRUST BEARING LINER
15. BALL BEARING
16. SELF LOCKING NUT
17. FLAT WASHER
18. ENGINE ACCESSORY DRIVE GASKET
19. ENGINE ACCESSORY DRIVE COVER
20. FLAT WASHER
21. SELF LOCKING NUT
22. ACCESSORY GEARBOX SUPPORT
23. FLAT WASHER
24. SELF LOCKING NUT
25. ACCESSORY DRIVE COVER
26. STARTER PAD GASKET
27. SOCKET HEAD BOLT
28. SEAL AND HOUSING ASSEMBLY
29. OIL SEAL HOUSING
30. PREFORMED PACKING
31. PREFORMED PACKING
32. PLAIN ENCASED SEAL
33. SPANNER NUT
34. LOCK CUP
35. SEAL SPACER
36. PREFORMED PACKING
37. RETAINING PLATE
38. THRUST BEARING SHIM
39. TABWASHER
40. HEX HEAD BOLT
41. STARTER PAD GASKET
42. TACHOMETER DRIVE FLANGE AND SEAL ASSEMBLY
43. TACHOMETER DRIVE BEARING RETAINER
44. PREFORMED PACKING
45. PLAIN ENCASED SEAL
46. DRILLED HEX HEAD BOLT
47. FUEL CONTROL DRIVE LINER
48. PREFORMED PACKING
49. PLAIN ENCASED SEAL
50. SEAL AND LINER ASSEMBLY
51. SOCKET HEAD CAP SCREW
52. FUEL OVERFLOW CONNECTOR
53. PREFORMED PACKING
54. BALL BEARING
55. OIL PUMP DRIVE GEARSHAFT ASSEMBLY
56. BALL BEARING
57. BALL BEARING
58. FUEL CONTROL DRIVE GEARSHAFT AS-SEMBLY
59. BALL BEARING
60. SHOULDERED BOLT
61. DRILLED HEX HEAD BOLT
62. PREFORMED PACKING
63. CHIP DETECTOR (PRE SB T5313B/17-0098)

63A. CHIP DETECTOR ASSY (POST SB T5313B/17-0098)

63B. PROBE

63C. VALVE

64. OIL STRAINER ASSEMBLY
65. ACCESSORY GEARBOX HOUSING AS-SEMBLY
66. CAP SCREW
67. PREFORMED PACKING
68. COVER GASKET
69. ACCESSORY GEARBOX BAFFLE
70. SLEEVE SPACER
71. DRILLED SOCKETHEAD BOLT
72. SCREW
73. ROLLER BEARING
74. ACCESSORY DRIVE GEAR ASSEMBLY
75. BALL BEARING
76. OIL AIR SEPARATOR DRIVE GEARSHAFT ASSEMBLY
77. BALL BEARING
78. LOCKPIN
79. LINER
80. PREFORMED PACKING
81. BALL BEARING
82. OUTER PINION GEARSHAFT ASSEMBLY
83. PINION GEARSHAFT AND BEARING AS-SEMBLY
84. PINION SHIM
85. RETAINING RING
86. BALL BEARING
87. OUTER PINION LINER
88. BEARING KEY WASHER
89. PLAIN ROUND NUT
90. BOLT*
91. RADIAL BEARING HOUSING*
92. PACKING*
93. NUT**
94. WASHER**
95. PAD COVER**
96. GASKET**

* Engines with radial housing

** Alternate configuration

Annex 3 – Maintenance Manual T5313B and T5317 Series 72-00-00 Page 120 -122

Honeywell MAINTENANCE MANUAL
T5313B AND T5317 SERIES

C. Lubrication System Contamination Trouble Shooting Procedure

NOTE: It is not unusual for a new engine to generate some small chips during the first 5 to 10 hours of operation. Fine particles generally indicate even, although possibly excessive, wear. Pieces of flat metal can be from lockcups, baffles or cotter pins. Pieces of very hard steel can be from chipped splines or gears. Slivers of metal may be machining chips from new parts not thoroughly cleaned before installation. Magnesium is not normally in contact with moving parts. Chips of magnesium indicate an unusual contact between parts. Analysis of steel particles can reveal definite areas that may be suspected such as shafts, gears, and bearings. Bronze material usually comes from bearing cages. Silver is used as plating material for certain bearing cages. Chrome is used as plating material on shafts, etc, and also is present in certain steels.

(1) Whenever an oil contamination inspection has revealed a continuance or an excessive amount of chips in the oil filter or on the chip detector, but output reduction gear carrier and gearbox assembly is free to move and emits no unusual noises, proceed as follows:

WARNING: PROLONGED CONTACT WITH LUBRICATING OIL MAY CAUSE A SKIN RASH. THOSE AREAS OF SKIN AND CLOTHING THAT MAY COME IN CONTACT WITH LUBRICATING OIL SHOULD BE THOROUGHLY WASHED IMMEDIATELY. SATURATED CLOTHING SHOULD BE REMOVED IMMEDIATELY. AREAS IN WHICH LUBRICATING OIL IS USED SHOULD BE ADEQUATELY VENTILATED TO KEEP MIST AND FUMES TO A MINIMUM.

CAUTION: LUBRICATING OIL MAY SOFTEN PAINT UPON CONTACT. IF LUBRICATING OIL IS SPILLED ON PAINTED SURFACES, THESE SURFACES SHOULD BE THOROUGHLY WASHED.

(a) Check main oil filter elements for chip accumulation which could have placed the filter into bypass. Remove chips and retain for analysis. Clean filter with dry cleaning solvent (62, Table 203). (Refer to SPM, SP C203, 72–15–03.) Install filter (79–20–03).

(b) Remove and inspect No. 2 bearing strainer and No. 3 and 4 bearing strainer bore for metal chips. If chips are present, remove and inspect three reduction gear oil transfer tube strainers (72–10–01) and overspeed governor and tachometer drive oil throttle strainer (72–60–02). Forward engine to overhaul facility if metal chips have clogged more than one–third of flow area of any one of previously mentioned strainers. If amount of chips is not excessive, clean and reinstall strainers and proceed to step (3).

(c) Presence of chips in previously mentioned strainers indicates that bypass of oil filter has occurred. Replace oil filter (79–20–03).

(d) Drain oil from accessory drive gearbox, aircraft oil tank and oil cooler.

(e) Remove any metal chips from chip detectors. Clean chip detectors with dry cleaning solvent (62, Table 203). (Refer to SPM, SP C203, 70–15–03.) Install chip detectors.

72–00–00 Page 120
Aug 1/05

(f) Check No. 2 bearing scavenge line for metal contamination. If chips are evident, inspect all oil wetted components for wear, and replace parts as needed. Flush components with dry cleaning solvent (62, Table 203). (Refer to SPM, SP C203, 70–00–13.) Install scavenge line.

(g) Check No. 3 and 4 bearing scavenge line for metal contamination. If chips are evident, remove combustor turbine assembly, disassemble power turbine and bearing housing assembly, and inspect bearings and other oil wetted components for wear. Replace if required (72–50–04). Flush components with dry cleaning solvent (62, Table 203). (Refer to SPM, SP C203, 70–15–03.) Install components.

(h) If chips are suspected to come from reduction gearing, remove reduction gearing and inspect its condition and replace, if required (72–10–01). Flush components with dry cleaning solvent (62, Table 203). (Refer to SPM, SP C203, 70–15–03.) Assemble reduction gearing.

(i) Remove accessory drive gearbox (72–60–01). Remove and inspect shaftgear assembly. Particularly note condition of upper and lower bearings on this shaft. Inspect and clean scavenge strainer. Flush shaftgear assembly and internal components of gearbox with dry cleaning solvent (62, Table 203). (Refer to SPM, SP C203, 70–15–03.) Assemble accessory drive gearbox.

(j) Flush aircraft oil system and replace oil cooler on aircraft not equipped with auxiliary external oil filter. (Refer to Aircraft Flight Manual.)

(k) Service oil system with new lubricating oil (41 or 42, Table 203). (See ENGINE–SERVICING, paragraph 2.)

<u>CAUTION</u>: ANY FLUCTUATION IN OIL PRESSURE IN EXCESS OF 5 PSI, OR RAPID RISE IN OIL TEMPERATURE AT ANY PRESET POWER SETTING, IS CAUSE FOR IMMEDIATE ENGINE SHUTDOWN.

(l) Operate engine at 70 to 80 percent N1 for 5 minutes. (Refer to Aircraft Flight Manual.) Shut down engine and allow to cool.

(m) Inspect chip detector and oil filter strainers for chips. Amount of chips noted should be less than original amount. If so, repeat preceding steps (j) and (k), increasing engine operating time to 10 minutes.

(n) If quantity of chips remains the same after the second engine run, do not reclean filters, strainers, or chip detector, reject engine for repair.

<u>NOTE</u>: Chips in oil filter may originate in oil supply tank, chips on chip detector originate in engine.

(o) Repeat inspection, servicing and operating cycle, increasing engine operating time to 30 minutes. If no appreciable amount of chips or other contaminants is noted, engine may be returned to service. If amount of chips or other contaminants remains the same or increases, perform oil sample analysis. (See ENGINE–INSPECTION, paragraph 1.G.) Forward engine to overhaul facility.

Honeywell MAINTENANCE MANUAL
T5313B AND T5317 SERIES

(p) Retain chips and oil samples for analysis.

NOTE: The following action is recommended to make sure that oil, chips, or other contaminant samples are available to aid in the diagnosis of the problem. If a Honeywell Engines representative is called in, retain the sample for his evaluation and action.

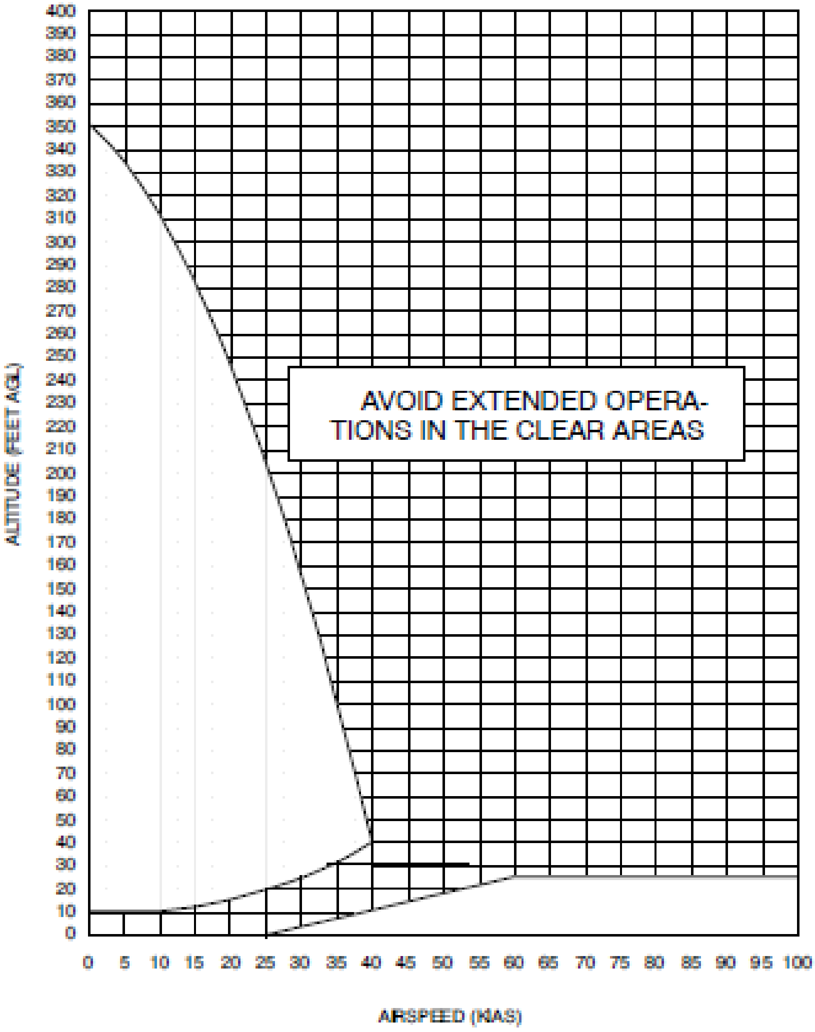
1 Exercise care to prevent additional contamination of sample.

2 Mark oil, chips, or contaminant sample to include operator's name, address, location on the engine from which the sample was taken, engine model and serial number, time since new, time since overhaul, and last related maintenance action. Include the oil vendor's name, batch number, and date of manufacture on the sample.

3 If the engine is being returned for repair or overhaul, return marked sample in engine container.

Annex 4 – Height-velocity diagram

Kaman K–1200
FAA Approved Rotorcraft Flight Manual



THE HEIGHT – VELOCITY DIAGRAM WAS DEMONSTRATED TO A HARD PREPARED SURFACE.

Figure 5–10. Height/Velocity Diagram

Page 5–13
FAA Approved February 17, 2004