Accident Investigation Board
Denmark

Report

HCLJ510-000433

Accident to Bombardier DHC-8-400,
registration LN-RDK,
at Aalborg Airport (Denmark),
on 9 September 2007

The report contained in this bulletin can be found on the AIB web site at http://www.AIB.dk

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Foreword

This report reflects the opinion of the Accident Investigation Board Denmark regarding the circumstances of the accident and its causes and consequences.

In accordance with the provisions of Danish law and pursuant to Annex 13 of the International Civil Aviation Convention, the investigation is of an exclusively technical and operational nature, and its objective is not the assignment of blame or liability. The investigation was carried out without having necessarily used legal evidence procedures and with no other basic aim than that of preventing future accidents.

Consequently, any use of this report for purposes other than preventing future accidents may lead to erroneous or misleading interpretations.

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GLOSSARY OF ABBREVIATIONS

ACARS	Aircraft Communication Addressing and Reporting System
ACC	Area Control Centre
AFM	Airplane Flight Manual
AFT	Aft
AIB	Accident Investigation Board, Denmark
ATC	Air Traffic Control
ATPL	Airline Transport Pilot's Licence
CA1	Cabin Attendant assigned to station no 1
CA2	Cabin Attendant assigned to station no 2
COC	Command and Control Group
CVR	Cockpit Voice Recorder
DLI	Dead Load Index
DME	Distance Measurement Equipment
DN	Down
DOI	Dry Operating Index
DOM	Dry Operating Mass
DOW	Dry Operating Weight
FDR	Flight Data Recorder
FL	Flight Level
FWD	Forward
GEO	Geographic
GP	Glide Path
GPWS	Ground Proximity Warning System
GVI	General Visual Inspection
ICAO	International Civil Aviation Organization
IFR	Instrument Flight Rules
ILS	Instrument Landing System
ILS CAT I	Instrument Landing System Category I
ILS CAT II	Instrument Landing System Category II
ILS CAT III	Instrument Landing System Category III
L/G	Landing Gear
LAM	Landing Mass
LAW	Landing Weight
LITOM	Loaded Index at Take-Off Mass
LITOW	Loaded Index at Take-Off Weight
LIZFM	Loaded Index at Zero Fuel Mass
LIZFW	Loaded Index at Zero Fuel Weight
LMC	Last Minute Change
MAC TOM	Mean Aerodynamic Cord at Take-Off Mass
MAC TOW	Mean Aerodynamic Cord at Take-Off Weight
MAG	Magnetic
MHz	Megahertz
MLG	Main Landing Gear
MSL	Mean Sea Level
MTOM	Maximum Take-Off Mass
NTSB	National Transportation Safety Board, USA
PAX	Passengers

PSEU	Proximity Switch Electronics Unit
PSU	Passenger Service Unit
QRH	Quick Reference Handbook
SITRUM	Military Operation Room
SSCVR	Solid State Cockpit Voice Recorder
SSFDR	Solid State Flight Data Recorder
TCAS	Traffic Alert and Collision Avoidance System
TIF	Trip Fuel
TOF	Take-Off Fuel
TOM	Take-Off Mass
TOW	Take-Off Weight
TSB	Transport Safety Board, Canada
TWR	Tower
UNDLD	Under Load
UTC	Coordinated Universal Time
VMC	Visual Meteorological Conditions
VFR	Visual Flight Rules
VOR	Very High Frequency Omni Directional Radio Range
ZFM	Zero Fuel Mass
ZFW	Zero Fuel Weight

FINAL REPORT

HCLJ510-000433	**Accident**		
Aircraft:	DHC-8-400	Aircraft registration:	LN-RDK
Engines:	2 Pratt and Whitney PW150A	Type of Flight:	Scheduled, IFR
Crew:	4 - 1 minor injury	Passengers:	69 - 6 minor injuries
Place:	Aalborg Airport EKYT	Date and time:	9.9.2007 1357 UTC

All times in this report are UTC. Local time was UTC + 2 hours.

Synopsis

The Accident Investigation Board, Denmark (AIB) was notified about the accident by the Area Control Centre on 9.9.2007 at 1359 hours.

The AIB notified the Transport Safety Board (TSB), Canada and Accident Investigation Board, Norway (AIBN) on 10.9. 2007.

The accident flight was a scheduled domestic flight from Copenhagen Airport, Kastrup (EKCH) to Aalborg Airport (EKYT).

During the approach to EKYT the flight crew selected the landing gear down and did not get the appropriate down and locked indication for the right main landing gear (MLG). After a number of unsuccessful attempts to achieve the appropriate down and lock indication the flight crew declared an emergency. Approximately two seconds after touchdown on runway 26R the right MLG collapsed.

There were a total of seven minor injuries amongst the four crew and 69 passengers on board.

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

Summary

AIB found that due to severe corrosion of the threaded connection between the right MLG retraction/extension actuator piston rod and rod end, the separation of the actuator piston rod and rod end caused the malfunctioning of the right MLG. When selecting the landing gear to down position, the landing gear was released from the landing gear up-lock hook. Due to the separation of the rod end from the actuator piston, the right MLG extended in a free fall condition. The kinetic energy cause the failure of the stabilizer brace link joint lugs. This failure rendered the stabilizer brace incapable of safely locking the right MLG in down position.

Safety recommendations

As a result of the investigation of this accident, the AIB has issued two recommendations. Two safety initiatives were made during the investigation.

1. Factual information

1.1 History of the flight

For the complete list summarising events, see the flight history timetable in appendix A.

The accident flight was a scheduled domestic flight from Copenhagen Airport, Kastrup (EKCH) to Aalborg Airport (EKYT).

The flight was uneventful until the landing gear was selected down during the approach to EKYT runway 26R. The nose landing gear and the left main landing gear (MLG) indicated down and locked. The right MLG indicated "in transit" (not down and locked).

The Aalborg Tower was informed about the problem with the right MLG indication. A go-around was initiated at 1100 feet MSL with a climb towards 2000 ft.

The flight crew consulted the Quick Reference Handbook (QRH). An alternate landing gear procedure was initiated. The right MLG indication remained in "transit".

A mayday call was made to Aalborg Tower and they were informed about the unsafe landing gear.

The flight crew reset the alternate gear extension system and subsequently they tried to make a normal gear up selection. The nose landing gear and the left MLG retracted normally, however the right main landing gear indication remained in "transit". A second attempt to use the alternate landing gear extension procedure was performed without any changes to the right MLG indication.

The aircraft entered a holding pattern in order to reduce the amount of fuel and at the same time to brief the passengers about the situation and to prepare the passengers for an emergency landing. Passengers seated at rows 6, 7 and 8 seats D and F were reseated away from the right propeller area.

During the approach the flaps were selected to 10° and the landing gear horn started. The warning horn continued throughout the remaining flight.

During the emergency landing the left MLG touched down on the runway first, followed by the right MLG. Shortly after the right MLG contacted the runway the right MLG collapsed.

The aircraft departed the runway to the right and came to rest on a heading of 340° at 1357:26 hrs.

1.2 Injuries to persons

Injuries	*Crew*	*Passengers*	*Others*
Fatal	-	-	-
Serious	-	-	-
Minor	1	6	-

1.3 Damage to aircraft

The aircraft was substantially damaged.

1.4 Other damage

The runway surface was found to have several cuts and marks from the aircraft. Two runway lights were hit and destroyed by the aircraft, when the aircraft slipped off the runway.

1.5 Personnel information

1.5.1 Commander (CDR):

Personal details:	Male, aged 61
Nationality:	Danish
License:	Airline Transport Pilot License (ATPL)
License valid until:	April 30, 2008
Medical class:	1
Medical certificate valid until:	November 1, 2007

Flying experience:	Last 24 hrs	Last 90 days	Total
All types	0 hrs	150 hrs	17000 hrs
DHC-8	0 hrs	150 hrs	1000 hrs
Landings (DHC-8)	0	125	-

1.5.2 First officer

Personal details:	Male, aged 37
Nationality:	Danish
License:	Airline Transport Pilot License (ATPL)
License valid until:	September 30, 2011
Medical class:	1
Medical certificate valid until:	September 1, 2008

Flying experience:	Last 24 hrs	Last 90 days	Total
All types	3 hrs	178 hrs	6540 hrs
DHC-8	3 hrs	178 hrs	1085 hrs
Landings (DHC-8)	3	178	456

1.6 Aircraft information

1.6.1 General aircraft information

Manufacturer:	Bombardier Aerospace Inc.
Type:	DHC-8-400
Year of manufacture:	2000
Serial number:	4025
Engines:	Pratt & Whitney, PW 150A
Propellers:	Dowty Aerospace Propellers, R408/6-123-F/17
Registration:	LN-RDK, registered in Norway on October 11, 2000
MTOM:	26,308 kg
Certificate of airworthiness:	The certificate was issued by the Civil Aviation Authority-Norway on December 12, 2006. It was valid until December 31, 2007.
Aircraft total flight hours:	12,141.37 Hrs
Aircraft total flight cycles:	14,795 Cycles
Maintenance:	The major inspection C3-check interval was 12,000 flight hours. C3-check was completed and the aircraft was released to service on 1 July, 2007 at aircraft flight hours 11,794.34. The last maintenance check (line check) was performed on September 9, 2007. The aircraft maintenance records were verified to be in compliance with the established maintenance program.

1.6.2 Landing gear system

1.6.2.1 General description

The tricycle gear is a retractable dual wheel installation. The main gears retract aft into the nacelles and the nose gear retracts forward into the nose section. Gear doors completely enclose the landing gear when it is retracted and partially enclose the gear when it is extended.
The cockpit advisory lights show the position of gear doors and down-locks. An audible warning sounds if the gear is not extended and the aircraft is in a landing configuration.

A Proximity Switch Electronics Unit (PSEU) monitors and controls the operation of the landing gear components.
An alternate landing gear extension method can be used to extend the gear if the primary extension method fails. There is also an alternate down-lock verification system.

Landing gear operation is controlled and monitored from the Landing Gear Control Panel, adjacent to the Engine Display in the cockpit. The landing gear is selected up or down by moving the landing gear selector lever. A Lock Release selector lever must be held down to let the gear selector lever move in either direction. An alternate down-lock verification system confirms down-lock engagement if the primary down-lock indication is in doubt. Three green down-lock verification lights are located under the Landing Gear Alternate Extension door in the cockpit floor.

1.6.2.2 Main landing gear retraction

Hydraulic pressure is supplied to each MLG down-lock release actuator to release the down-lock. Hydraulic pressure is supplied through an energized solenoid sequence valve to the open side of the MLG aft door actuators. This causes the MLG aft doors to open. The operation of the down-lock release actuator and the MLG aft door actuators are monitored by the PSEU. The MLG door mechanism operates a mechanical sequence valve to interlock the retraction/extension part of the hydraulic system. This continues until the doors are wide enough open for the landing gear to retract so that it does not touch the doors. At approximately 93 percent travel of the MLG aft doors, the MLG aft door linkage activates the mechanical sequence valve. When the mechanical sequence valve has been activated, hydraulic pressure is supplied to the up side of the MLG retraction/extension actuator. The MLG starts to travel to the fully retracted position where it is locked in place by the mechanical up-lock. The proximity sensors monitor the gear and door positions. When the PSEU receives the input signals that the MLG is up and locked, the PSEU de-energizes the solenoid sequence valves. This causes the solenoid sequence valves to supply pressure to the close side of the MLG door actuators and close the doors. At approximately 7 percent reverse travel of the MLG doors, the mechanical sequence valves stop their operation. This action removes pressure from the up side of the MLG retraction/extension actuators. Inline restrictors bypass the mechanical sequence valves and keep the MLG retraction/extension actuators pressurized to 3000 psi. Pressure is kept at 3000 psi until the landing gear hydraulic system is depressurized upon completion of the retraction cycle.

1.6.2.3 Main landing gear extension

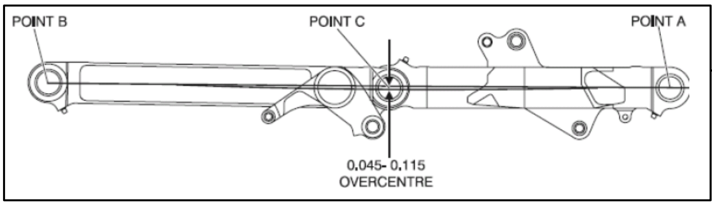
When the LANDING GEAR selector lever is moved to the DN position, the solenoid sequence valves remain de-energized. The de-energized solenoid sequence valves supply hydraulic pressure to the open side of the MLG aft doors actuators to open the MLG aft doors. At approximately 93 percent travel of the MLG aft doors, the MLG aft door linkage activates the mechanical sequence valve. The valve supplies hydraulic pressure to the up-lock release actuators and to the down side of the MLG retraction/extension actuators. The in-line restrictors slow the movement of the MLG retraction/extension actuator and the uplock release actuator, until the doors reach the 93 % open position at which point the activation of the mechanical sequence valve ports full flow to the two actuators.

The MLG starts to travel to the down and locked position. There are three proximity sensors used to monitor the MLG extension sequence. Each MLG has two down and locked sensors and one MLG aft door closed sensor. When the PSEU receives input signals that the MLG is down and locked, the PSEU energizes the solenoid sequence valves. Pressure is supplied to the MLG aft door actuators to close the MLG aft doors. At approximately 7 percent reverse travel of the MLG doors, the mechanical sequence valves stop their operation. This action removes pressure from the up side of the MLG retraction/extension actuators. Inline restrictors keep the MLG retraction/extension actuators pressurized to 3000 psi (20684 kPa) at the end of the extension sequence.

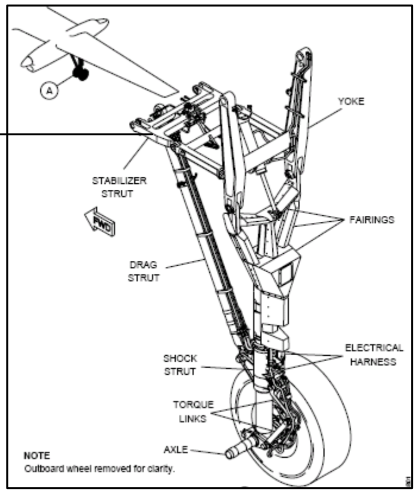
The advisory light sequence during extension starts with the LEFT, NOSE, and RIGHT red unsafe lights and the amber gear selector handle light coming on. Then the amber door advisory lights illuminate to indicate the hydraulically operated gear doors are open. When the landing gear is fully extended, hydraulic pressure is applied to a down-lock actuator to bring the stabilizer brace lock links into an over-centre position to lock the gear in its down position.

When the landing gear is locked in the down position, the red unsafe lights and the selector handle light go out. Then the green LEFT, NOSE, and RIGHT advisory lights come on. Finally, the gear door advisory lights go out when the hydraulically operated doors are closed.

The solenoid selector valve stays powered to allow for continued hydraulic pressure acting on the gear when down and locked, but primary down-lock is by the overcentre locks.



MLG stabilizer brace link - overcentre



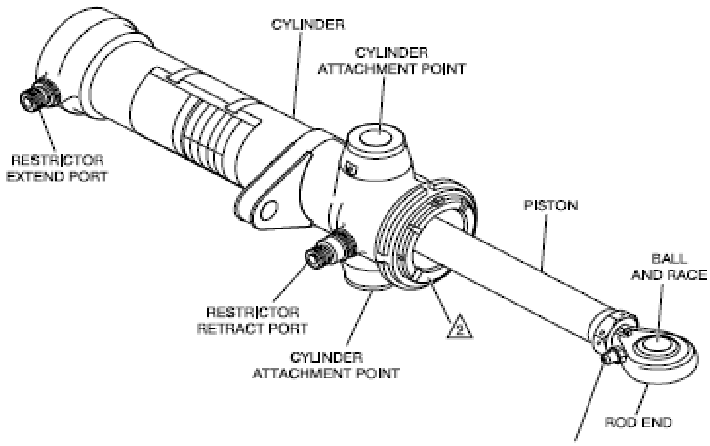
1.6.2.4 Landing gear alternate extension

The landing gear extension INHIBIT switch is installed in the cockpit ceiling, adjacent to the main LANDING GEAR ALTERNATE RELEASE door. The switch sends a signal to the PSEU to remove power from the landing gear selector valve and the door solenoid sequence valves. Additionally, the PSEU will bring on the LG INOP caution light. When the main LANDING GEAR ALTERNATE RELEASE door on the cockpit ceiling is opened it mechanically opens a bypass valve in the normal hydraulic extension system, porting the UP and DN lines to return and gives access to the MAIN L/G RELEASE handle. Pulling the handle releases the MLG doors and up-locks. The main gear will free fall but may not fully extend.

The LANDING GEAR ALTERNATE EXTENSION door, on the cockpit floor, must then be fully opened giving access to the alternate extension hand-pump and the NOSE L/G RELEASE handle. Opening the door mechanically operates the MLG alternate selector valve. If the MLG does not reach the down and locked position, the extension pump handle, located behind the copilot, is inserted into the pump handle socket and operated to complete main gear extension and subsequent down-lock. Both the LANDING GEAR ALTERNATE EXTENSION door and the MAIN LANDING GEAR ALTERNATE RELEASE door must be left fully open after alternate landing gear extension. When the NOSE L/G RELEASE handle is pulled, the nose gear up-lock and doors are released and the nose gear free falls to a down and locked position, assisted by the airflow.

1.6.2.5 Main landing gear retraction/extension actuator

The MLG retraction/extension actuator is a hydraulic device that has two ports. There are restrictors in the retract and extend ports. The rod end of the actuator piston has a ball and race with a lubrication fitting. The MLG retraction/extension actuator cylinder is attached to the lower front of the MLG yoke cross beam. The rod end is attached to the centre top of the MLG shock strut.The retraction/extension actuator acts as a damper through the restrictor in the retract port, when the gear is moving to the down position. (The restrictor allows a larger volume of hydraulic fluid to pass when the gear is moving up and less fluid when the gear is moving down).



MLG Retraction/extension actuator.

1.6.3 Mass and centre of gravity (extract from Load Sheet Final)

The aircraft version: 76 passengers.

CPH	AAL	LN-RDK	Crew 2/2
DOW dry operating weight (kg):	18,295 kg		
ZFW zero fuel weight (kg):	24,922 kg	MAX	26,308 kg
TOF take-off fuel (kg):	2386 kg		
TOW take-off weight (kg):	27,308 kg	MAX	28,998 kg
TIF trip fuel (kg):	800 kg		
LAW landing weight (kg):	26,508 kg	MAX	28,009 kg
UNDLD under load (kg):	1386 kg		
PAX M passengers:	69	TTL	69
DOI dry operating index:	19		
DLI dead load index:	34		
LIZFW loaded index at zfw:	17		
LITOW loaded index at tow:	17		
MAC TOW mean aerodynamic cord at tow:	22		
BALANCE LIMITS BEFORE LMC			
FWD / AFT:	10 / 32	AT ZFW	
	10 / 32	AT TOW	

The aircraft was within the mass and balance limitations during the entire operation. The estimated mass of the aircraft at the time of the accident was approximately 25,722 kg (ZFW plus 800 kg fuel).

1.6.4 Airplane Flight Manual (AFM) and Quick Reference Handbook (QRH)

The basic aircraft documentation consists of a manufacturer's AFM, approved by the authorities.
The manufacturer had issued a QRH based on the AFM. The QRH was an extract of the AFM procedures and checklists.

The purpose of the QRH is to assist trained pilots verify that the proper procedures have been carried out. The QRH provides the flight crew with abbreviated information derived from the approved AFM to operate the airplane in most normal and non-normal/emergency situations.

It is the operator's responsibility to ensure the checklists are applicable to their type of operation. In the event of an inconsistency between any checklist and the approved AFM, the AFM takes precedence.

The operator has chosen to develop a customized QRH based on the manufacturer's QRH.

1.7 Meteorological information

The Terminal Area Forecasts and Metrological Aerodrome Reports at the time of the accident at EKYT:

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091100 TAF-FC     ekyt 091140z 091221 33007kt 9999 few035 sct250 becmg 1618
                       27010kt bkn020=
091400 TAF-FC     ekyt 091440z 091524 30010kt 9999 few035 bkn250 becmg 1618
                       27010kt bkn020 becmg 2123 23012g22kt 6000 -ra sct005
                       bkn012 tempo 2324 3000 ra bkn005=


091320 METAR      ekyt 091320z 30008kt 270v330 9999 few038 bkn250 18/08
q1014=
091350 METAR      ekyt 091350z 29008kt 260v320 9999 few038 bkn250 18/09
q1014=
091420 METAR      ekyt 091420z 29010kt 260v320 9999 few038 bkn250 18/10
q1014=
091450 METAR      ekyt 091450z 27008kt 240v310 9999 few038 bkn250 17/09
q1013=
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1.8 Aids to navigation

At the time of the accident, Aalborg Airport had the following radio navigation and landing aids for runway 26R: ILS CAT II, GP, DME and VOR. All navigation aids were functioning at time of the accident without any remarks.

1.9 Communications

The flight crew was in radio contact with Aalborg Tower (ATC) on frequency 123.975 MHz during the events. There were no communication problems between the aircraft and the ATC. Communications between the ATC and the aircraft were recorded and used in the investigation

1.10 Aerodrome information

1.10.1 Aalborg Airport

1.10.1.1 General

EKYT has been approved for VFR and IFR operations. The airport was a combined military and civil airport with two parallel runways 26R/08L and 26L/08R. The dimensions of runway 26R/08L were 2654 x 45 meters asphalt. The dimensions of runway 26L/08R were 2549 x 23 meters asphalt. Only runway 26R was approved for ILS category II Operations. The runway used during the accident was 26R (GEO/MAG 263°).

1.10.1.2 Fire Service

EKYT had an approved ICAO category 7, level B - Rescue and Fire Fighting Service. According to this requirement the aerodrome must have fire fighting services with a capacity to discharge 12,100 litres of water and 5,300 litres of foam per minute respectively to aircraft of up to an overall length of 48 meters and a fuselage width up to 5 meters. (For more information refer to ICAO Annex 14).

1.10.1.3 Emergency plan

Aalborg Airport had a detailed emergency plan in place to be applied in the event of an accident.
At the time of the accident the emergency plan was a collection of coordinated measures, regulations and procedures elaborated to minimize the effects of an emergency situation in the airport or other areas defined in this plan. The main objectives of this plan were:

- To save human lives
- The protection of property
- To sustain airport operations for aircraft and airport installations

The plan, various departments are involved in achieving these objectives when an accident occurs inside the airport premises:

- The Control Tower (Air Traffic Control, ATC)
- The Area Control Centre, Copenhagen (ACC)
- The Rescue and Fire Fighting Services
- The Medical Services (Hospitals etc.)
- The Police
- Airlines
- Other companies operating at the airport

Under the emergency plan, the control tower activates the alarm simultaneously for:

- The Rescue and Fire Fighting Services
- The Military Operation Room (situation room, SITRUM)

- The Airport Office
- The Head of ATC Aalborg

Under the emergency plan, the staff (military) of the SITRUM raises the alarm and coordinates the activities of all services involved during the emergency such as:

- Medical services
- Police
- The press room.
- Military staff
- Other rescue services

SITRUM staff must also act as a support for the Command and Control group (COC).

From the moment the alarm is activated, the Rescue and Fire Fighting officer on duty takes command of the accident site until the COC is in place.

The COC consisted of:

- The police officer on duty
- The fire fighting officer on duty
- The officer on duty for the rescue readiness
- The co-ordinating doctor on duty

1.10.1.4 Training drill

According to the information provided, the last simulation of an aeronautical emergency at the airport was carried out on January 26, 2006. According to ICAO annex 14, a full-scale aerodrome emergency exercise must be performed at intervals not exceeding two years.

1.10.2. Passengers

The injured passengers were taken by ambulance to the hospital. Passengers with no injuries were transferred, by a variety of means, to the Airport Terminal where airport staff had closed departure hall three. The airline staff at the departure hall provided the passengers with the attention they required (medical or other).

Some passengers had difficulties in making phone calls to their relatives because they had left their mobile phones onboard the aircraft. Passengers were worried about their personal belongings which were still inside the aircraft either in the passenger cabin as hand baggage or in the cargo compartments.

1.10.3 Relatives

There were no reports of relatives arriving the airport. A number of relatives were waiting there for family and friends etc. The emergency plan did not cover this item.

1.11 Flight recorders

1.11.1 Cockpit Voice Recorder (CVR)

The aircraft was equipped with a Honeywell CVR, type SSCVR part number 980-6022-011 serial number 1078. The CVR was removed from the aircraft on the day of the accident. The data from the CVR was of good quality and was used in the investigation.

1.11.2 Flight Data Recorder (FDR)

The aircraft was equipped with a Honeywell FDR, type SSFDR part number 980-4700-027, serial number 5604. The FDR was removed from the aircraft on the day of the accident. The data from the FDR was of good quality and was used in the investigation.

1.12 Wreckage and impact information

1.12.1 General

Approximately two seconds after touchdown on runway 26R the right MLG collapsed. The aircraft veered to the right and left the runway. The aircraft came to rest in the safety zone approximately 45 meters from the runway centreline and on a heading of 340°. There were two fires at the right side of the aircraft. The fires went out before the aircraft came to rest.

Both the left and right engines were operating at the time of the accident.
When the right propeller sustained a ground strike the right engine was substantially damaged due to inertial overload in the forward engine section. The right engine mount was found to be broken and a major crack was found in the forward engine case section.
The right nacelle was damaged as result of the ground contact. The centre section of the nacelle received minor damage. The aft nacelle composite structure was badly cracked on the outboard side.

The right MLG had suffered substantial damage due to the collapse of the gear during landing. The nose landing gear was substantially damaged due to side slip out of the runway into soft ground and long grass. The nose landing gear tires had deflated and the oleo gland nut was found to be broken. The nose wheels and tires were substantially damaged.
The aft lower fuselage suffered substantial damage while skidding on the runway into the grass area. The right fuselage between fuselage station x258.00 and x301.00 was severely damaged as a result of the right propeller blades fragmenting after striking the ground. The fuselage skin, stringers and frames were damaged along with the cabin windows and frame. The ice protection shield was damaged.

The right outer wing and outer flaps section sustained damage as a result of ground contact.

When the gear collapsed the propeller blades struck the runway. Three propeller blades separated from the propeller dome. One blade was found on the runway. A second blade was found wedged into the right side of the fuselage at row 7. The third propeller blade had entered the cabin through the right cabin window at row 8. This resulted in extensive damage to the left and right interior sidewalls, including the overhead bins and passenger service unit (PSU) components.

Propeller blade wedged into the fuselage

The FDR showed that the maximum vertical, lateral and longitudinal g were 1.64, 1.00 and 0.92 respectively during the gear collapse. An unknown number of people had been in and out of the cockpit after the accident. Therefore cockpit switch and handle positions could have been changed. The AIB found the following:

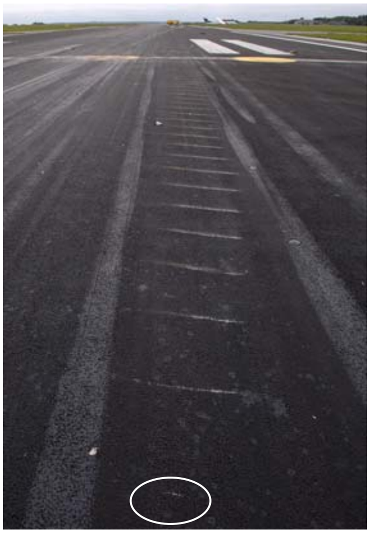
- Wing flaps were selected to 35 degrees.
- Nose wheel steering was selected “ON”
- Anti-skid switch was selected “ON”
- Spoiler switch was selected to “FLIGHT”
- Park Brake was “ON”
- Power levers positioned were full aft in the “MAX REV” position
- Condition levers were full aft and in the fuel “OFF” position
- Control lock was “OFF”

- Landing gear selector lever was selected “DOWN”
- Emergency hydraulic & fuel handle for Engine 2 was pulled fully “OUT”.
- Pitch and roll disconnect handles were “NOT PULLED”.
- Aileron trim toggle selector switch was “CENTRED”.
- Rudder trim selector knob was “CENTRED”.
- Overhead alternate MLG release handle was pulled fully “DOWN”.
- Emergency light switched “off”.
- Audible evacuation switched “off”.

1.12.2 Right engine and propeller

Out of six propeller blades three consecutive blades were found separated from the propeller. The remaining three blades were found on the propeller with major damage from striking the runway. One propeller blade was found on the runway, one was wedged into the fuselage and one was found inside the passenger cabin.

The witness marks - from the propeller - on the runway indicated that the three blades had departed the propeller almost instantly after impact with the runway and before the aircraft outer wing came in contact with the runway.



The first blade contact. All six blades did contact the runway.

At this point it shows that three blades had left the propeller dome and the engine was still running.

The right engine suffered a major engine case separation due to inertial overload in the forward engine section. The cause to this separation was the precipitous stop of the propeller, when the aircraft vent into the grass area.

The aft right lower fuselage suffered major damage. The outer skin and the stringers were gone at the area of contact with the runway.

1.12.3 MLG and components

The investigation focused on the right MLG assembly which had significant fracture damage. The stabilizer brace link was fractured and separated at both joint lugs. The aft stabilizer brace torque tube was bent, and a large section had broken and separated. The aft stabilizer brace link was connected to the forward stabilizer brace link by the down-lock springs only. The down-lock proximity sensors were displaced from their respective targets (figure A).

The retraction/extension actuator was found with the rod end separated from the retraction/extension actuator piston rod. Due to its weight and mounting design the retraction/extension actuator was found up-side down (figure B).

During the investigation of the right MLG, it was observed that the shock strut piston and the rolling gear had abnormal clearance in the torque link assembly, which facilitated rotational motion of the rolling gear about the piston axis in excess of +/- 2 degrees.

The left and right MLG brake units were inspected. All of the brake wear indicators were within limits. The left and right MLG tires and wheels (four) were in good condition. All tires remained inflated.

The right MLG retraction/extension actuator, the retraction/extension actuator rod end, and the forward and aft stabilizer brace assembly were removed from the aircraft for further examination.

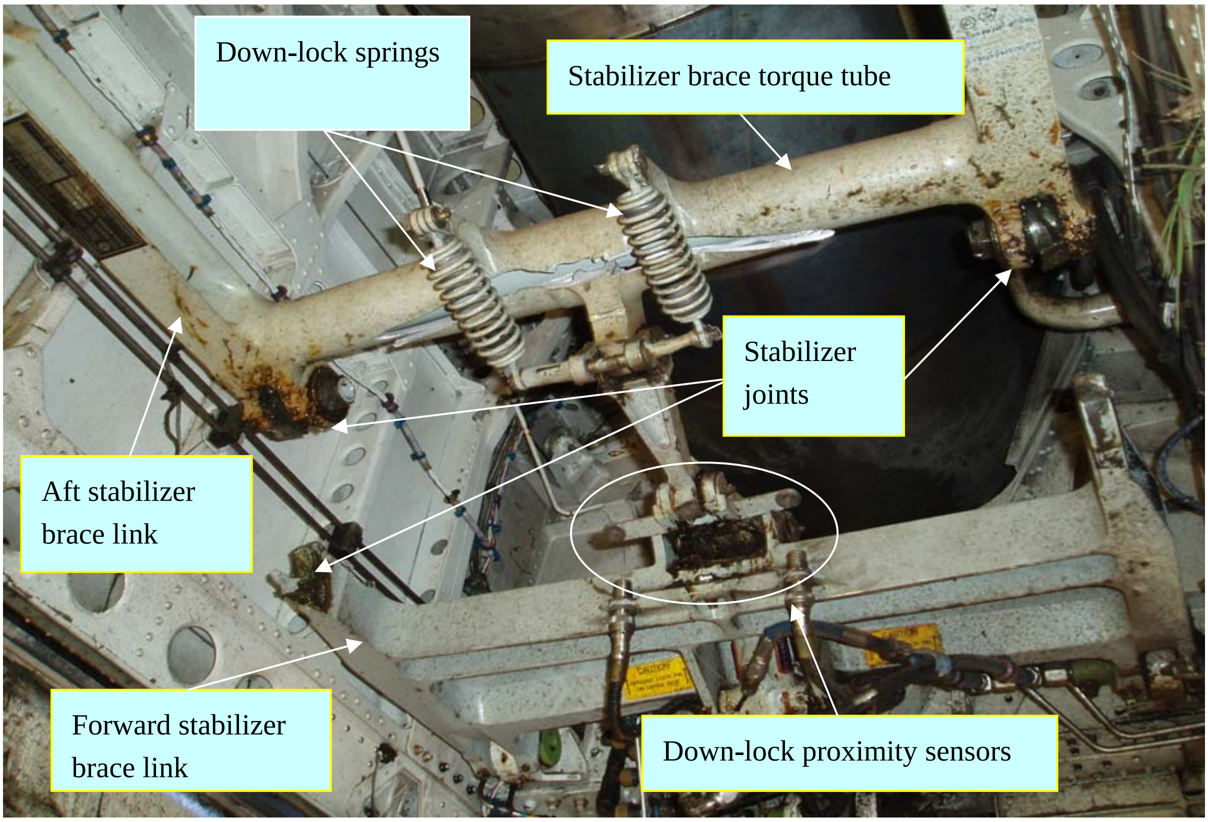


Fig. A. Right MLG stabilizer brace.

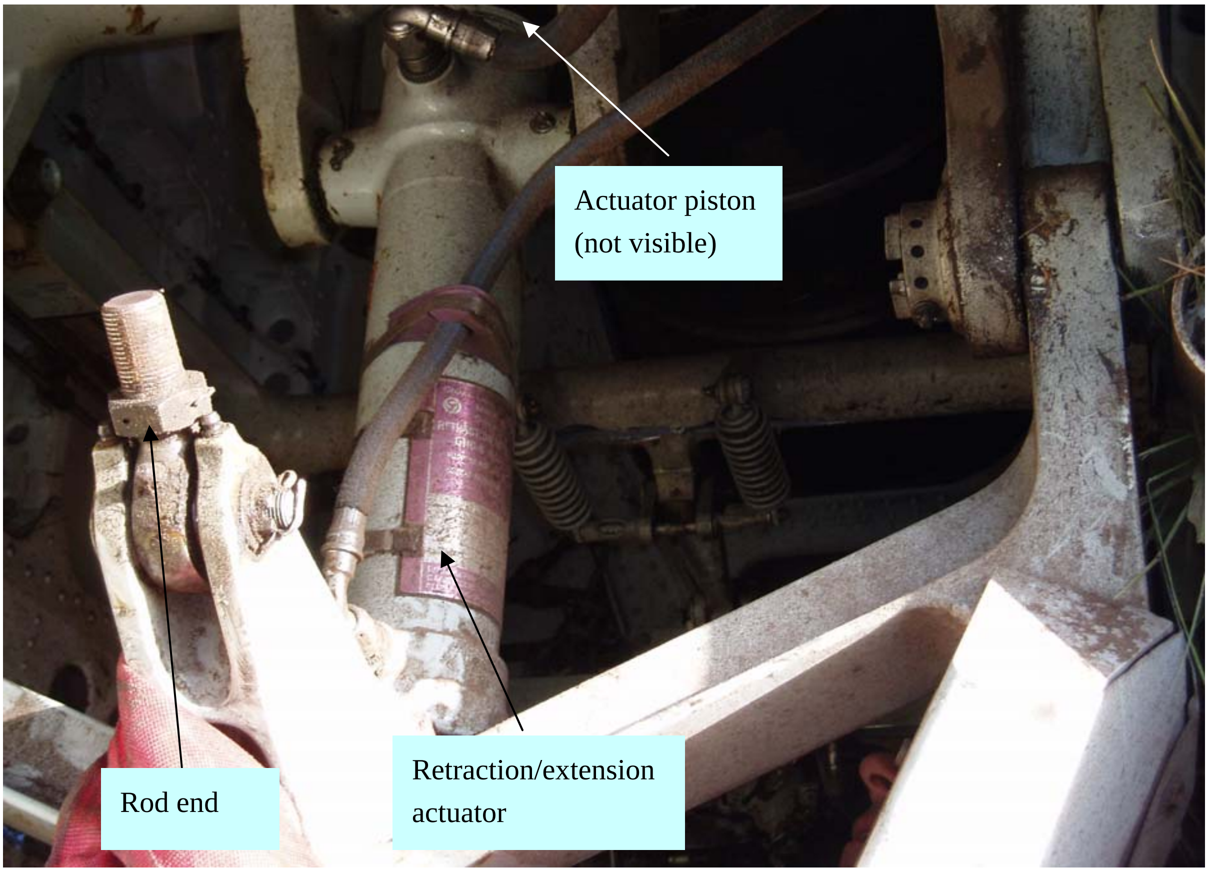


Fig. B. Right MLG retraction/extension actuator

1.12.3.1 Examination of the right MLG Stabilizer forward brace (fig. A).
The following were observed for the right MLG stabilizer forward brace:

- All joints showed adequate lubrication.
- Pieces of lugs missing at both lugs.
- Lock links were intact, but had local areas of plastic deformation indicative of high load contact with the lock link and aft stabilizer brace.
- Connection at the nacelle fittings appeared to be in good condition

The examination of the forward brace showed that the joint lugs had failed. The fracture surfaces were magnified and showed grainy texture with shear lips which are characteristic for an overload condition. No sign of striations was observed, see figure A.

1.12.3.2 Examination of the right MLG stabilizer aft brace (Fig. A).
The following were observed for right MLG stabilizer aft brace:

- Joints showed adequate lubrication.
- Aft connections at yoke were in good condition with no observable signs of damage.
- The joint lugs to the fwd stabilizer brace were intact.
- The torque tube cross-member was bent and had an elongated diamond shaped section torn out.

Examination of the torque tube cross member showed that the fracture surfaces exhibited characteristics of an overload failure with origin at the centre top surface adjacent to the lock link attachment lug. The fracture surfaces were magnified and showed grainy texture with shear lips. No sign of striations was observed.

1.12.3.3 Examination of right MLG retraction/extension actuator and rod end (fig. B).
The following were observed:

Right MLG retraction/extension actuator parts number 46550-7 serial number MAL-0063:

- Rod end was separated.
- Piston rod internal threads were noticeably stripped out to the depth of the rod end engagement.
- The retraction/extension actuator piston rod revealed the presence of internal corrosion.

Right MLG retraction/extension actuator rod end:

- The bearing surfaces were adequately lubricated.
- The jam nut was present and lock-wire was intact, but without the manufacturer’s originally installed lead seal.
- The threads were clogged with what appeared to be corrosion.

Due to above-mentioned findings both the right and left MLG extension and retraction/extension actuator and piston rod ends were taken to an independent facility capable of making chemical and metallographic analyses. The purpose of the examination was to describe the condition of the submitted parts and to elucidate the cause(s) that led the rod end to separate from the piston rod.

The examinations including figure references below in this chapter (1.12.3.3) have been taken from the laboratory report and therefore the figures are not numbered in succession. The complete laboratory report is attached to this report as appendix B.

Figure 1 shows a reconstructed photo of the actuator, piston rod and rod end. Figure 2 shows close up views of the piston rod female thread and rod end male thread in "as found" condition.

Figure 1: View of right MLG retract actuator with piston rod and rod end.

Figure 2: Threaded parts of piston rod and rod end in “as found” condition.

The threaded end of the piston rod was sectioned longitudinally as shown in figures 3, 4 and 5. Figure 6 shows a section of the piston rod before and after cleaning. It was evident that the female threads were severely damaged and partly destroyed by corrosion. Figure 10 shows the appearance of threads in the non-engaged part of the thread. The contour of the non-engaged threads appears intact but upon closer view it was evident that corrosion had also occurred in these parts.

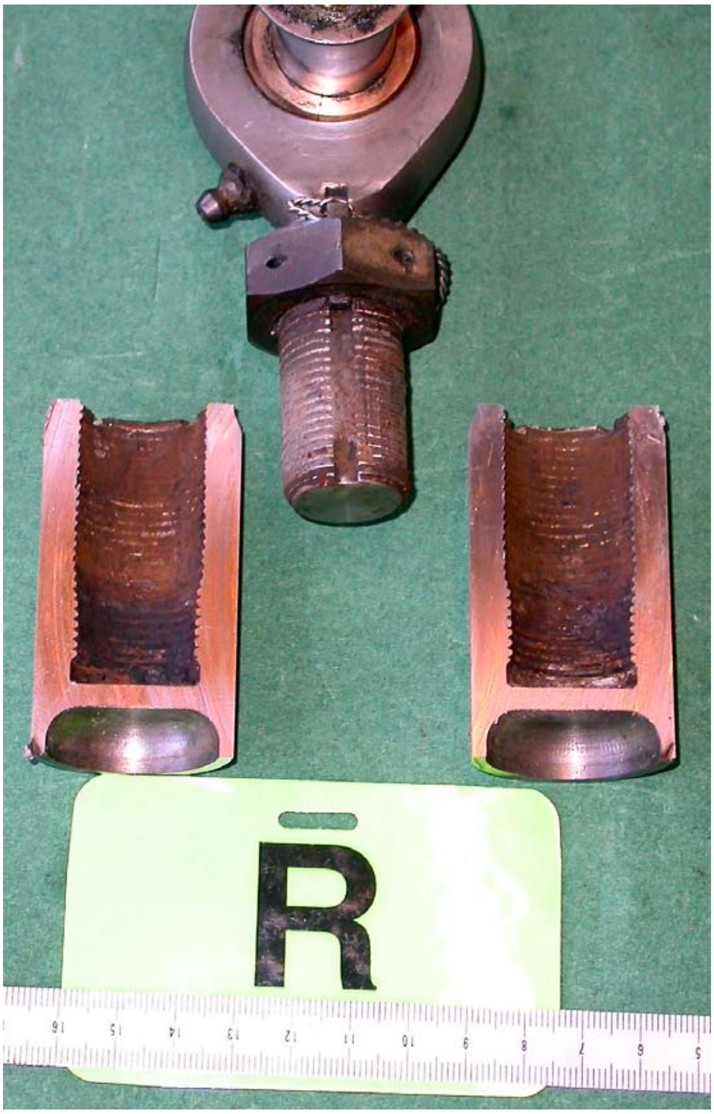


Figure 3: Longitudinal sectioning of piston rod end.

Figure 4: Higher magnification of Figure 3

Figure 5: Higher magnification of Figure 3

Figure 6: Part of piston rod in cleaned condition. Note the severe corrosion of thread tops and bottoms.

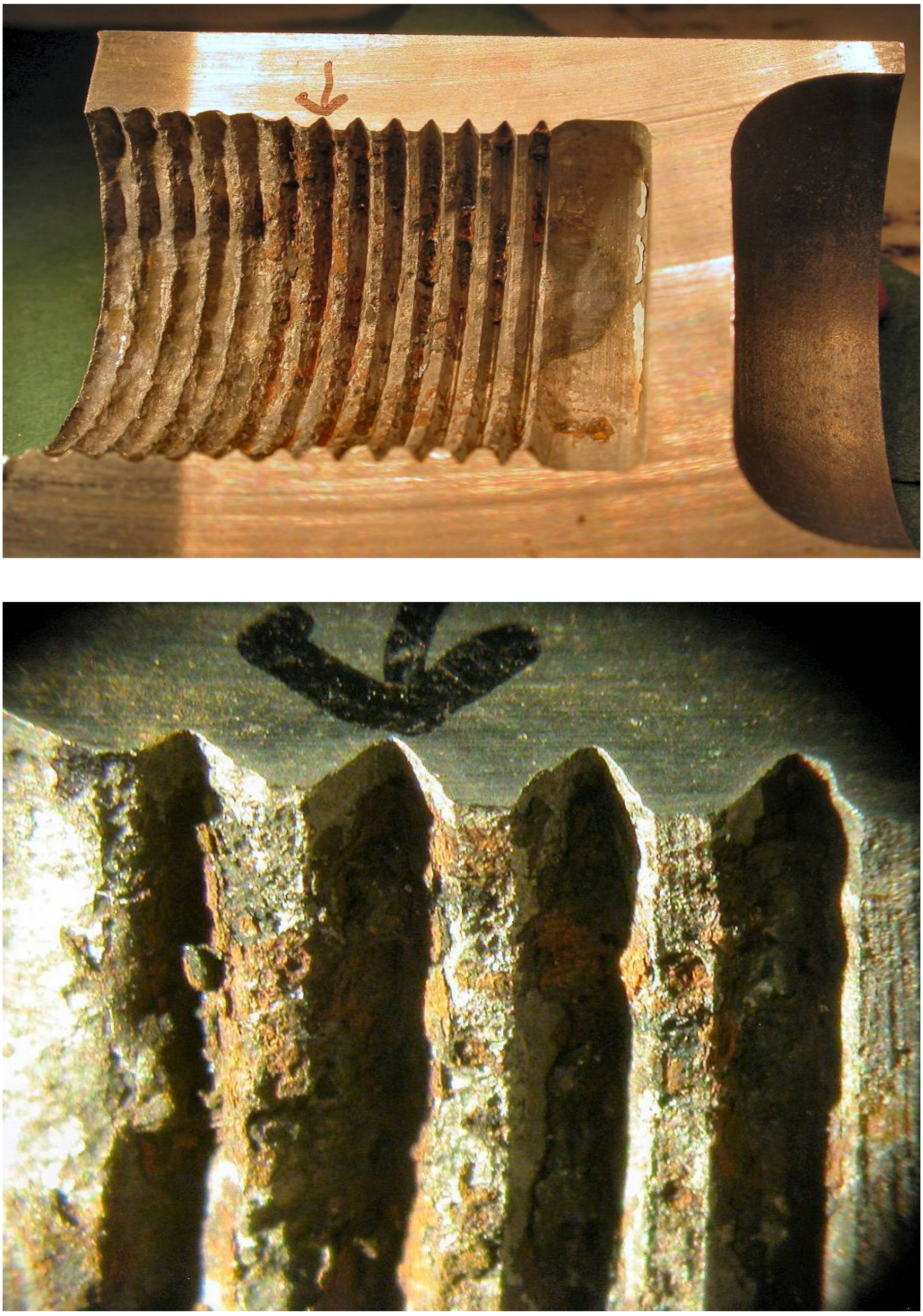


Figure 10: View of threads near bottom of piston rod. The arrow points to the last engaged thread.

The areas of the threads coinciding with the position of the key way in the rod end (visible in Figure 3) were less attacked by corrosion, but corrosion attacks were still apparent.

Figures 17 and 18 show the appearance of the rod end male thread. The thread valleys were filled with a dry powder-like product and metallic ligaments. A longitudinal cut in the male thread is shown in Figure 19.

Figure 17: Right MLG actuator rod end in “as found” condition.

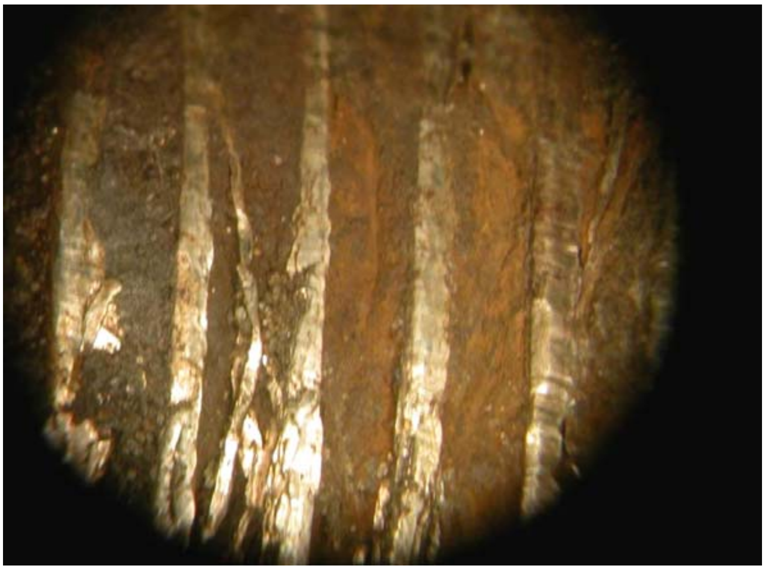


Figure 18: Close up view of the male threads in Figure 17

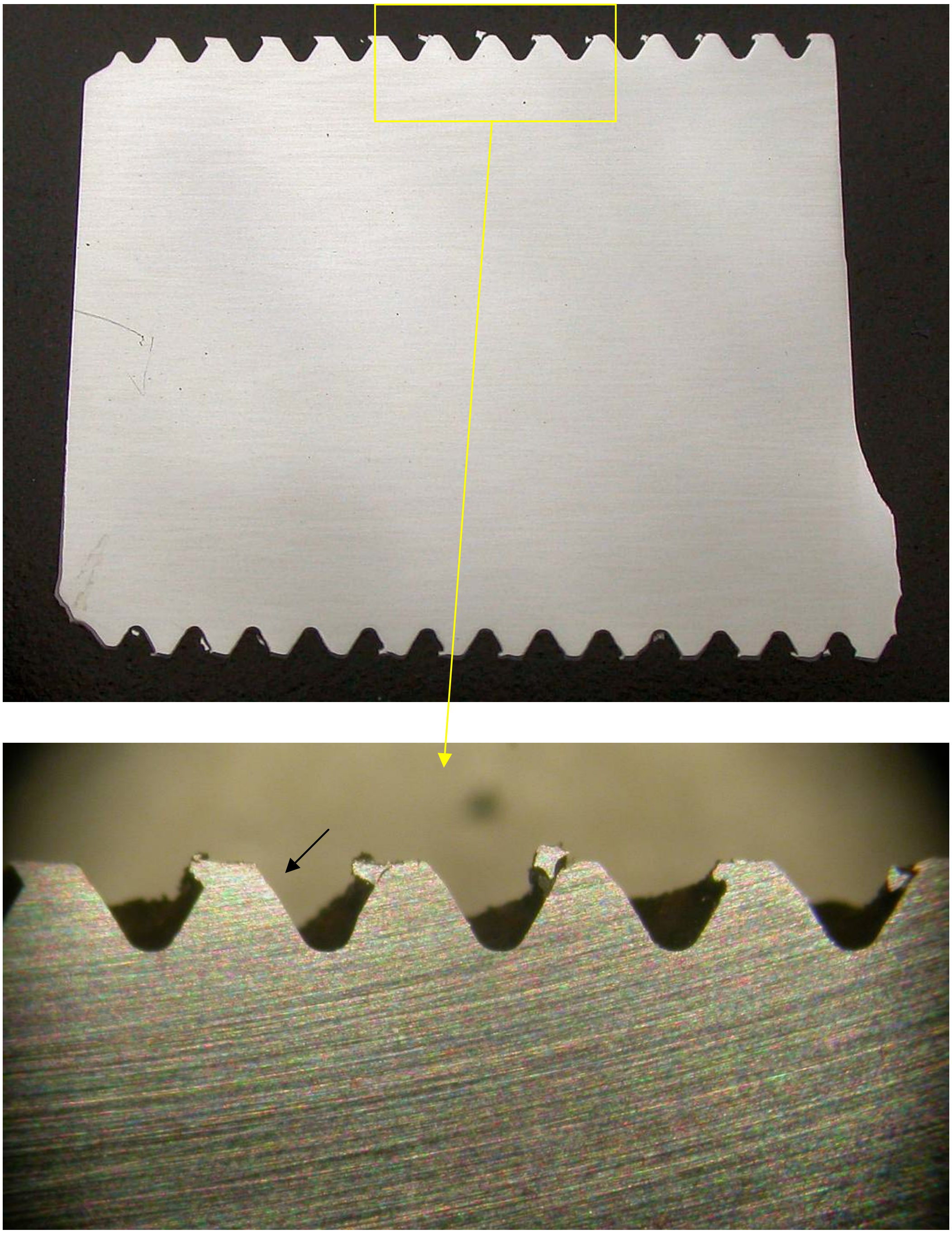


Figure 19: Longitudinal section of male thread showing some deformation/wear near top (example at arrow) and sheared off metal at the thread tip corners.

1.12.3.4 Examination of the left MLG retraction/extension actuator part number 46550-7 serial number MAL-0058

The examinations including figure references in this chapter (1.12.3.4) have been taken from the laboratory report and therefore the figures are not numbered in succession. The complete laboratory report is attached to this report as appendix B.

The left side actuator piston rod and rod end was dismantled and examined for comparison with the right hand actuator parts.

It was noted that the lock wire was intact and in place before dismantling. The lock nut could easily be moved on the rod end, but there was remarkably more resistance while unscrewing the rod end from the piston rod. The rod end threads shown in figure 30 appeared undamaged as did the piston rod threads at first glancefrom the outside. However, cleaning and longitudinal sectioning of the piston rod revealed some metal loss, figure 31. The left piston also features less corrosion at the position of the rod end key way as shown in figure 32. While corrosion attacks were obvious there was also evidence of some mechanical contact marks in the thread tops.

Figure 30: Rod end (as dismantled).

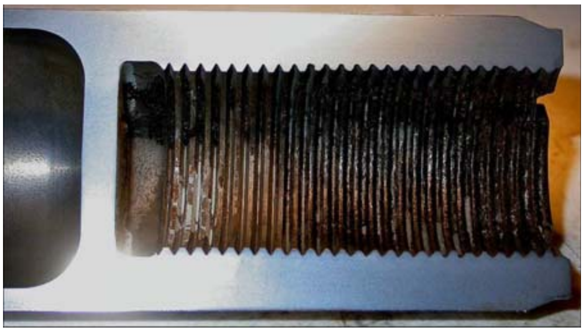


Figure 31: Part of sectioned piston rod (after cleaning prior to sectioning).

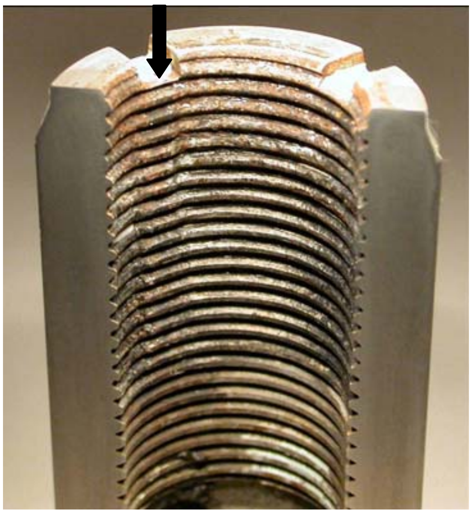


Figure 32: Overview of piston rod section showing less corrosion in the key way area (at arrow).

1.12.3.5 Right MLG retraction/extension actuator maintenance

An examination of the maintenance performed previous to the accident on the right MLG gear showed that the retraction and extension actuator jam nut had been retightened. The following text was written on the associated complaint card (Appendix C):

During Line check found rod end on RH MLG retraction actuator loose in piston end.

Action taken:

Found nut loose. Nut fastened and operational test of main landing gear primary extension and retraction perf. Wo/rem. Acc to amm 32-00-710-801.

The complaint card and action taken took place on June 6 and June 7, 2007 respectively.

The complaint card does not contain any information about the torque applied to the jam nut. It was not possible for the AIB to discover torque value applied to the jam nut. The AIB was told that a big wrench was used on the jam nut, but it was not possible to tighten the jam nut any further.

1.12.3.6 Maintenance requirement.

This chapter is an extract from the aircraft manufacturer's approved Maintenance Requirements Manual:

This report outlines the initial minimum scheduled maintenance/inspection requirements to be used in the development of an approved continuous airworthiness maintenance program for the airframe, engines (on−wing engine only), systems and components of the DHC−8−400 aircraft. These Maintenance Review Board (MRB) requirements are a basis from which each air carrier develops its own continuous airworthiness maintenance program.

The responsible Regulatory Authority inspector shall ascertain that all of the applicable scheduled maintenance/inspection requirements in this report are included in the air carrier's initial continuous airworthiness maintenance program.

This report is approved by the Transport Canada Maintenance Review Board (MRB) and other Regulatory Authorities and denoted on the Transport Canada Revision Approval page, FAA Revision Acceptance page and JAA Revision Acceptance page, issued with each revision of this report.

An average utilization of 2500 Flight Hours per year in passenger service is assumed for the DHC−8−400, for the purposes of this report. In the event that an airplane's annual utilization differs significantly from this figure, or the type of operational differs significantly from this profile, such as a change to cargo operation, the operator will have to undertake a review of all tasks in this report with the manufacturer and their respective Regulatory Authority.

The Regulatory Authority of the state of registry of the aircraft may require tasks, in respect of certain components, systems, or structure, which are not contained in this report. Such requirements are beyond the scope of this report.

DESCRIPTION OF THE MAINTENANCE PROGRAM

The maintenance program for the DHC−8−400 is made up of Systems, Structures, Zonal, EWIS, CPCP and L/HIRF Programs, as detailed in the following sections:

A. The Systems Program gives tasks, arising from the MSG−3 Systems and Powerplant/ APU analyses.

B. The Structures Program lists specific, directed inspections of each Structural Significant Item, developed through the MSG−3 Structures analysis of their fatigue, environmental, and accidental damage characteristics.

C. The Zonal Program lists general visual inspections of system installations and structure on a zone−by−zone basis. This program has been developed in conjunction with the other programs to prevent task duplication, and to ensure complete coverage of the aircraft systems and structure.

D. The Electrical Wiring Interconnection System (EWIS) Inspection Program lists general visual inspections and detailed inspections of wiring installations on a zone−by−zone basis. This program was developed by applying the Enhanced Zonal Analysis Procedures (EZAP) to determine where additional tasks were required over and above the existing Zonal Inspection Program.

E. The Corrosion Prevention and Control Program (CPCP) is established to maintain the aircraft's corrosion protection against age−related deterioration caused by environmental interaction. This program is expected to allow control of the corrosion on the aircraft to Corrosion Level 1 or better.

For purposes of organization, several fundamental work pages have been identified as the initial monitoring and maintenance intervals for the DHC−8−400 aircraft. They are defined as follows:
'L' Check:
The Line 'L' Check is to be repeated at every 50 flight hours.
'A' Check:
The 'A' Check is to be repeated every 400 flight hours. [The operator of the accident aircraft LN-RDK had 500 flight hours between A check, approved by the CAA].
'C' Check:
The 'C' Check is to be repeated every 4000 flight hours.
Likewise 2A, 3A...nA intervals are 800, 1200...nx(400) flight hours and 2C, 3C...nC intervals are 8000, 12000...nx(4000) flight hours respectively. [The operator of the accident aircraft LN-RDK had likewise 2A, 3A…nA intervals 500, 1000…nx (500) flight hours, approved by the CAA].

For tasks that are not assigned to a fundamental work package of 'L', 'A' or 'C', they have a specific interval listed, such as hours, cycles, calendar, engine change, etc. and may have abbreviations as follows:
Flight Cycles FC
Flight Hours FH
Engine Hours EH
Auxiliary Power Unit APU

1.12.3.7. Maintenance task card

The MLG retraction/extension actuator was installed in the aircraft at the time the aircraft was manufactured and at the time of the accident had completed 14,795 flight cycles.

A line check (“L”) was completed on June 7, 2007 with one reported defect on the right MLG retraction/extension actuator jam nut.

The last C-check performed was a C3 check and was completed on July 1, 2007 at aircraft flight cycles 14,381 without any defect reported on the affected actuator rod and rod end.

The last maintenance (“L” check) was performed on September 9, 2007, also without any defect reported.

The maintenance requirement for the right and left MLG was in the zonal inspection program – task number Z700-04E - with an interval of 500 flight hours (“A” Check). The task required was an external General Visual Inspection (GVI) of the MLG. This task was performed at the last C-3 check (Appendix D).

The Maintenance task card FRQ067002 referring to task number Z700-04E (task number 05-47-04-210-802) was the only inspection to be performed on the right MLG (Appendix E).

There were no specified inspection tasks for the MLG retraction/extension actuator and rod end. However there was a restoration requirement at an interval of 22,400 flight cycles for the actuator. This requirement did call for replacement of the actuator rod end. The requirement was the only direct specified inspection to be performed on the actuator and rod end according to the Maintenance Requirements Manual.

The MLG had a restoration requirement at an interval of 15,000 flight cycles.

1.13 Medical and pathological information

The AIB has decided not to undertake any medical or pathological investigations.

1.14 Fire

The video recording showed sparks and fire erupting when the aft right fuselage made contact with the runway. The fire went out when the aircraft skidded out into the grass area.

A momentary fire occurred in the right engine area at the time when the aircraft skidded out into the grass area. This fire originated from a major engine case separation due to inertial overload in the forward right engine section as the propeller struck the runway. The fire went out before the aircraft came to rest.

The Rescue & Fire Fighting Services arrived at the aircraft approximately 32 seconds after the aircraft came to rest. They saw smoke coming out from the right engine area and applied foam to reduce the possibility of post fire. The Rescue & Fire Fighting Services stopped applying foam 14 seconds later, when the smoke from the right engine area had disappeared.

Some of the foam from the fire engine passed over the fuselage into the area at the aft left door and some of the foam entered the passenger cabin and was at first identified as fuel by mistake.

The Fire Incident Officer ordered a team of smoke-divers into the aircraft to look for any remaining passengers and possible internal fire. They did not find any passengers or any fire.

The type of foam used was FC-203A Light Water Brand AFFF mixed in 3% dissolution. Foam distributions on runways prior to an emergency landing were no longer used in Denmark for environmental protection reasons.

1.15 Survival aspects

While the aircraft was in the holding pattern the passengers in rows 6, 7 and 8, seats D and F were reseated away from the right propeller area (Appendix F.) The left side rows 6, 7 and 8, A and C, were not reseated since there was only one empty seat available for further reseating, after having moved passengers from seats 6, 7 and 8, D and F.

The cabin attendants selected passengers and deadhead crew members (crew travelling as passengers) as able bodies. One company-employed deadhead crew member who was sitting in row 11, seat A was reseated to row 1 seat F. He was to assist the cabin attendant after landing. The able body in row 1 seat A was instructed in the emergency procedure including how to open the forward left door in case of the forward cabin attendant (CA1) being incapacitated. The cabin attendant was sitting next to the forward left door facing aft.

In the aft cabin the passenger sitting on row 21 seat C was instructed in the emergency procedure including how to open the aft left exit door in case of the aft cabin attendant (CA2) being incapacitated. The cabin attendant was sitting behind row 21 seat C and was facing forward.

Two company-employed deadheaded crew were sitting in cabin row 12, seats D and F. It was decided by the cabin attendant that the two deadheaded crew members should stay in their seats and be prepared to assist the cabin attendant to evacuate the middle section of the cabin. The deadheaded crew were also to reassure the passengers in the middle section of the cabin.

The cabin attendant (CA1) briefed the passengers in the emergency procedures. The passengers were briefed individually after a general emergency briefing. Each of the passengers was asked to demonstrate the brace procedure.

Three propeller blades separated from the propeller dome when the propeller struck the runway. One blade was found on the runway. Two blades penetrated the passenger cabin. One of the propeller blades was wedged into the fuselage at row 7 seat F and one entered the cabin through the cabin window at row 8 seat F (between fuselage station 258.5 and 281.0) (figure C). This blade crossed the passenger cabin and left a witness mark in the opposite sidewall above row 8, seat A.

One passenger in row 8, seat C was hit by the propeller blade and suffered minor injuries to his left hand. One passenger suffered minor injuries as she was sitting with folded legs during the landing. Five other passengers/crew suffered minor injuries during the evacuation.

Figure C: One propeller blade was wedged into the cabin

The passenger cabin suffered substantial damage. The overall cabin structure remained intact. All the seats remained undamaged and attached to their seat tracks (there were four seats abreast named from left to right ACDF and separated by an aisle.

The visibility in the cabin was very poor after the accident due to dust and/or smoke. The deadheaded cabin attendant seated at 12F claimed that she saw electrical sparks and smoke when the propeller blades entered the cabin in front of her. The cockpit crew were not able to see the aft end of the cabin due to dust and/or smoke when they left the cockpit. Passengers seated in the middle of the cabin found it difficult to find the way to the nearest emergency exit, due to dust and/or smoke. Passengers reported that the fluorescent path (emergency escape lighting system) on the aisle floor was difficult to see due to daylight, dust and/or smoke.
Some debris was found lying on the cabin floor including a large propeller fragment (figure D). Some storage bins were found deployed.

The maximum vertical acceleration during the accident was 1.64g.

Figure D: One Propeller blade was found inside the cabin.

The seat meal tables in front of following seats were found deployed (i.e. meal serving position): 3D, 6C, 7C, 8F, 9F and 16C. Seats C and D are the seats next to the aisle (figure E).
The latch of the meal tables was found slack and easy to move. The latch could rotate both to the left and to the right. All latch pins was found moved towards the aisle and therefore the tables could have been released during the emergency evacuation.

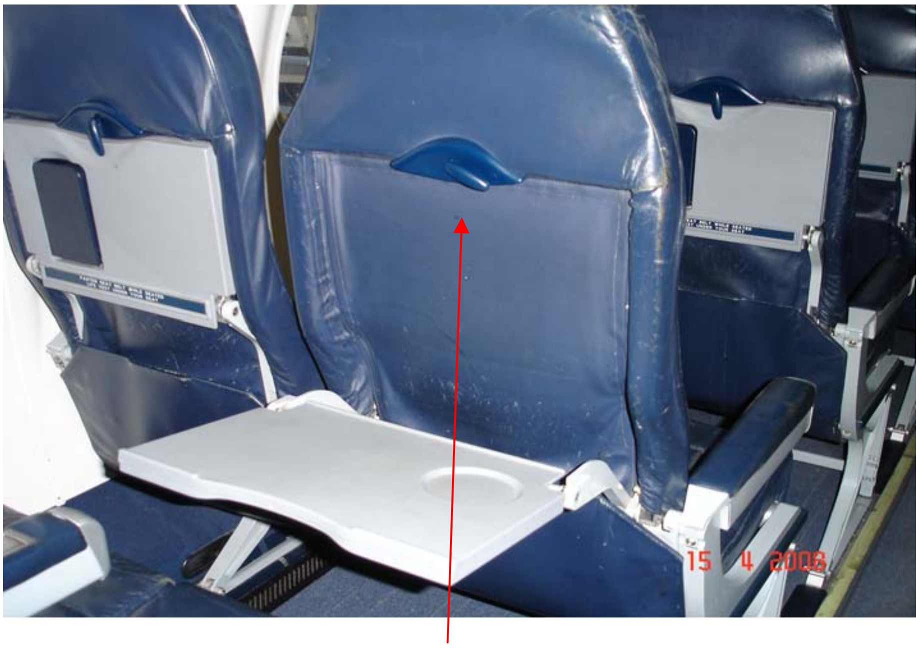


Figure E: Latch moved toward the aisle

The evacuation was initiated by the cabin attendants eight seconds before the commander ordered the evacuation and 28 seconds before the evacuation signal sounded.

The forward left and right doors and the aft left door were used during the evacuation. The aft right door was not used due to the aircraft attitude of 13.2° of bank to the right. The cabin crew felt that extra force should be used to open the left doors. The evacuation took 1 minute and 12 seconds from the time the aircraft came to rest in the grass area until the last person was out of the aircraft.

1.16 Tests and research

1.16.1 Manufacturer's undamped free fall test

The manufacturer of the MLG performed a 15-degree free fall test (without damping) of the MLG. The MLG was placed in a jig and raised until the drag brace had achieved an angel of 15 degrees from the down and locked position and then released (when the MLG was in full-up position the MLG was approximately at 90 degrees in reference to vertical axis).

The test was documented using high speed cameras (1000 fps). The visual result from the cameras showed that the joint lugs between the MLG forward and aft stabilizer brace were temporarily elongated (elastic area of the material) evidentially. The lugs did fracture, but did not separate from the joint. The video showed that the kinetic energy generated during undamped free fall, from 15 degrees position, produced significant g loading and strain gauge results indicated very high stresses at the joints. A great deal of vibration and stress in the whole main gear assembly could be seen on the video.

1.17 Organizational and management information

The operator's maintenance organization has subsequently made an inspection of its DHC-8-400 fleet and found that 26 out of 40 MLG retraction/extension actuator rod ends had loose jam nuts.

21 DHC-8-400 were inspected for loose MLG retraction/extension actuator jam nuts, the results were as follows:

Aircraft registration	Left MLG actuator jam nut	Right MLG actuator jam nut
LN-RDQ	loose	loose
LN-RDD	not loose	loose
LN-RDJ	loose	not loose
LN-RDL	loose	loose
LN-RDP	not loose	loose
LN-RDA	loose	not loose
LN-RDB	loose	loose
LN-RDC	loose	not loose
LN-RDE	not loose	loose
LN-RDF	loose	not loose
LN-RDG	loose	not loose
LN-RDH	loose	not loose
LN-RDI	loose	not loose
LN-RDK	Incident A/C	Incident A/C
LN-RDM	loose	not loose
LN-RDR	loose	loose
LN-RDS	Incident A/C	Incident A/C
LN-RDO	?	?
LN-RDT	loose	loose
OY-KCD	loose	loose
OY-KCE	loose	not loose
OY-KCF	not loose	not loose
OY-KCG	loose	loose

During the investigation, the AIB noted that the difference between the QRH and the manufacturer’s AFM had not been revealed by the quality system. Nor was the complaint card for the retraction/extension actuator rod end revealed by the quality system.
The AIB did not find any other items concerning the quality system. For that reason, the AIB did not audit the operator’s quality system.

1.18 Additional information

1.18.1 Exposure of a high-resolution video.

A relatively high-resolution video was obtained from a Danish news media by the AIB. The video was analyzed:

- Observable crosswind from the right side of the aircraft.
- The aircraft touched down nose high, left MLG first, followed immediately by the right MLG. The right MLG exhibited what appeared to be lateral oscillations at approximately 5 Hz for 2 seconds.
- The right MLG collapsed.
- The aircraft slid down the runway with right wing low and on the aft fuselage.
- It could also be seen that a fire broke out from the aft fuselage while the aircraft was sliding on the runway. Another fire started in the right engine area when the aircraft was sliding into the grass. The fire from the aft fuselage went out when the aircraft entered the grass. The fire from the engine area went out before the aircraft came to rest.
- After the aircraft came to rest smoke could be observed from the right engine area.

1.19 Useful or effective investigation techniques

None

2. Analysis

2.1 Flight crew

The flight crew was properly licensed.

2.2 Aircraft

The aircraft had a valid certificate of airworthiness and the centre of gravity was within the envelope. The aircraft maintenance records were in compliance with the established maintenance program.

2.3 Weather

The weather at the time was VMC and did not influence sequence of events.

2.4 The significant sound

As the Landing Gear Lever was moved from “up” position to “down” position a significant sound was heard. The flight crew could not at first identify the origin of this sound. However, the crew located in the passenger cabin were able to identify the origin to be at the right MLG.

2.5 Passenger briefings

The commander briefed the passengers several times. All the briefings were useful and honest. The commander chose to command the passengers to brace himself. Instead of making the passengers assume the brace position one minute before the landing he chose 10 seconds before landing. This was to prevent some passengers from looking up during the landing. The passengers could hold their breath and tighten their muscles for 10 seconds but hardly for one minute. This procedure prolonged the time of situation awareness for the passengers. This new procedure should be open for discussion.

The cabin attendant (CA1) briefed the passengers using the PA system. The cabin attendants then addressed the passengers individually.

The passengers responded as instructed 10 seconds before the landing.

2.6 Information to ATC

The cockpit crew chose to inform Aalborg Tower about the landing gear problem in due time. The Mayday was also transmitted in due time. The “ground crew” was ready and in position approximately 23 minutes before the landing. The information to the tower was useful and timely.

2.7 Airplane Flight Manual (AFM) and Quick Reference Handbook (QRH)

The AIB found that both the operator’s QRH and the manufacturer’s QRH had some differences from the procedure and checklists in the manufacturer’s AFM. There were some differences between the two QRH’s as well. The AIB has not made a discrimination concerning the difference between the two QRH’s. The AIB has in the following stated, that the QRH divergence from the manufacturer’s AFM.

The commander looked for a checklist concerning an unsafe landing gear in the QRH, but he did not find any checklist with that header. He went through the complete section concerning landing gear problems and found that the checklist “Alternate Landing Gear Extension” was the only checklist he could use (Appendix G).

The QRH alternate landing gear extension checklist referred to one condition in the header (“LDG GEAR INOP” Caution Light). However the landing gear inoperative light was not illuminated. The commander had no other useful procedure than the alternate landing gear extension procedure.

The QRH had only one condition as header in the alternate landing gear extension checklist (“LDG GEAR INOP” Caution Light). However, the AFM had several (Appendix H).

Landing Gear Malfunction (ILLUMINATION OF LDG INOP CAUTION LIGHT), OR
PARTIAL LOSS OF NO. 2 HYDRAULIC SYSTEM QUANTITY (ILLUMINATION OF #2 HYD ISO VLV CAUTION LIGHT), OR
LOSS OF NO 2 HYDRAULIC SYSTEM PRESSURE (ILLUMINATION OF #2 ENG HYD PUMP CAUTION LIGHT).

The QRH had three notes and no cautions in the alternate landing gear extension checklist while the AFM had four notes and two cautions. Only one note in the QRH was the same as in the AFM. It is the AIB's opinion that the lack of useful information in the QRH was significant.

The QRH had a note in the alternate landing gear extension checklist: *"If alternate landing gear extension procedure fails, proceed to QRH page 14.2"*. The items on page 14.2 were: "*Landing gear indication malfunction and landing gear door malfunction"*. The reference to page 14.2 did not lead to any useful information, because page 14.2 was revised without revising the note and therefore the note in the alternate landing gear extension checklist became misleading.

The QRH checklist EMERGENCY LANDING (Both engines operating) was not used by the cockpit crew. This checklist contained the information concerning moving passengers away from the propeller area. The checklist also contained information about which GPWS circuit breakers to pull in order to avoid continuous GPWS warnings during the approach and landing. The alternate landing gear extension checklist did not have the information about which circuit breakers to pull in order to avoid continuous GPWS warnings.

Both AFM and the QRH assumed that the alternative landing gear extension procedure would be successful. The QRH and the AFM should refer to the next appropriate checklist if the procedure being followed was unsuccessful; however this was not a requirement by the authorities.

The QRH and AFM did not contain a procedure labelled "Unsafe landing gear"**.** The cockpit crew instinctively looked for the item "Unsafe landing gear" in the QRH. The QRH did not contain the "Landing Gear Malfunction" event along with the alternative landing gear extension procedure. The AFM did contain the "Landing Gear Malfunction" event along with the alternative landing gear extension procedure.

In the case of this accident, having had a procedure would not have had any impact, as the accident was unavoidable. However the consequences of the accident could have been reduced. Especially, if there had been a consideration in the AFM containing information concerning an in-flight shut down of the engine on the affected side before landing; however this was not a requirement by the authorities.

2.8 Approach and landing

The landing gear warning started and continued after flaps 10° was selected. The GPWS warning started and continued after the aircraft descended below 1000 feet. These warnings made communication in the cockpit difficult and caused unnecessary stress among the cockpit crew. However the information about which circuit breakers to pull was given in the QRH under "Emergency Landing" checklist.

2.9 Cockpit door

The commander chose to leave the cockpit door open during the last part of the flight as a passenger service. However there were more issues to consider. One was faster evacuation of the cockpit crew.

Another was easier crew communication. And it would be easier for the cabin attendants if the cabin attendants had to assist the cockpit crew in case of an accident. More importantly, the open cockpit door provides an additional emergency exit for the passengers through the cockpit escape hatch.

2.10 Left passenger doors

The cabin crew reported that the left passenger doors felt heavier than usual to open. This was probably due to the aircraft right bank angle of 13.2°. The force the cabin attendants needed to use to open the doors was increased, as they had to overcome some of the weight of the doors. Consideration should be given to having an additional able body for the purpose of assisting the cabin attendants in opening the doors.

2.11 Landing gear operation

During retraction, the pressure in the retract retraction/extension actuator is somewhat below the nominal system pressure of 3,000 psi. As the main gear approaches ‘up-lock’, the pressure reaches 3,000 psi, where it is maintained for approximately 3 seconds following closure of the last landing gear door. At this point, the landing gear selector valve de-energizes, and the pressure in the landing gear system reverts to return pressure (50 psi).

Upon extending the landing gear, when the main gear is released from the up-lock, there is a dynamically induced pressure peak of 3300 psi as the MLG shock strut ‘bounces’ against the fluid column in the actuator retract annulus (which tensions the retract actuator; there is a significant braking effect provided by the fluid being exhausted through a restrictor as the landing gear is being extended.) In the absence of the attachment of the retraction/extension actuator to the shock strut, the tensile strength capability of the stabilizer stay during dynamic engagement is induced.

2.12 FDR review

A review of the relevant portions of the FDR’s data confirmed that the right MLG did not reach ‘down-lock’ after the initial down selection, the nose landing gear and the left MLG did. In addition, it was confirmed that the right MLG did not retract when the crew selected the landing gear up. This was consistent with the separation of the retraction/extension actuator piston from the rod end prior to or early in the ‘extend’ cycle, but certainly prior to gear collapse (Extract from the FDR enclosed as appendix I).

2.13 CVR review

The CVR data were reviewed in order to confirm the flight crew statement of a noticeable ‘bang’ coinciding with the initial landing gear extension. It was consistent with the high-energy engagement of the stabilizer stay following the ‘extend’ selection on the approach to EKYT.

2.14 Video recording

With reference to the video recording, the video showed that both engines were running and the ground spoiler was deployed when both main wheels touched the runway (weight on wheels). The video showed that the right gear was unstable and the left gear was stable.

From the video it could be seen that there were lateral oscillations of the right MLG shock strut after touchdown. The oscillations were caused by ether the shock strut piston and the rolling gear having excessive clearance in the torque link assembly, which facilitated rotational motion of the rolling gear about the piston axis in excess of +/- 2 degrees or by the loss of the stabilizer stay, which provides considerable torsional stability to the shock strut / yoke assembly or in a combination of both.

2.15 Fire

Two fires occurred when the aircraft was sliding on and away from the runway. The fires went out by themselves before the aircraft came to rest in the grass area. There was no fire in the cabin, but the fire outside the cabin did create some smoke. The Rescue & Fire Fighting Services came to the scene approximately 32 seconds after the aircraft came to rest. They helped passengers away from the aircraft and prevented further fire from occurring.

2.16 Aalborg Airport emergency plan

Aalborg Airport had – in accordance with the regulations - a detailed emergency plan in place at the time of the accident. This plan was followed without any major deviation.

The injured passengers were transported to Aalborg Hospital. The uninjured passengers were taken to the Airport Departure terminal three.

The Aalborg emergency plan did not include family assistance plans, such as:

- Notification of family members of victims.
- Determining the location and status of victims.
- Providing for the return of personal effects.
- Providing daily briefings to families.

Accordant to ICAO annex 14 a full-scale aerodrome emergency exercise must be performed at intervals not exceeding two years. The last simulation of an aeronautical emergency to the airport was carried out on 26. January 2006, and was therefore within the time limits.

2.17 Survival aspects

During the accident, the data from the FDR showed that the maximum vertical, lateral and longitudinal g forces were 1.64g, 1.00g and 0.92g respectively. The airframe did not exceed the certification requirements specified by Joint Aviation Regulation (JAR) and Federal Aviation Regulation (FAR) Sec. 25.561 (9g forward, 3g upward, 3g sideward on the airframe and 4g on the seats and their attachments). These requirements are established to ensure that under these loads each occupant has every reasonable chance of escaping serious injury in a minor crash landing and also that heavy items in the passenger cabin do not become deformed in any manner that would impede subsequent rapid evacuation of the occupants.

In this case, it seems that both requirements were complied with, because only minor injuries occurred during the accident and subsequent emergency evacuation and because there was no evidence that the rapid evacuation was impeded by loose items or massive objects.

Destruction and disturbance of items in the cabin was caused by the impact and the two propeller blades entering the cabin, which could have either caused direct injuries to occupants or have affected the evacuation. However, one passenger suffered minor injury from one of the blades entering the cabin.

A number of meal trays were found deployed and the latch pins were found moved towards the aisle. The table latch pins were found slack. It was demonstrated that this latch arrangement could cause the meal tray to be easily released during normal movement out of seats. In this accident it did not delay or hinder the evacuation, but in case of rush due to panic, even a minor factor such as this could cause the passengers to block the escape way for passengers sitting in A and F seats.

Some overhead storage bins were found deployed with personal goods inside. It could not be determined if passengers had opened them or if it had happened during the accident.

The reseating of the passengers from right side row, 6, 7 and 8, seats D and F reduced the number of injuries. The left side rows 6, 7 and 8, A and C, were not re-seated since there was only one empty seat available for further reseating, after having moved passengers from seats 6, 7 and 8, D and F; as a consequence one passenger sitting in row 8 seat C was hit by the propeller blade.

In JAR and FAR Sec. 25.803 it must be demonstrated that when the aircraft is at maximum seating capacity, the aircraft, including the crewmembers, can be evacuated to the ground under simulated conditions within 90 seconds. In this case it took 72 seconds, (from 1357:26 to 1358:38) and was within the regulation demonstration time.

The emergency escape lighting system in the right side of the aisle had almost no effect during the evacuation as the accident took place in daylight condition and due to dust and/or smoke.

The accident was survivable.

2.18 Right MLG retraction/extension actuator and rod end

The threaded connection between right retraction/extension actuator piston rod and rod end had suffered severe corrosion. The thread profile in the female part had been undermined to the extent that the pull out strength of the connection had diminished significantly, eventually leading to the parting of the rod end from the actuator piston rod.

The corrosive environment is believed mainly to be caused by condensed water that had collected inside the threaded connection as a result of temperature and pressure variations.

It is evident that the corrosion had attacked the piston rod threads that were in direct engagement with the rod end threads whereas the corrosion attacked in the key way area and in the non-engaged threads was less severe. This suggested that galvanic action between the nobler martensitic stainless steel and the less noble 4340 steel material had enhanced corrosion. There was some evidence of polishing of the male threads from some sort of mechanical rubbing. This mechanical rubbing may also have enhanced the corrosion process by maintaining a metallic clean and thus more efficient surface for the electrochemical cathode reaction and also by perhaps interrupting and removing some of the corrosion products at the corroding steel surfaces.

The AIB found that there was no agreement between the complaint card and what was declared as having being done to the rod end jam nut. It was not possible for the AIB to establish what had been done. But the investigation team had discussed whether the retightening of the jam nut could have had any influence on the sequence of events. The complaint card did not contain any information about the torque applied to the jam nut, but explains why the manufacturer’s original lead seal on the jam nut lock wire was missing. There was no maintenance procedure describing how to re-torque the jam nut, if loose. The Component Maintenance Manual (CMM) had a procedure which is exclusively used when a component is shipped to an overhaul facility. According to the CMM, the required torque of the jam nut was 660-980 Inch Pounds (74.6-110.7 Newton Meters). With no torque value available on the complaint card, the laboratory facility was not able to determine whether or not the re-tightening could have led to an acceleration of the event (disengagement of the rod end from the actuator piston). Taking in consideration the finding of 26 other loose jam nuts, the AIB do not find the re-tightening of the jam nut on LN-RDK to be a contributing factor in this event.

2.19 Left MLG retraction/extension actuator and rod end

While the integrity of the left actuator piston rod and rod end was apparently intact, it was evident from the dismantling and sectioning of the parts that degradation by corrosion and mechanical wear contact had occurred. The left actuator piston rod and rod end connection showed corrosion and mechanical wear, but the deterioration had not yet reached a level, where the applied load sufficed to pull out the rod end from the piston rod. Instead, fatigue cracks had started to appear, which in time could have resulted in complete rupture of the piston rod if the connection had not failed before due to pulling out of the rod end.

It had not yet reached a level where the pull-out strength was low enough to jeopardise the integrity of the connection. However, the looseness created by the corrosion may have shifted the loads down towards the last engaged threads and thereby caused development of cracks in the piston rod threads. The cracking had the appearance of low cycle fatigue at least in the beginning, but as the cracks grew deeper there was a tendency for the crack morphology to change to intercrystalline cracking. This in combination with the many cracks starts points to the influence of corrosion. The cracks were still small, but could develop with time causing complete rupture of the piston rod material.

2.20 MLG retraction/extension actuator maintenance.

Neither the Maintenance Review Board’s (MRB) Report nor the approved Maintenance Requirement Manual contains any specific inspection procedure to be carried out on the MLG retraction/extension actuator and rod end in so far as L-, A- and C-checks. However, the MLG retraction/extension actuator had an overhaul restoration requirement of an interval of 22,400 flight cycles. The restoration requirement calls for replacement of the actuator rod end. The actuator had no specified time between overhaul (“on condition”). At the time of the accident the actual actuator and rod end had completed 14,795 flight cycles. The remaining flight cycles were 7,605.

The inspection to be performed according to the Maintenance Requirement Manual was a zonal inspection program under task number Z700-04E, only.
The maintenance task card FRQ067002 referring to task number Z700-04E (task number 05-47-04-210-802) was the inspection to be performed on the right MLG. The maintenance card did not call for inspection on the retraction/extension actuator and rod end. The items to be inspected on the task card for the right MLG were yoke assembly, outer cylinder, drag strut, wheel and tire assembly and torque links.

The operator's maintenance organization found 26 out of 40 MLG retraction/extension actuator rod ends had loose jam nuts when they subsequently made an inspection of its DHC-8-400 fleet.

2.21 Manufacturer's undamped free fall test

The main landing extension / retraction actuator is used to raise and lower the main landing gear in a controlled manner. The actuator provides dampening both during extension and retraction to control the time it takes to raise and lower the gear. When the main landing gear is fully down, an over centre condition of the stabilizer struts provides a positive down-lock for the gear leg.

The manufacturer of the MLG performed a 15-degree free fall test (without damping) of the MLG. The MLG was placed in a jig and raised until the drag brace had achieved an angel of 15 degrees from the down and locked position and then released (when the MLG was in full-up position the MLG was approximately at 90 degrees in reference to vertical axis).

From the free fall test it was concluded, that undamped free fall from 15 degrees position or higher will have sufficient kinetic energy to cause the stabilizer joint lugs to fail, due to the fact that the stabilizer lugs did fracture during the test.

2.22 Accident scenario and failure sequence

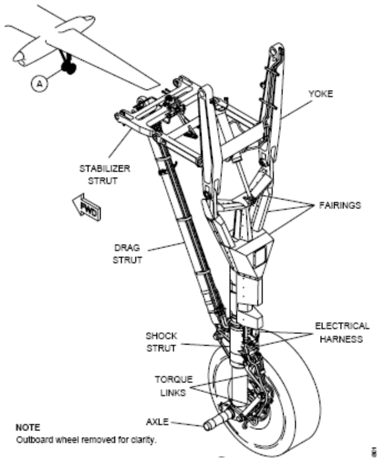
Following the undampened extension of the right main landing gear (after disconnection of the rod end from the actuator piston rod), the ability to lock the landing gear down was lost. The rapid extension of the landing gear resulted in a failure of the stabilizer strut joint lugs, preventing a positive down-lock.

The presence of moisture and the use of dissimilar materials in piston and rod end had resulted in galvanic enhanced corrosion in the less noble part of the metal couple, i.e. the piston rod material.
The retraction/extension actuator rod end separated due to severe corrosion in the threaded connection of the retraction/extension actuator internal piston and rod end. As corrosion had progressed, the looseness of the connection had increased thus allowing the threads to move relative to each other, thereby enhancing the deterioration rate of the threads load carrying capability.
The threads corroded to the point where the tension load on the actuator, which peaks early in the 'extend' cycle, pulled the rod end out.

Eventually the deterioration of the piston rod threads had reached a state where the service load sufficed to pull out the rod end from the piston rod.

Based on evidence at the scene, interviews of the flight and cabin crew, review of the CVR, FDR and video, subsequent metallurgical analyses, and the undamped free fall test of the MLG, the following describes the accident failure sequence (figure F):

- All landing gear retracted normally following take-off.
- Sequence 1: At some point between up and locked position following retraction and reaching ‘down-lock’ following landing gear ‘down’ selection the retraction/extension actuator rod end separated from the actuator piston, effectively disconnecting it from the shock strut.
- Sequence 2, 3 and 4: The right MLG extended under undamped free fall conditions on approach to EKYT with sufficient kinetic energy to cause failure of the stabilizer joint lugs. This failure rendered the stabilizer incapable of safely locking the right main gear in the ‘down’ position, (indication of ‘unsafe’ gear was given).
- Approximately two seconds after touchdown, the right MLG collapsed.
- Sequence 5: During the landing gear collapse, the aft stabilizer was forced over the forward stabilizer, which resulted in the overload tear out of the stabilizer torque tube section and over-travel lock link damage. Damage to the stabilizer assembly was consistent with the post-collapse hypothesis.



Sequence 1: Gear up position

Sequence 2: Gear in transit (Free fall).

Sequence 3: Gear down position.

Sequence 4: Failed stabilizer joint lugs due to free fall.

Sequence 5: The aft stabilizer was forced over the forward stabilizer.

Figure F: Sequence of failure.

3. Conclusions

3.1 Findings

1. The flight crew were properly licensed.
2. The aircraft had a valid airworthiness certificate.
3. The mass and centre of gravity was within the limitations.
4. The weather at the time of the accident was VMC.
5. The aircraft maintenance records were verified to be in compliance with the established maintenance program.
6. The FDR readouts showed that the right main landing gear was in transit from the first time the crew selected gear down.
7. The CVR readouts indicated that the flight crew were not able to find a procedure in the quick reference handbook (QRH) for an “unsafe landing gear”.
8. Neither the QRH nor the manufacturer’s AFM contained a procedure for an “unsafe landing gear”. However the AFM had a checklist covering landing gear malfunctioning.
9. Both the QRH and the AFM assumed that the Alternative Landing Gear Extension procedure would be successful.
10. Neither the QRH nor the AFM referred to an appropriate checklist if the procedure was unsuccessful.
11. Neither the QRH nor the AFM mentioned any consideration about shutting down the engine on the affected side.
12. Neither the QRH nor the AFM contained procedures in the “Landing Gear” chapter to reseat passengers at the affected side. However, a procedure to reseat passengers was covered in the “Emergency Landing” chapter.
13. The QRH checklist EMERGENCY LANDING (Both engines operating) was not used by the cockpit crew.
14. The right MLG was unstable during the two seconds ground roll.
15. Separation of the right MLG retraction/extension actuator from the actuator piston rod end.
16. The jam nut for the right MLG actuator rod end was found with a lock wire intact and in place but without the original manufacturer-installed lead seal.
17. The right and left MLG retraction/extension actuator piston and rod end were made of noble martensitic stainless steel and the less noble 4340 steel material respectively.
18. Retightening of the right MLG retraction/extension actuator jam nut was performed June 7, 2007.
19. There was no agreement between the complaint card and what had been declared as having been done on the rod end jam nut.
20. The difference between the QRH and the AFM was not revealed by the quality system. Neither was the complaint card for the retraction/extension actuator rod end detected by the quality system.
21. The right MLG stabilizer joint lugs failed.
22. Severe corrosion was found in the threaded connection between the right MLG actuator rod and rod end.

23. Moisture had accumulated inside the threaded piston rod to rod end connection of the right retract actuator due to temperature and pressure effects.
24. The left MLG retract actuator piston rod and rod end connection showed corrosion and mechanical wear.
25. There were no specified inspection tasks for inspection of the MLG retraction/extension actuator and rod end either in the MRB's report or in the Maintenance Requirement Manual in so far as "L", "A" and "C" checks.
26. There was no overhaul requirement MLG retraction/extension actuator.
27. There was a replacement requriment for the MLG retraction/extension actuator rod end at interval of 22,400 flight cycles.
28. It was observed that the right MLG shock strut piston and the rolling gear had excessive clearance in the torque link assembly.
29. Six passengers and one crew member suffered minor injuries.
30. A number of meal tables were found deployed.
31. The left passenger doors felt heavier than usual to open.
32. Aalborg Airport emergency plan did not cover a family assistance program.

3.3 Factors

There were five factors' leading to the accident:

1. There were no specified inspection tasks for inspection of the MLG retraction/extension actuator and rod end either in the MRB's report or in the Maintenance Requirement Manual in so far as "L", "A" and "C" checks.

2. The right and left MLG retraction/extension actuator piston and rod end were made of noble martensitic stainless steel and the less noble 4340 steel material, respectively.

3. Severe corrosion in the threaded connection between the right MLG actuator rod and rod end.

4. Separation of the right MLG retraction/extension actuator from the actuator piston rod end.

5. The right MLG stabilizer joint lugs failed.

3.4 Summary

AIB found that, due to severe corrosion of the threaded connection between the right MLG retraction/extension actuator piston rod and rod end, the separation of the actuator piston rod and rod end caused the malfunctioning of the right MLG. When selecting the landing gear to down position, the landing gear was released from the landing gear up-lock hook. Due to the separation of the rod end from the actuator piston, the right MLG extended in an undamped free fall condition. The kinetic energy cause the failure of the stabilizer brace link joint lugs. This failure rendered the stabilizer brace incapable of safety locking the right MLG in down position.

4. Safety Recommendations

4.1 Safety initiatives during the investigation

During the course of the investigation the following safety recommendations were issued:

The following air worthiness directives (AD) were issued:

- **Transport Canada Airworthiness Directive CF-2007-20 dated September 12, 2007.**
- **EASA Emergency Airworthiness Directive No. 2007-0252-E dated September 13, 2007.**

The above AD's were revised after additional information became available during the investigation.

- **Transport Canada Airworthiness Directive CF-2007-20R1 dated October 11, 2007.**
- **EASA Airworthiness Directive No. 2007-0272 dated October 16, 2007.**

4.2 Safety recommendations

The Accident Investigation Board, Denmark makes the following recommendations to the European Aviation Safety Agency (EASA):

a) It is recommended to review the design, the certification and the maintenance program of the MLG retraction/extension actuator and rod end.
REK-01-2009

b) It is recommended to review the landing gear abnormal and emergency procedures contained in the manufacturer's Airplane Flight Manual and Quick Reference Handbook.
REK-02-2009

5. Appendices

Appendix A: Flight history - timetable
Appendix B: LAB report
Appendix C: Complain card
Appendix D: Zonal inspection requirement
Appendix E: Maintenance task Card
Appendix F: Cabin layout
Appendix G: Operator's QRH
Appendix H: Airplane Flight Manual (checklist)
Appendix I: FDR data

Appendix A

Flight history – timetable.

The timetable is based on a summary of events from FDR, CVR, radar, communication and interview data.

1219 – 1232:46 hrs	The aircraft was parked at the domestic terminal at EKCH. The engines were at idle power at 1219 hrs and taxi for runway 04R was initiated at 1221 hrs. The First Officer was the pilot flying. The aircraft started the take-off run at 1232:12 hrs and was airborne at 1232:38 hrs. The Landing Gear Lever was moved from Extend position to Retract position at 1232:41 hrs. Both Nose Landing Gear and MLG were retracted at 1232:46 hrs. The flight crew did not observe any abnormal sounds or warnings during the gear retraction.
1233:32 – 1253:22 hrs	The flaps were retracted from 5° to Up position as the aircraft climbed through 2100 feet at 1233:32 hrs . The aircraft reached its cruising altitude (FL140) at 1240:32 hrs and initiated the descent inbound to EKYT at 1253:22 hrs.
11300:25 – 1301:06 hrs	The aircraft descended through the initial approach altitude (2000 feet at 1300:25 hrs) on final run to runway 26R. At 1300:58 hrs the flaps were selected from Up to 5°. At 1301:01 hrs, the Landing Gear Lever was selected from Retract to Extend. The crew heard a significant loud sound during the landing gear extension as if the landing gear was in a free fall. At first they thought that the sound originated from the nose gear. At 1301:06, the landing gear indication was: Nose Gear Down and Locked, Left MLG Down and Locked and Right MLG in Transit (Not Down and Locked). The first officer informed the commander that one of the landing gears showed an unsafe indication. The commander also checked the green landing gear Advisory Lights and found only two green lights (Left MLG and Nose Landing Gear).
1301:15 – 1301:40 hrs	Aalborg Tower was informed about the problem with the right MLG indication (1301:15 hrs). The Auto Pilot Disengage Warning sounded as the auto pilot was manually disengaged (1301:25 hrs). At 1301:40, a go-around was initiated and flaps were selected from 5° to 10°. The go-around was initiated from 1100 feet MSL. The landing gear selector remained in the Extend position.
1301:53 – 1303:00 hrs	The commander briefed the passengers at 1301:53 hrs. They were informed about a problem with the landing gear and that they would follow an alternate gear extension procedure. Flaps 5° were selected at 1302:38 hrs and flaps were selected Up at 1302:48 hrs. The aircraft was still heading west maintaining 2000 feet. The aircraft turned right towards Aalborg VOR (AAL) holding at 1303:00 hrs. Crew located in the passenger cabin were sure that the significant sound during the landing gear extension originated from the right MLG.

1302:57 hrs	The commander consulted the Quick Reference Handbook (QRH) trying to find the appropriate checklist concerning an unsafe landing gear (1302:57 hrs). He did not find any appropriate checklist concerning an unsafe landing gear.
1303:45 hrs	The first officer asked the cabin attendant (CA1) if he could see whether or not the right MLG was down. The cabin attendant (CA1) informed the first officer that the right MLG appeared to be down (1303:45 hrs). The commander continued looking for an appropriate checklist for an unsafe landing gear.
1303:49 hrs	Via the interphone, cabin attendant (CA2) informed the cockpit crew that she had heard a loud bang as the landing gear was extending (1303:49 hrs).
1304:08 – 1304:31 hrs	The commander consulted the QRH for all landing gear malfunctions trying to find one checklist that was suitable (1304:08 hrs). He went through Alternate Landing Gear Extension, Landing Gear Indicator Malfunction, Landing Gear Door Malfunction, Gear Retraction Failure and Unsafe Gear-indication After Gear-up Selection. He decided that the Alternate Landing Gear Extension checklist was the checklist that was the most suitable (1304:31 hrs).
1304:31 - 1305:34 hrs	The commander began the first attempt to correct the landing gear problem using Alternate Landing Gear Extension checklist (1304:31 hrs). This checklist stated a condition ("LDG GEAR INOP" Caution Light) at the top of the checklist. The commander noted that the Landing Gear Inoperative Caution Light was not illuminated. The Landing Gear Indication was: Nose Landing Gear Down, Left MLG Down and Right MLG remained in Transit. Aalborg Tower cleared the flight to 3000 feet (1305:11 hrs). The commander stated that the only checklist he could find to solve the landing gear problem was Alternate Landing Gear Extension checklist. The aircraft initiated a climb from 2000 feet to 3000 feet at 1305:34 hrs.
1306:26 – 1309:24 hrs	The commander continued to follow the Alternate Landing Gear Extension checklist at this time to the point of manually pumping the landing gear down, but without any success (1306:26 hrs). The cockpit crew decided to retract the landing gear. The commander used the Alternate Gear Extension checklist in reverse order. The Landing Gear Lever was selected from Down to Up at 1307:57 hrs. The Landing Gear Indication was at 1308:02 hrs: Nose Gear Up, Left Main Landing Gear Up and Right MLG remained in Transit. The commander asked the cabin attendant (CA1) to report the position of the MLG (1308:15 hrs). Cabin attendant (CA1) reported that the Left MLG was up and the Right MLG was down (1308:53 hrs). The first officer asked the cabin attendant (CA1) how much time was needed to prepare the passengers for an emergency landing. He informed the cabin attendant that the landing could be rough. The commander went through the Alternate Landing Gear Extension checklist again at 1309:24 hrs.

	During this Alternate Gear Extension procedure the right MLG green light illuminated for a second.
1309:53 – 1312:04 hrs	The Landing Gear Lever was selected from Up to Down at 1309:53 hrs while the Landing Gear Alternate Extension Door was in open position. The Landing Gear Indication was: Nose Landing Gear Up, Left MLG Up and Right MLG remained in Transit. The Landing Gear Alternate Release Door was opened and Main Gear Release Handle was pulled. The commander started manually trying to pump down the landing gear, but without success. The commander noted that he had to use more and more force to move the Hydraulic Pump handle. At 1310:54 hrs the Landing Gear Indication was: Nose Landing Gear Down, Left MLG Down and Right MLG remained in Transit. The commander continued using the Alternate Landing Gear Extension checklist. He had reached the final three items in the checklist. The three last items were "*Anti Skid ... Test*", a note: "*If alternate landing gear extension procedure fails, proceed to QRH page 14.2" and "After Landing: As soon as possible after engine shut down: Ground Locks ... Install"* (1312:04 hrs).
1312:19 – 1312:50 hrs	The first officer suggested that he should make a mayday call in order to prepare the ground crew (1312:19 hrs). The commander agreed. At 1312:33 the First Officer made a mayday call to Aalborg Tower and informed the tower about the landing gear problems. The tower was informed that the cabin attendants needed some time to instruct the passengers before the approach and landing. Aalborg Tower asked for their intensions and was informed that it was to stay at 3000 feet in the holding pattern (1312:50 hrs).
1313:41 hrs	The commander went through the text in the Alternate Landing Gear Extension checklist again. He confirmed that there were only two green lights on each of the two landing gear indication systems (1313:41 hrs). The commander concluded that it was not possible for him to pump the landing gear down.
1314:12 – 1314:24 hrs	The first officer suggested that the cabin attendants could begin to instruct the passengers for an emergency landing, and the commander agreed (1314:12 hrs). The first officer informed the cabin attendant (CA1) that they should prepare the passengers for an emergency landing (1314:24 hrs). The cabin attendant was informed that they had plenty of time as they would need to use more fuel before the approach and landing.
1314:46 hrs	The commander informed the passengers that the Alternate Landing Gear Extension procedure had failed. The passengers were informed that it was not clear whether or not the landing gear would remain down during the landing. The passengers were also informed that the flight would remain in the holding pattern in order to use fuel and thereby reduce the landing weight. They were instructed to pay attention to the briefing the cabin attendants would be giving shortly (1314:46 hrs).

1314:57 hrs	The cockpit crew concluded that there was no procedure that could solve the landing gear problem (1315:57 hrs).
1316:12 hrs	The cabin attendant (CA1) asked the commander to which level he should prepare the passengers and he was told to prepare the passengers as much as possible (1316:12 hrs).
1316:23 hrs	The commander left the cockpit and made a visual inspection of the Right MLG (1316:23 hrs).
1317:32 – 1318:27 hrs	The first officer contacted the operator at Aalborg. He informed the operator about the situation (1317:32 hrs). Aalborg Tower informed the first officer that it would take about 15 minutes before the ground crew would be up to scratch (1318:27 hrs).
1318:37 hrs	The commander returned to the cockpit and informed the first officer that the Right MLG looked normal (1318:37 hrs).
1318:48 hrs	The cockpit crew discussed whether they could land with 1000 kg fuel. They agreed on landing with less than 1000 kg of fuel (1318:48 hrs).
1318:54 hrs	The cabin attendant (CA1) began the passenger briefing at 1318:54 hrs. After the general passenger briefing the passengers were briefed individually and instructed to demonstrate the brace position.
1319:00 – 1319:07 hrs	The commander and the first officer discussed if they could do anything else. The commander felt that he needed a checklist for unsafe landing gear (1319:00 hrs). The first officer suggested that he could have a look in the checklist and the commander agreed. Flight control was handed over to the commander (1319:07 hrs).
1319:15 hrs	Aalborg Tower asked the commander if he would like a visual inspection from a military aircraft. The commander explained that he could see the MLG from the passenger cabin. He informed the tower that the gear was down but he could not see if it was locked (1319:15 hrs).
1321:14 hrs	The cockpit crew tried once more to pump the landing gear down and were able to feel that force was required to move the Hydraulic Pump handle (1321:14 hrs).
1321:35 – 1322:10 hrs	The commander reported that he was turning inbound. Aalborg Tower asked if he wished to start the approach. The commander informed the tower that they needed to use more fuel and that they would stay in a holding position for about 20 more minutes (1321:35 hrs). The commander suggested and selected flaps 10° to increase drag and fuel flow. The landing gear warning horn started at the same time (1321:55 hrs). The flaps were retracted to flaps 5° in order to stop the landing gear warning horn (1322:10 hrs).

1323:08 hrs	The cockpit crew discussed which runway to use. If they used runway 08L the left MLG would touch the runway first but if they used runway 08L they would have to make a tailwind landing. A decision was made to land on runway 26R (1323:08 hrs).
1323:11 hrs	The first officer started the Alternate Landing Gear Extension procedure again and began manual pumping of the landing gear alternate hydraulic system. He also felt that force was required to move the Hydraulic Pump handle (1323:11 hrs).
1324:05 hrs	At this time, Aalborg Tower was stopping unnecessary air traffic from taking off from EKYT. However, the commander reminded the tower that they would stay in the holding pattern for about 20 minutes more (1324:05 hrs).
1324:44 – 1326:33 hrs	The first officer suggested that he would like to make a visual inspection of both left and right MLG. The commander agreed (1324:44 hrs). The first officer returned to the cockpit and informed the commander that the cabin attendants were still briefing the passengers individually (1326:33 hrs). The commander handed over the flight controls to the first officer and asked him to fly and land the aircraft (1326:33 hrs).
1326:45 – 1327:38 hrs	The cockpit crew discussed if they should move the passengers away from the right propeller area. They agreed on moving the passengers away from the right propeller area. The commander checked how many empty seats were available and the first officer suggested moving passengers to the aft part of the cabin (1326:45 hrs). [The centre of gravity LIZFW was 17 and the limitations were between 10 and 32]. The first officer instructed the cabin attendant (CA2) to move the passengers away from the right propeller area and to reseat the passengers in the aft part of the cabin. He explained to her that if the landing gear collapsed there was a possibility that the propeller fragments would penetrate the fuselage. The first officer also instructed her to inform the passengers about this possibility (if asked) (1327:38 hrs). There were a total of 7 empty passenger seats. [The cabin version was a 76 passenger seat version with 69 passengers onboard].
1328:55 hrs	The commander asked if able bodies had been briefed and the first officer informed him that they had (1328:55 hrs).
1329:11 hrs	The commander informed the first officer that he would use and read the On Ground Emergencies checklist (if required) (1329:11 hrs).
1329:56 hrs	The cabin attendant (CA2) asked the commander if it was OK to move the passengers seated near the left engine as well and the commander replied that it was only required to move the passengers at the right side of the passenger cabin (1329:56 hrs). The first officer suggested moving as many as possible of the passengers from the right side of the cabin. The passengers seated in rows 6, 7 and 8, seats D and F were reseated.
1330:11 hrs	The TCAS issued a traffic advisory at 1330:11 hrs.

1330:46 hrs	At 1330:46 hrs the commander briefed the passenger about the reason for holding. It was to use fuel and thereby make the aircraft as light as possible before the landing. He explained that the amount of fuel at this time was 1250 kg and that he would like to get the amount of fuel down to 500 kg.
1330:58 – 1331:28 hrs	Aalborg Tower asked about the amount of fuel on board at the time of landing and the first officer estimated 600 to 700 kg (1330:58 hrs). The first officer suggested 600 kg as landing fuel, as 600 kg fuel would make a go around possible. The commander agreed (1331:28 hrs).
1331 – 1332:48 hrs	At 1331 hrs the technical department sent an Aircraft Communication Addressing and Reporting System (ACARS) message to the crew. The technical department requested information concerning the landing gear problem (if time permitted). At 1332:48 hrs a circular phone conversation was made between the commander and the technical department. However the phone connection failed and no useful technical information was obtained.
1334:45 hrs	Aalborg Tower reported that the ground crew were ready and in position (1334:45 hrs).
1335:01 – 1335:25 hrs	At 1335:01 hrs the first officer requested surface wind information and the tower informed him that the wind direction was 300 degrees and the velocity was 9 knots. The crew concluded that they should land on runway 26R (1335:25 hrs).
1335:46 – 1337:51 hrs	The cockpit crew discussed what could happen during and after the landing. The commander was not sure if the antiskid system would be serviceable. The first officer was instructed not to use too much wheel brake during the landing run. After the landing the commander would install landing gear safety pins in the landing gear (1335:46 hrs). The commander informed Aalborg Tower of his intensions. After the landing the commander would stop the engines and place landing gear safety pins in the landing gear. The commander asked the tower if it was possible to get a bus to transport the passengers to the terminal building. The controller would try to arrange a bus for the passengers (1337:51 hrs). The commander briefed the cabin attendant (CA1) what was planned after landing, e.g. that the engines would be stopped. The commander suggested that the deadhead crew should be used as able bodies; they should be instructed to operate the doors and should be seated accordingly. The cabin attendant (CA1) was instructed to use all exits except if the area at the door was on fire. The cabin attendant was informed that landing was expected within 15 to 20 minutes.
1340:57 hrs	An ACARS message from the technical department stated that they could not assist with further information but to follow the checklist and they suggested that the flight should make a diversion to EKCH (1340:57 hrs). The flight crew considered the present fuel on board and decided to make the landing at EKYT. The flight crew was confident that the fire brigade at EKYT had enough capacity to handle an emergency. The first officer replied to the ACARS message from the operator.

	The first officer informed the commander that he had already locked his shoulder harness. The cockpit crew gave a briefing on the approach and landing (visual approach and threshold speed 118 knots).
1343:41 hrs	At 1343:41 hrs the commander decided that the cockpit door should remain open during the rest of the flight. The open cockpit door was intended to have a positive effect on the passengers. The cabin attendant (CA1) felt that the cockpit/cabin communication was easier with the open cockpit door. The cabin attendant (CA1) was informed that they expected to land in 10 to 15 minutes. The commander closed the Landing Gear Alternate Extension Door to prevent the first officer from stumbling during an evacuation.
1345:56 hrs	The cockpit crew discussed whether they should start the approach earlier than planned. There were two considerations, the amount of landing fuel and not keeping the passengers in suspense. It was decided to make one more turn in the holding pattern before they would start the approach. The final holding pattern was initiated at 1345:56 hrs, and the first officer informed the tower that the flight was ready for the approach. Aalborg Tower cleared the flight to descent to 2000 feet and that they should report when starting the descent.
1346:40 – 1348:06 hrs	The commander informed the crew that he would inform the passengers during the approach (1346:40 hrs). The commander briefed the passengers. He would inform them when the aircraft passed 1000 feet descending and 10 seconds before landing at which time he would instruct the passengers to brace. He informed the passengers to hold their breathe and to tightened up their muscles while they were in the brace position. This procedure was intended to provide greater protection (1348:06 hrs).
1351:46 hrs	The flaps were selected from 5° to 10° and the landing gear warning horn started. The warning horn continued throughout the remaining flight (1351:46 hrs).
1354:49 – 1355:16 hrs	The commander informed the passengers at 1354:49 hrs that the aircraft was passing 300 meters descending (1000 feet). At 1355:16 hrs an automatic altitude call was issued “one thousand”.
	The first officer asked the commander if he had given the brace command. The commander replied that he would give the command 10 seconds before landing in order to prevent the passengers from looking up.
1356:12 hrs	During the final approach The Ground Proximity Warning System issued continuous warnings “Too Low Gear” (1356:12 hrs).
1356:53 hrs	The commander ordered the passengers to bend forward and bend down approximately 10 seconds before touchdown (1356:53 hrs). The cabin attendant (CA1) located in the forward part of the passenger cabin was facing aft. He saw all the passengers responding as instructed. The cabin attendants repeated the command “brace” continuously until the aircraft came to rest.
1358:08 -	At 1357:08 the Left MLG made contact with the runway followed by the Right

1357:11 hrs	MLG. The Spoilers were extended one second later (1357:09 hrs). The Right MLG collapsed at 1357:10 hrs and the Right Propeller made contact with the runway at 1357:11 hrs. Fragments from the propeller went through the fuselage and into the passenger cabin. One large fragment went through a cabin window and into the passenger cabin. The maximum vertical acceleration during the accident was 1.64 g.
1357:14 – 1357:18 hrs	As the aft right fuselage made contact with the runway, flames and sparks were emitted (1357:14 hrs). Some smoke appeared in the mid to aft part of the passenger cabin. Shortly after the propeller had made contact with the runway a fire occurred in the right engine area (1357:16 hrs). The aircraft departed the runway to the right. The fire in the fuselage went out as the aircraft departed the runway into the grass area (1357:18 hrs).
	The cabin attendant (CA2) located in the aft part of the passenger cabin was facing forward. She was using an "H" type seatbelt. Even though she had fastened the seatbelt tight she had a tendency to slide under and out of the seatbelt.
1357:22 hrs	The fuel valves were closed at 1357:22 hrs. [The FDR data did not specify which fuel valves were closed].
1357:26 – 1357:39 hrs	The aircraft departed the runway to the right and came to a rest on a heading of 340° at 1357:26 hrs. The commander started the On Ground Emergency checklist at the same time. The fire in the right engine area went out but some smoke continued to originate from the engine area (1357:30 hrs). The first cabin door was opened at 1357:31 hrs. The forward left and right doors and the aft left door were used during the evacuation. The aft right door was not used because the aircraft attitude was banking 13.2° to the right. The cabin crew felt that extra force was needed to open the left doors. The commander ordered the cabin attendants to start the evacuation at 1357:39 hrs.
1357:58 – 1358:12 hrs	A fire engine intercepted the aircraft on the grass area. The fire engine started fire-fighting procedures from the aircraft 2 o'clock position 32 seconds after the aircraft came to rest (1357:58 hrs). The fire engine stopped fire-fighting procedures 14 seconds later. At that time the smoke from the right engine area had disappeared (1358:12 hrs). Some of the foam from the fire engine passed over the fuselage into the area at the aft left door. Some of the foam entered the passenger cabin and was at first mistakenly identified as fuel.

1357:59 – 1358:02 hrs	The Evacuation signal started to sound at 1357:59 hrs and the last crew member was outside the aircraft at 1358:38 hrs. The final SSFDR data was recorded at 1358:02 hrs.
	From her position cabin attendant (CA2) could not see if all the passengers and crew were evacuated. The Rescue and Fire-fighting service was informed by the commander that all “Souls Onboard” had been evacuated. The Fire Incident Officer ordered a team of smoke-divers into the aircraft to look for any remaining passengers and possible internal fire. They did not find any passengers or any fire.

Report on Examination of Retract Actuator Piston Rod and Rod End
Q-400 Reg. LN-RDK SN. 4025 Accident Denmark

Requested by: Accident Investigation Board Denmark

Reported by: Curt Christensen, FORCE Technology

Reviewed by: Hans Peter Nielsen, FORCE Technology

Our ref.: 107-34859 CC/mal

31 October 2007

Materials and Environment

Introduction

FORCE Technology was requested to examine the retract actuator piston rods and rod ends of the right and left main landing gear of the Bombardier Dash-8 Q 400 aeroplane that crash landed in Aalborg Airport on 7 September 2007.

The purpose of the examination is to describe the submitted parts' conditions and to elucidate on the cause(s) that led to pull out of the rod end from the right actuator piston. The examinations include visual inspection supplemented by scanning electron microscopy and metallographic and chemical analyses.

Results

Right hand retract actuator

Part number 46550-7
Serial number Mal-0063
Date 11-99
Figure 1 shows a photo of the actuator and the piston rod end. Figure 2 shows close up views of the piston rod female thread and the rod end male thread in "as received" condition.

The threaded piston rod end was sectioned longitudinally as shown in Figures 3, 4 and 5. Figure 6 shows a section of the piston rod before and after cleaning. It is evident that the female threads were severely damaged and partly eaten away by corrosion. Figures 7 and 8 show a scanning electron microscope image and a longitudinal section through some of the severely damaged threads. Figure 9 shows tearing and shearing of the remaining thread profile tips at the mouth of the piston rod during final pull out of the rod end. Figures 10 and 11 show the appearance in the non-engaged part of the threads. The contours of the non-engaged threads appear intact but at closer view it is evident that corrosion has also occurred in these parts.

The thread areas coinciding with the position of the key way in the rod end (visible in Figure 3) are less attacked by corrosion, but corrosion attacks are still apparent, c.f. Figures 12 and 13.

Figure 14 shows distribution of corrosion along the bore. All engaged threads show broadening of the thread valleys and significant reduction of the thread crests. The loss of material is apparently bigger in the lower half of the engaged threads as illustrated by the superimposed dashed line representing the position of the nominal thread bottom. The remaining thread tips are deformed in direction of the pull-out. Figures 15 and 16 show pictures of the extent of corrosion and also show the general tip deformation and white etching layer from intimate contact with the rod end during pull-out.

Figures 17 and 18 show the appearance of the rod end male thread. The thread valleys are filled with a dry powder-like product and metallic ligaments. A longitudinal cut of the male thread is shown in Figure 19. The thread tops appear slightly deformed and the very top is partly sheared off as illustrated in Figure 20. The slight concaveness of the flank at the arrow in Figure 19 is caused by wear, i.e. polishing contact with opposing material (or corrosion products). This is further evidenced in Figure 21 by way of oblique light mirror reflections from the polished, concave thread flanks.

Some minor cracks were identified at the bottom of thread nos. 9 and 10 counted from the rod end. The crack in thread no. 10 is shown in Figure 22 at the arrow. Micrographs and scanning electron images of the cracks are shown in Figures 23, 24, 25 and 26. The crack path is mainly transcrystalline, but with some tendency to follow prior austenite grain boundaries.

The piston rod and the rod end were analysed by emission spectrometry. The results are shown in Appendices 1 and 2. The rod material corresponds to 4340 material and the rod end is made of 12% Cr stainless steel with ~8% Ni. The microstructures are shown in Figures 27 and 28. It consists of tempered martensite in both cases. The Vickers hardness of the materials is ~ 420 for the piston rod and ~ 410 for the rod end.

Corrosion products in the female threads were analysed by energy dispersive x-ray analysis in scanning electron microscope. The products consist mainly of Fe and O (iron oxide) with small amounts of Si, P, S and Ca, c.f. Figure 29.

Left hand retract actuator

Part number 46550-7

Serial number Mal-0058

Date 11-99

The left side actuator piston rod and rod end were dismantled and examined for comparison with the right hand actuator parts. It was noted that the lock wire was intact and in place before dismantling. The lock nut could easily be moved on the rod end, but there was remarkably more resistance during un-screwing of the rod end from the piston rod. The rod end threads shown in Figure 30 appear undamaged as did the piston rod threads at first look from the outside. However, cleaning and longitudinal sectioning of the piston rod revealed some metal loss, c.f. Figure 31. The left hand piston also features less corrosion at the position of the rod end key way as shown in Figure 32. Figure 33 shows the thread's appearance in more detail. While corrosion attacks are obvious there is also evidence of some mechanical contact marks in the thread tops.

The rod end threads were partly filled with a hard brittle compound that could be easily plied out by a small screw driver, see Figure 34. Energy dispersive analysis of the plied-out compound is shown in Figure 35. It contains large amounts of Fe and O (iron oxide) and small amounts of Si, P and K.

Figure 36 illustrates distribution of the metal loss along the threaded bore of the piston rod. It appears fairly evenly distributed apart from the first and the last engaged threads.

Cracking was observed in the bottom zones of the last engaged threads as shown in Figure 37. The cracking appears as a series of more or less discontinuous and partly overlapping cracks each running over a length of ~ 30 mm. The Light optical photos in Figures 38 and 39 show the cracking at the thread bottom. The scanning electron microscope image in Figure 40 shows the cracking coinciding with local corrosion pits at some point. Figures 41 and 42 show metallographic cross sections of the cracks. The larger of the cracks was opened by an artificial cryogenic fracture. The free-laid crack surface is shown in Figures 43 to 46.

Energy dispersive analyses of corrosion products from the key way and greasy compounds collected outside the piston rod at the lock nut, c.f. Figure 47, are shown in Figures 48 and 49 respectively. In both cases large amounts of iron oxide (Fe and O) and some carbon (C) are found. Also small amounts of Si, P and S are present. In the key way products there were small amounts of (K). In the greasy compound there was Al, Cd, K and Ca.

Discussion

Based on the examination reported above we can conclude that the threaded connection between right retraction actuator piston rod and rod end has suffered severe corrosion. The thread profile in the female part has been undermined to the extent that the pull out strength of the connection has diminished significantly eventually leading to parting of the piston rod from the rod end.

The corrosive environment is believed to be mainly condensed water that collects inside the threaded connection as a result of temperature and pressure variations. The presence of calcium, Ca, and potassium, K, in some of the corrosion products may signify that de-icing salts, e.g. calcium magnesium acetate and potassium chloride, could have contributed to the corrosive environment, but the small amounts and the lack of e.g. chloride indicate that the contribution was very modest. The lack of chloride in the greasy compound from the lock nut, Figure 49, could also suggest that potassium and calcium were integral constituents present in the grease.

It is evident that corrosion has attacked the piston rod threads that were in direct engagement with the rod end threads whereas the corrosion attacks in the key way area and in the non-engaged threads are less severe. This suggests that galvanic action between the nobler martensitic stainless steel and the less noble 4340 steel material has enhanced corrosion. There is some evidence of polishing of the male threads from some sort of mechanical rubbing. This mechanical rubbing may also enhance the corrosion process by maintaining a metallic clean and thus more efficient surface for the electrochemical cathode reaction and also by perhaps interrupting and removing some of the corrosion products at the corroding steel surfaces.

The small cracks found in the right hand actuator rod end are akin to hydrogen stress cracking. Part of the electrochemical corrosion process at the rod end threads is liberation of atomic hydrogen. Hydrogen atoms may enter into the rod end material and as the microstructure is sensitive to hydrogen embrittlement to a certain extent small cracks may form in the stressed part. The cracks have had no influence what so ever on the pull-out of the rod end but are merely a consequence of the corrosion attacks that lead to the loss of integrity of the piston rod to the rod end connection.

While the integrity of the left actuator piston rod and rod end were apparently intact it is evident from the dismantling and sectioning of the parts that degradation by corrosion and mechanical wear contact has occurred. It has not yet reached a level where the pull out strength is lowered enough to jeopardise the integrity of the connection. However, the looseness created by the corrosion may have shifted the loads down towards the last engaged threads thereby causing development of cracks in the piston rod threads. The cracking has the appearance of low cycle fatigue at least in the beginning, but as the cracks grow deeper there is a tendency for the crack morphology to change to intercrystalline cracking. This in combination with the many crack initiations points to an influence from corrosion. The cracks are still small, but could develop with time causing complete rupture of the piston rod material.

It is noted that the microstructures and hardness of the piston rod and rod end materials are homogeneous and there are no signs of inherent material defects or deficiencies as being causative or contributory to the pull-out failure.

Conclusion

The pull out of the rod end from the right hand retract actuator was the result of severe corrosion in the threaded connection.

Water has accumulated inside the threaded piston rod to rod end connection of the right hand retract actuator.

The presence of water and the use of dissimilar materials in the piston rod and rod end have resulted in galvanically enhanced corrosion in the less noble of the metal couple, i.e. the piston rod material.

As corrosion has progressed the looseness of the connection has increased thus allowing the threads to move relative to each other, thereby enhancing the deterioration rate of the threads load carrying capability.

Eventually, deterioration of the piston rod threads has reached a state where the service load has sufficed to pull out the rod end from the piston rod.

The left actuator piston rod and rod end connection also did show corrosion and mechanical wear, but the deterioration had not yet reached a level at which the applied load sufficed to pull out the rod end from the piston rod. Instead, fatigue cracks had initiated which in time could have resulted in complete rupture of the piston rod if the connection would not have failed before as a consequence of the rod end pull out.

CORROSION & METALLURGY

Hans Peter Nielsen
Hans Peter Nielsen

Curt Christensen
Curt Christensen

Figure 1: View of right hand retract actuator with piston rod and rod end at top.

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Figure 2: Threaded parts of piston rod and rod end in “as received” condition.

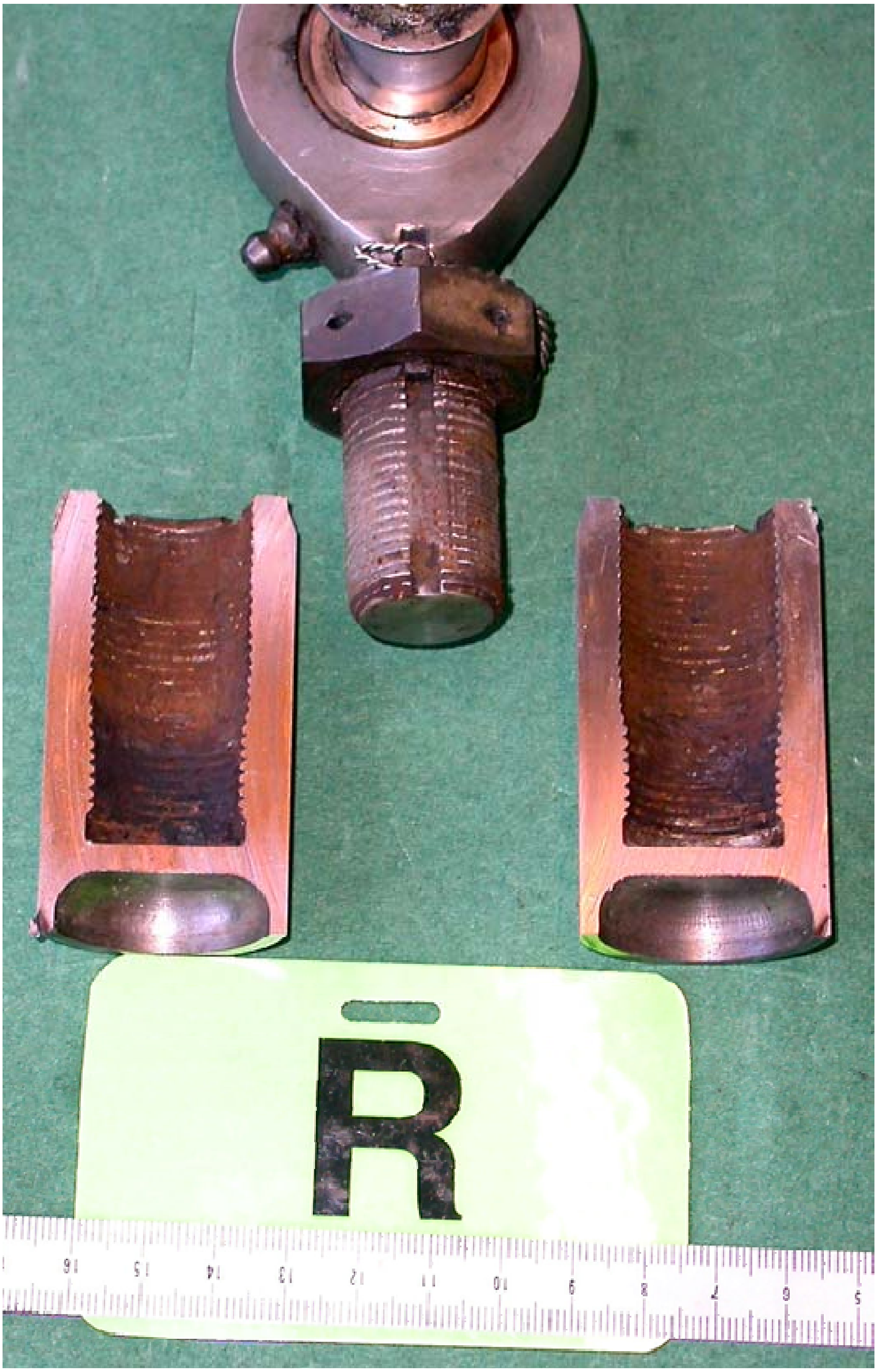

Figure 3: Longitudinal sectioning of piston rod end.

9

Figure 4: Higher magnification of Figure 3.

Figure 5: Higher magnification of Figure 3.

11

Figure 6: Part of piston rod in “as received” and cleaned condition. Note the severe corrosion of thread tops and bottoms.

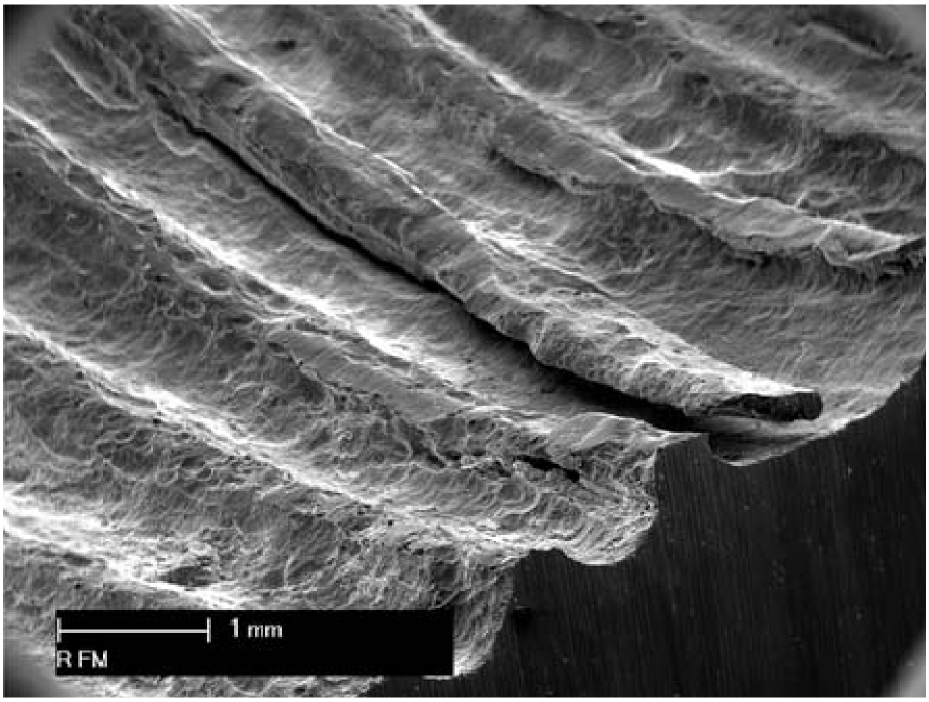

Figure 7: Scanning electron microscope image and metallographic section of severely corroded threads.

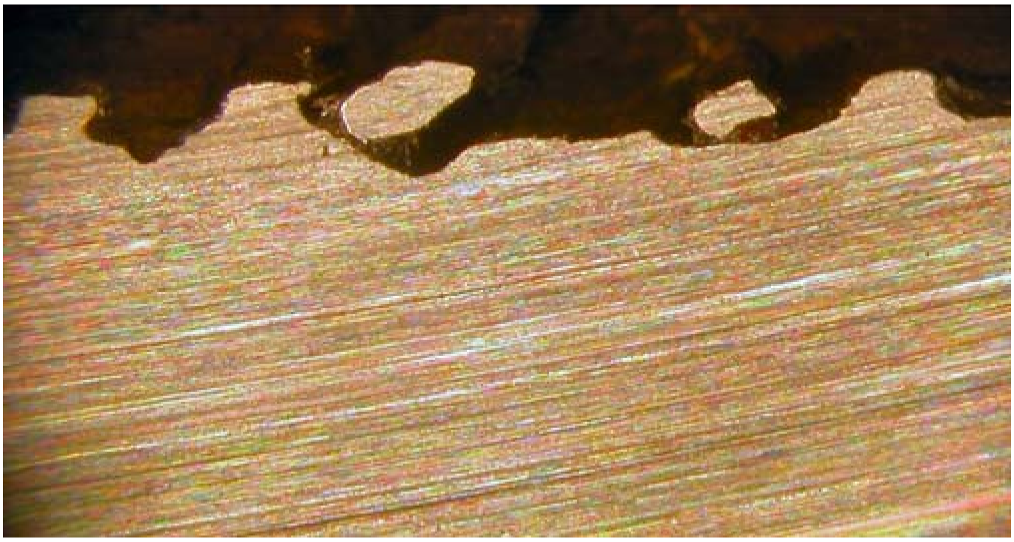

Figure 8: Metallographic section of severely corroded threads in Figure 7. Note that 2 of the threads are completely undermined by corrosion.

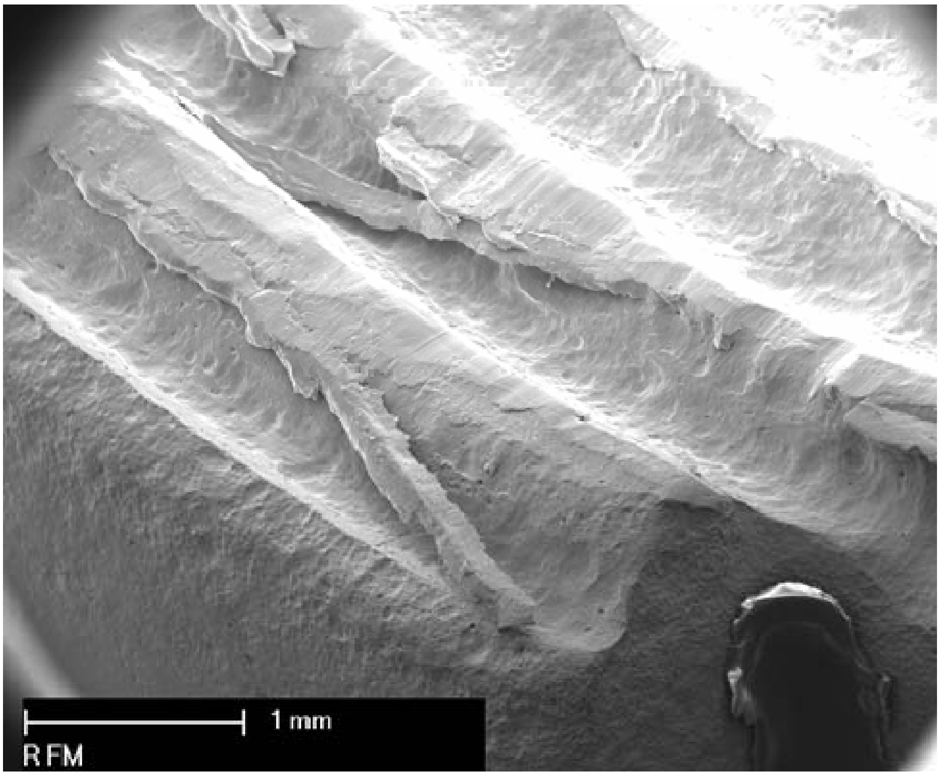

Figure 9: Scanning electron microscope image of threads at mouth of piston rod, showing shearing off of thread tops during final disengagement.

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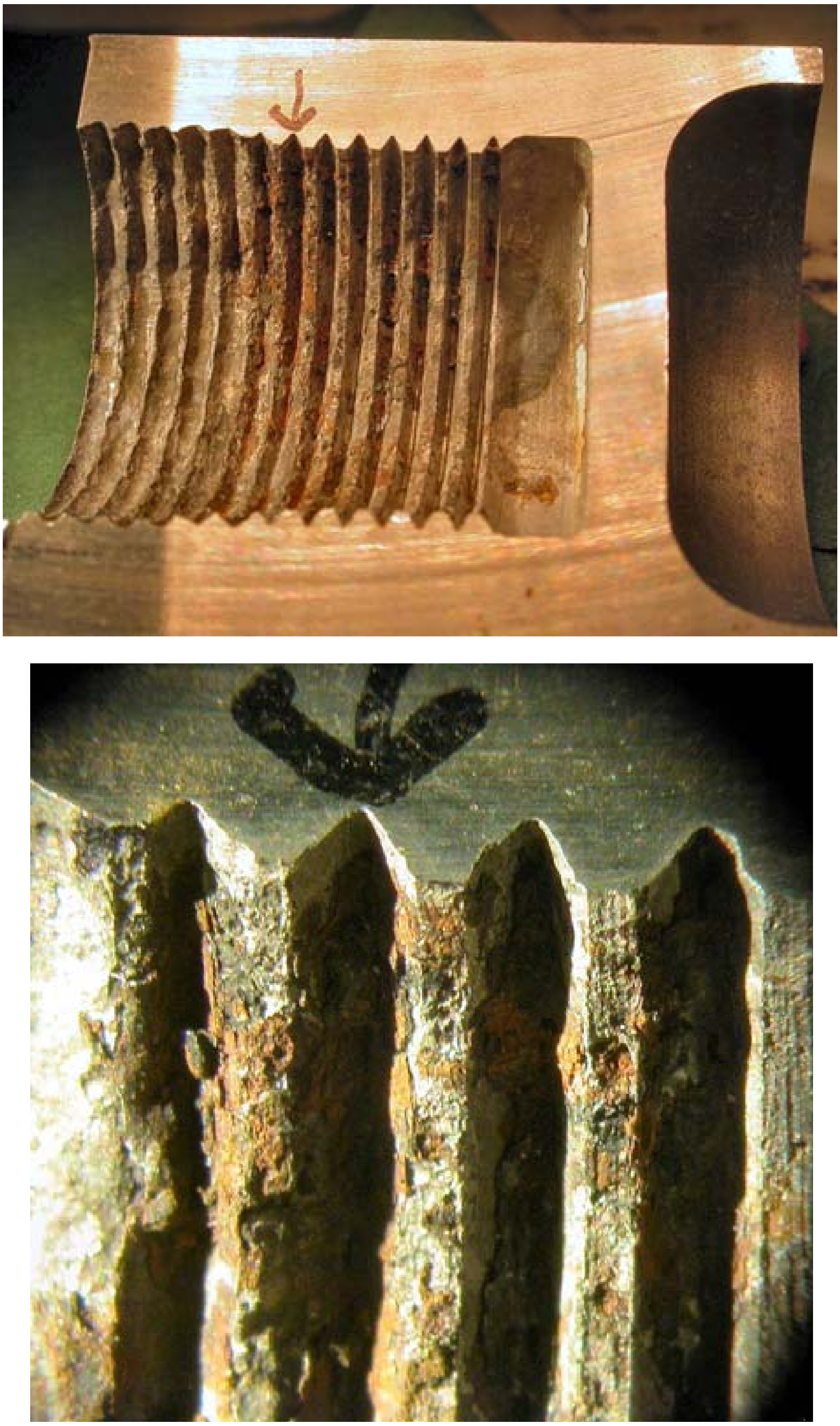

Figure 10: View of threads near bottom of piston rod. The arrow points to the last engaged thread.

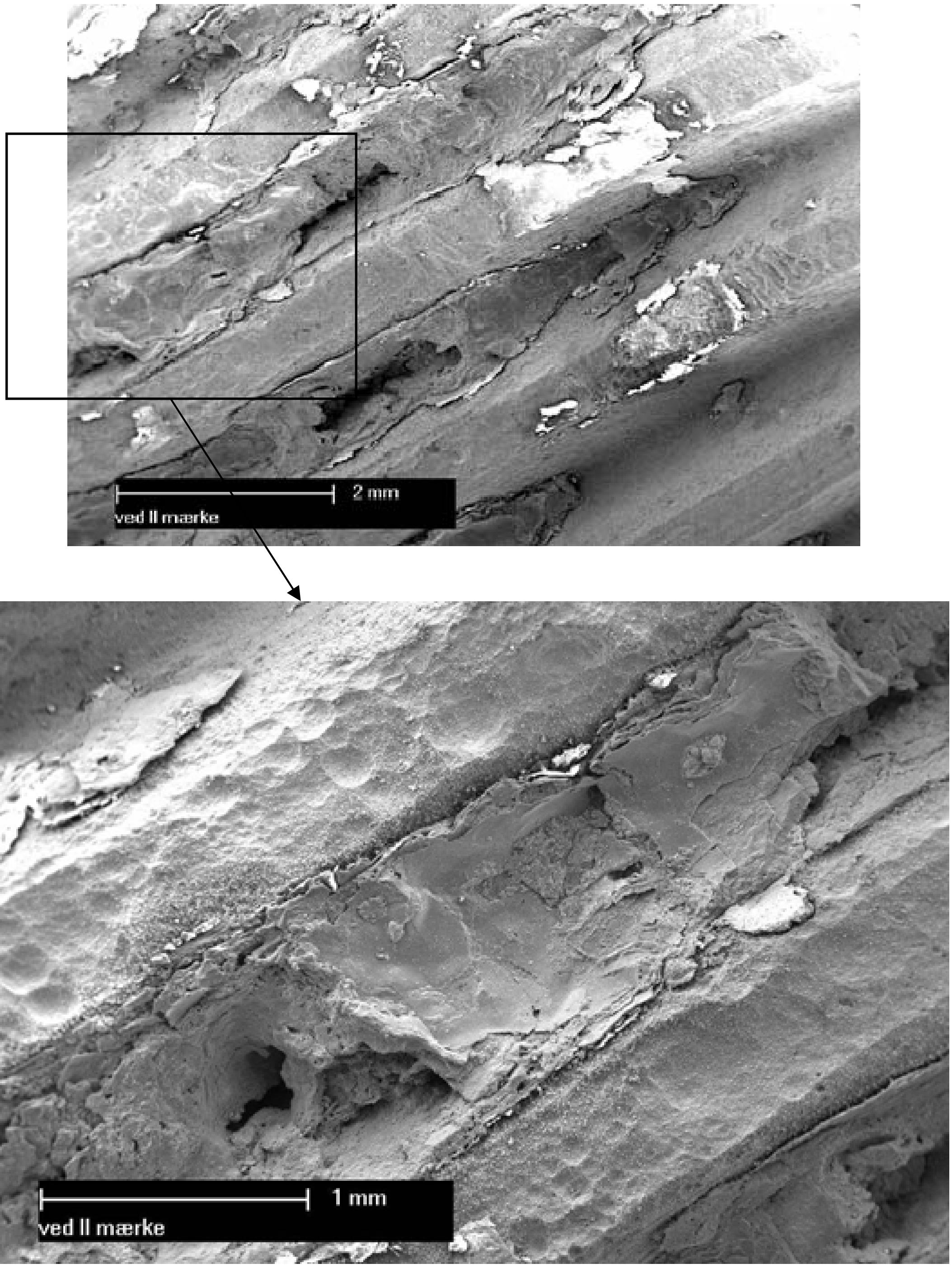

Figure 11: Scanning electron microscope images of non-engaged threads. Note the corrosion attacks in the thread tops.

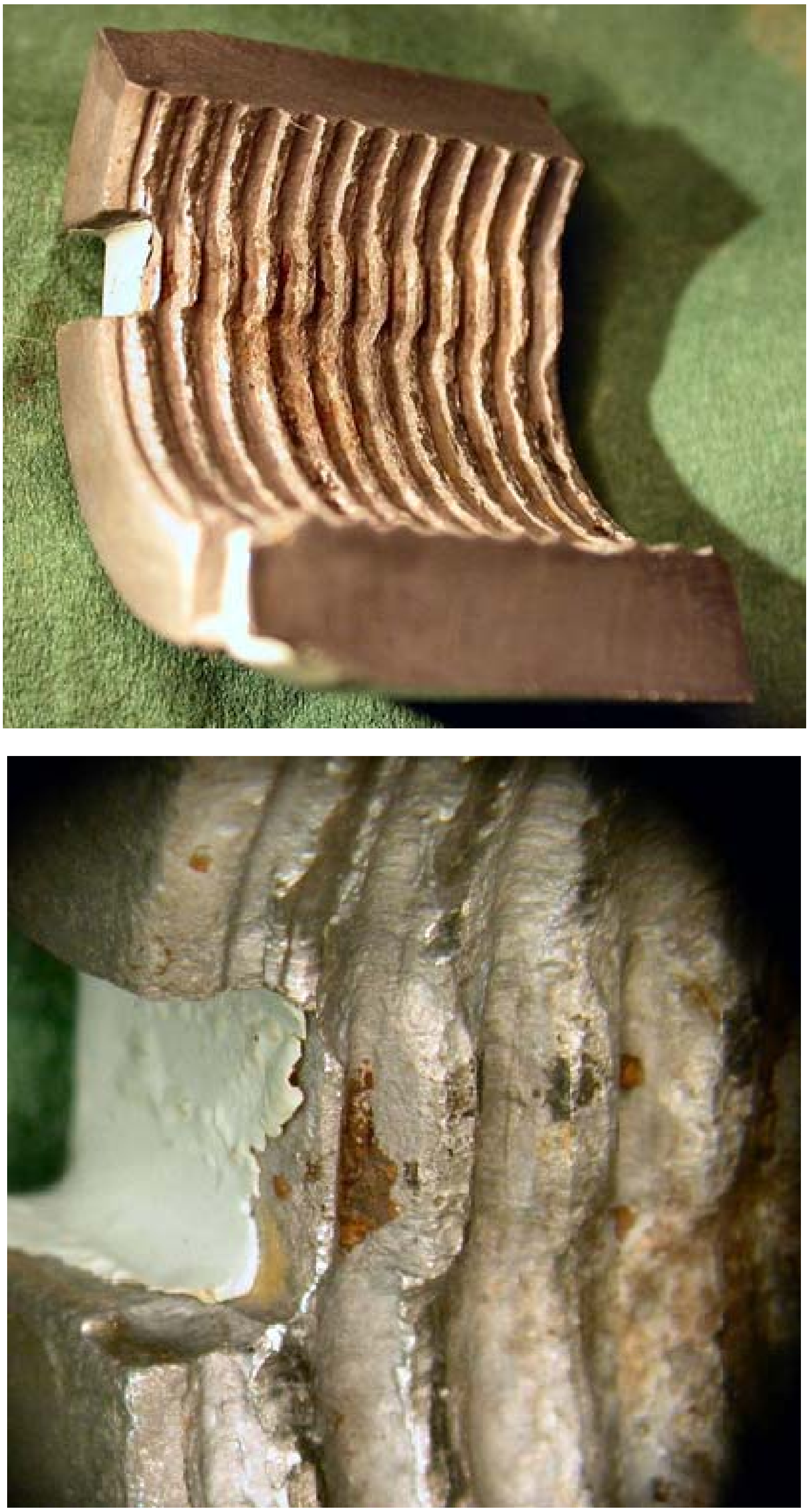

Figure 12: View of threads near piston rod mouth showing significantly less metal loss in the key way area.

17

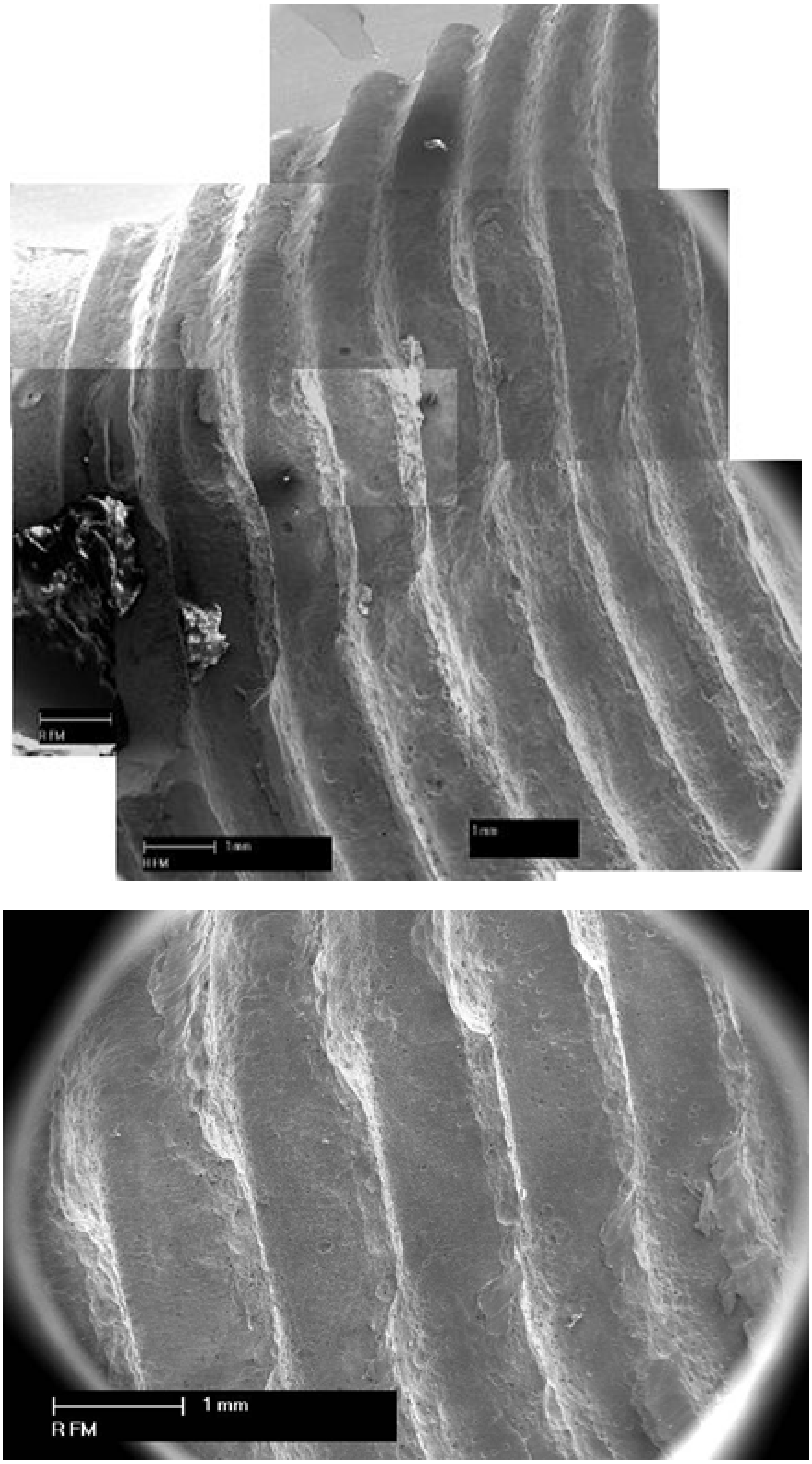

Figure 13: Scanning electron microscope images of same area as in previous figure.

18

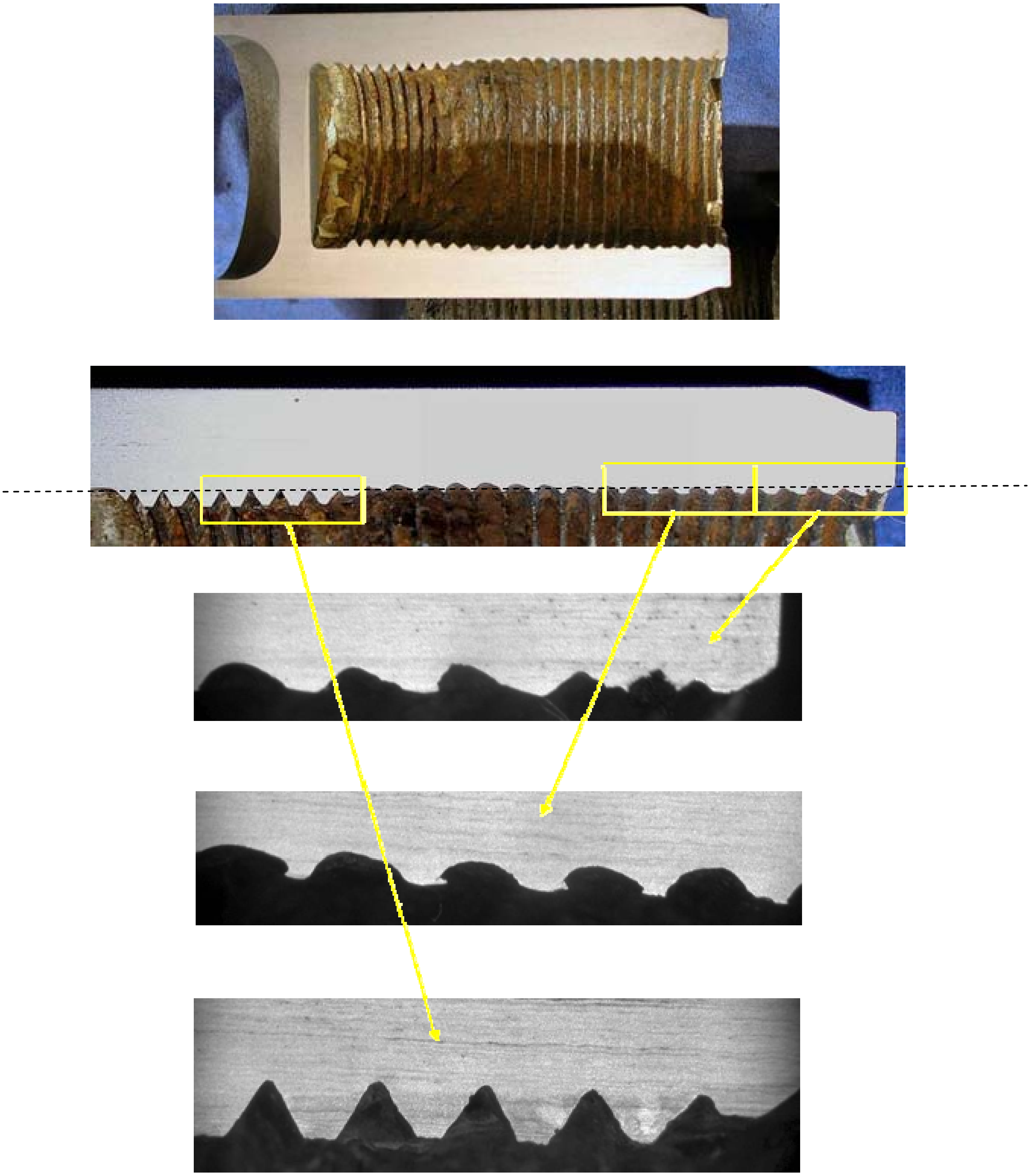

Figure 14: Illustration of the thread condition along the bore of the piston rod end. The super imposed dashed line shows the nominal thread depth.

19

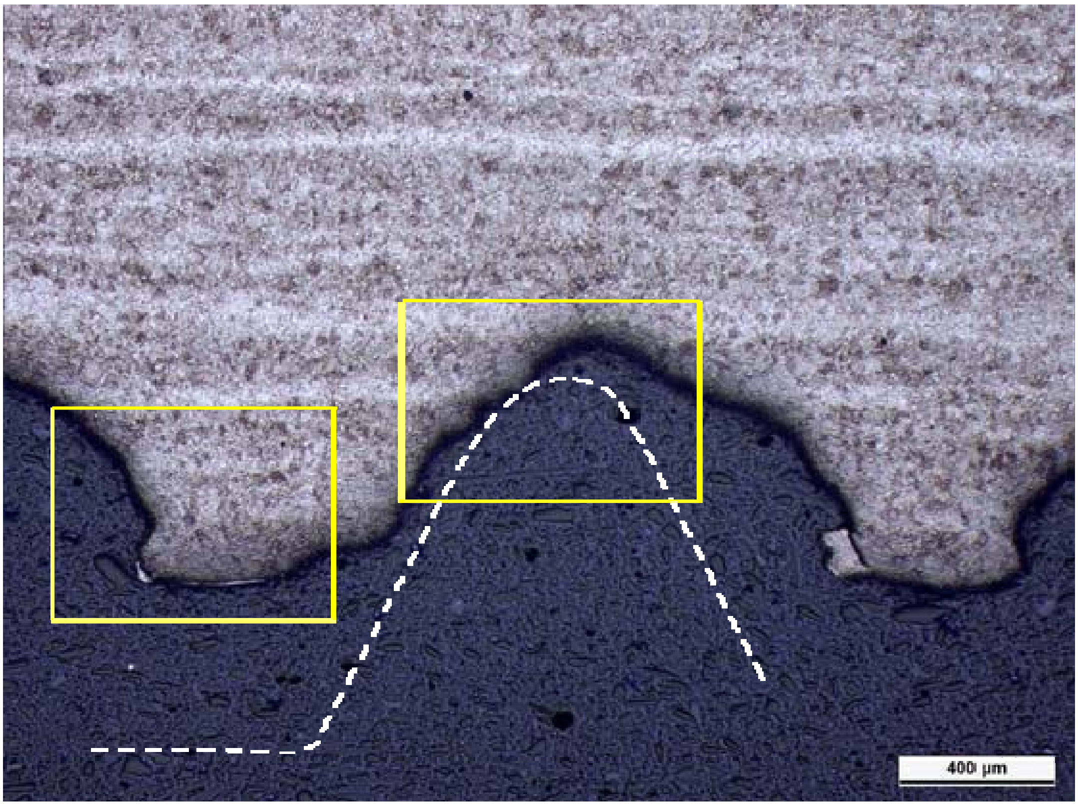

Figure 15: Metallographic section through remaining thread profile. The superimposed dashed line shows the nominal thread profile. The framed areas are shown in subsequent figures.

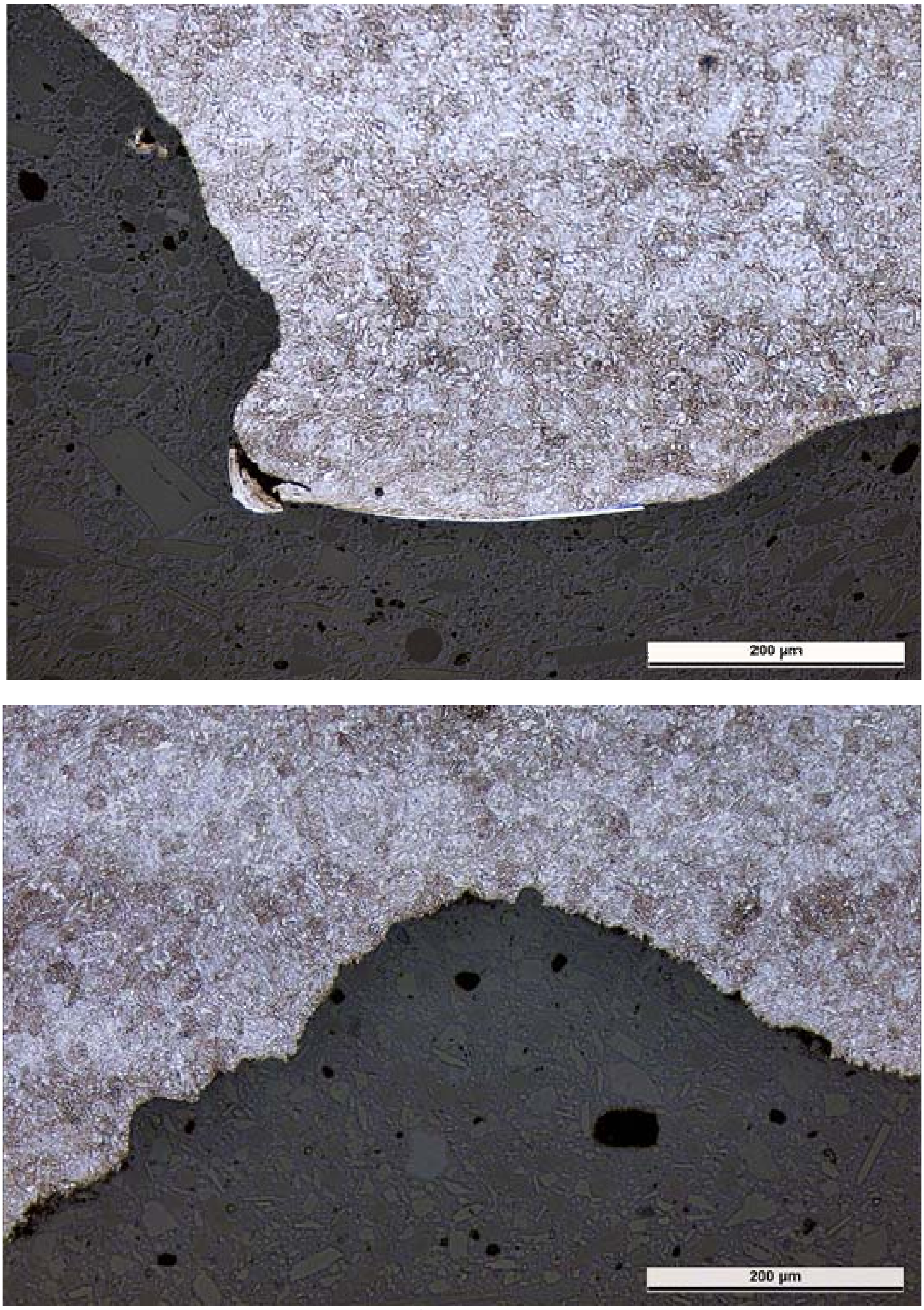

Figure 16: Metallographic images of thread top and bottom. Note the white etching layer from intimate adhesive wear contact with opposing threads during pull out. The contour at the thread bottom shows presence of severe corrosion.

Figure 17: Right hand actuator rod end in as received condition.

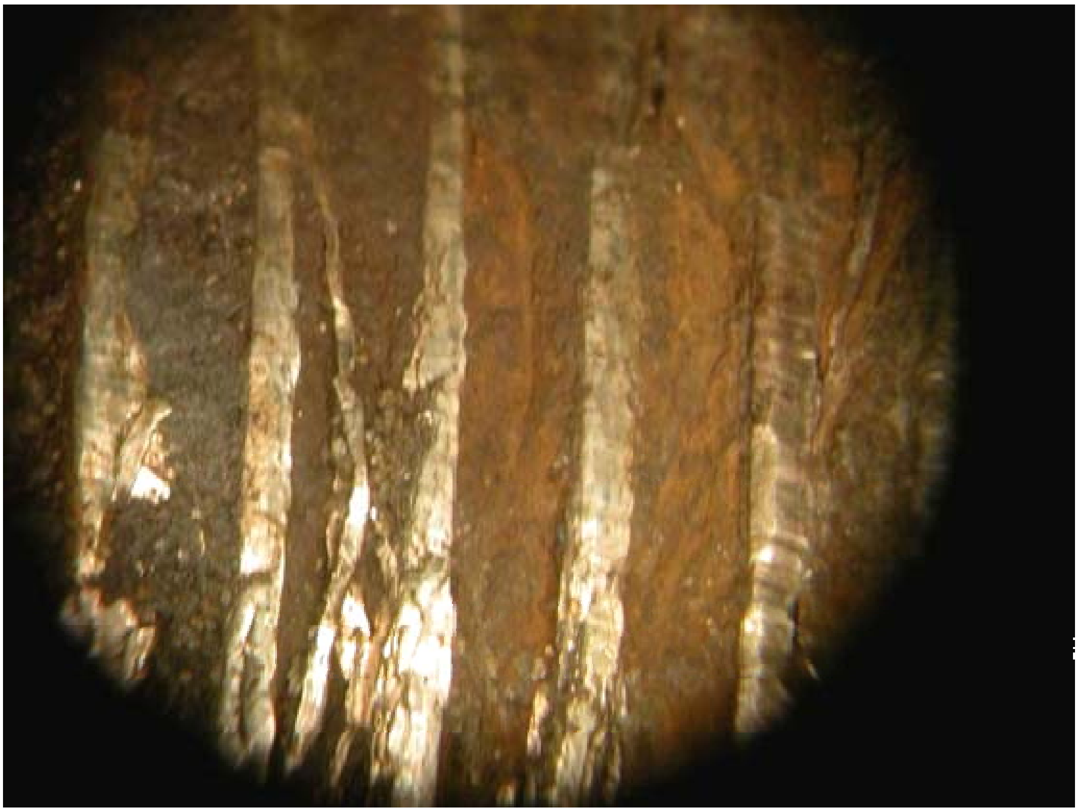

Figure 18: Close-up view of the male threads in Figure 17.

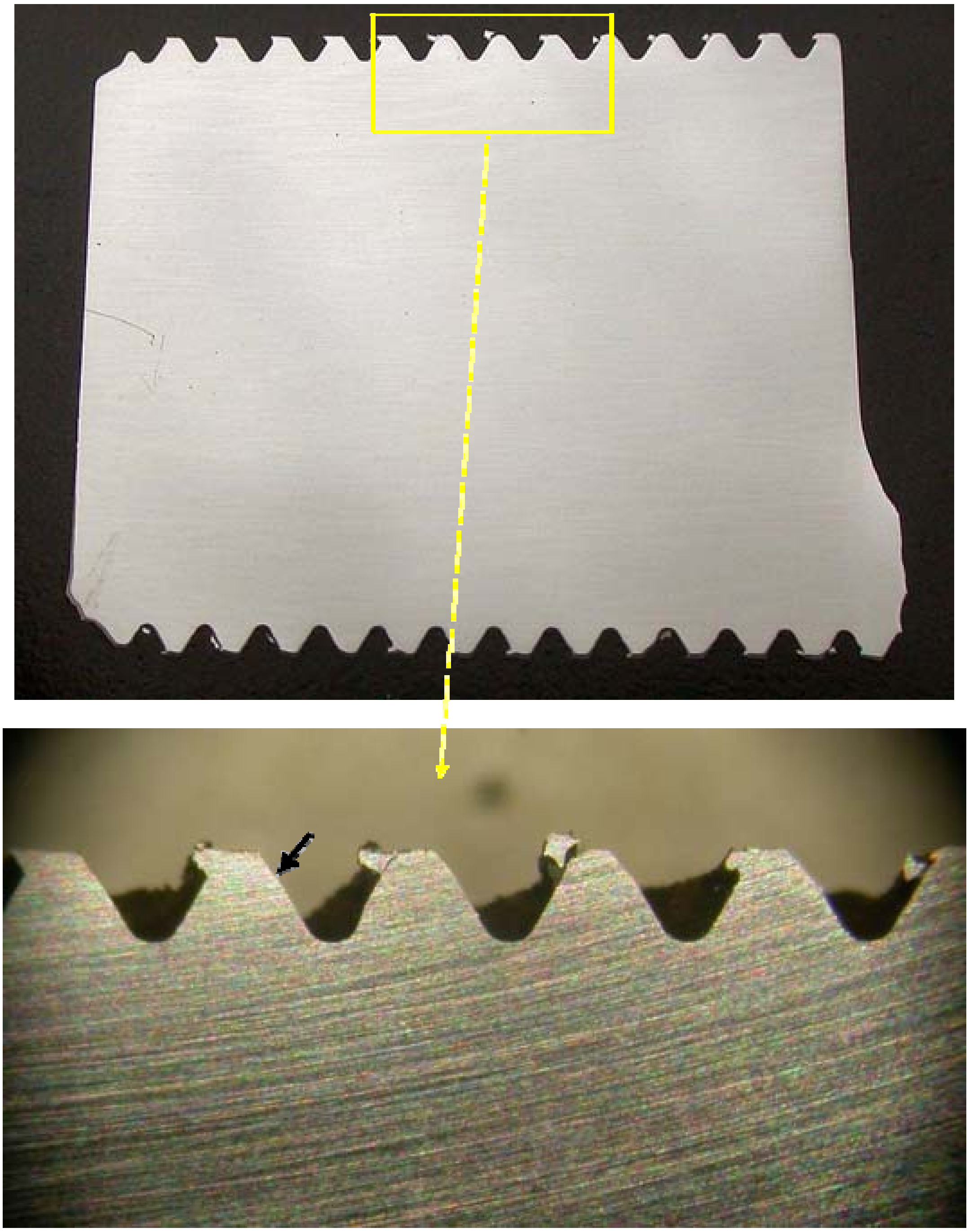

Figure 19: Longitudinal section of male thread showing some deformation/wear near top (example at arrow) and sheared off metal at the thread tip corners.

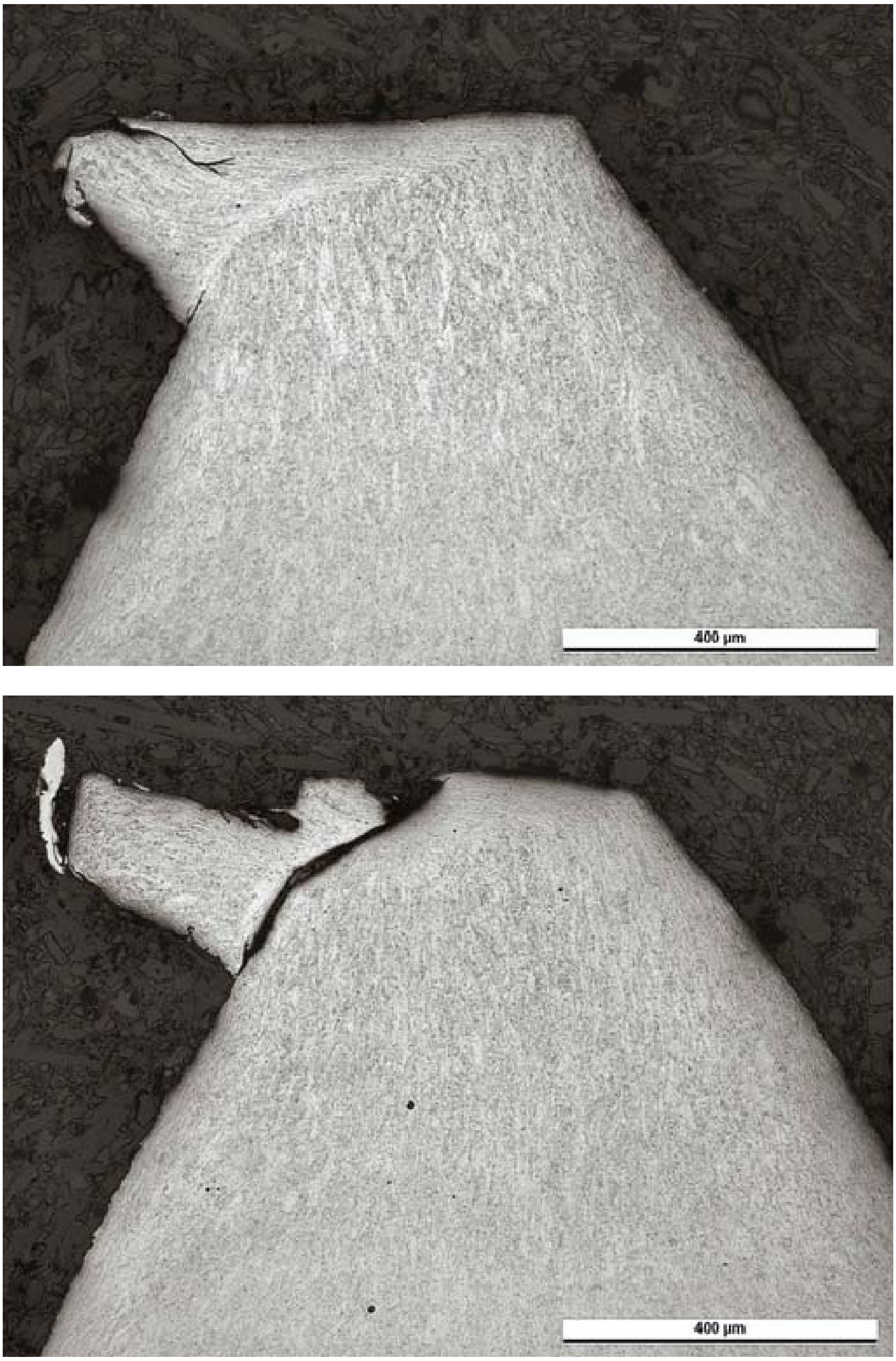

Figure 20: Metallographic sections through threads.

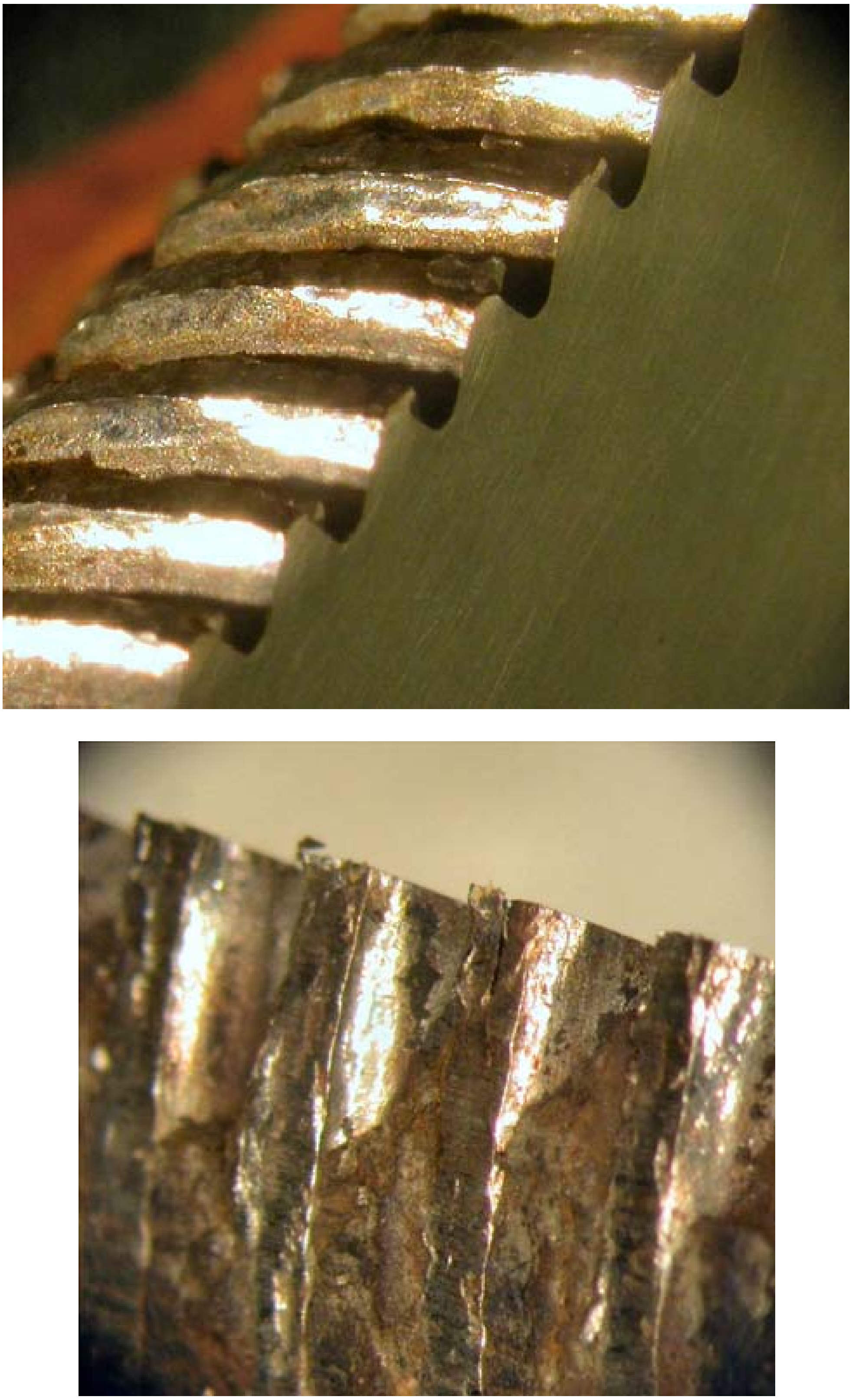

Figure 21: Light optical photos showing polishing wear contacts in upper part of thread flanks.

25

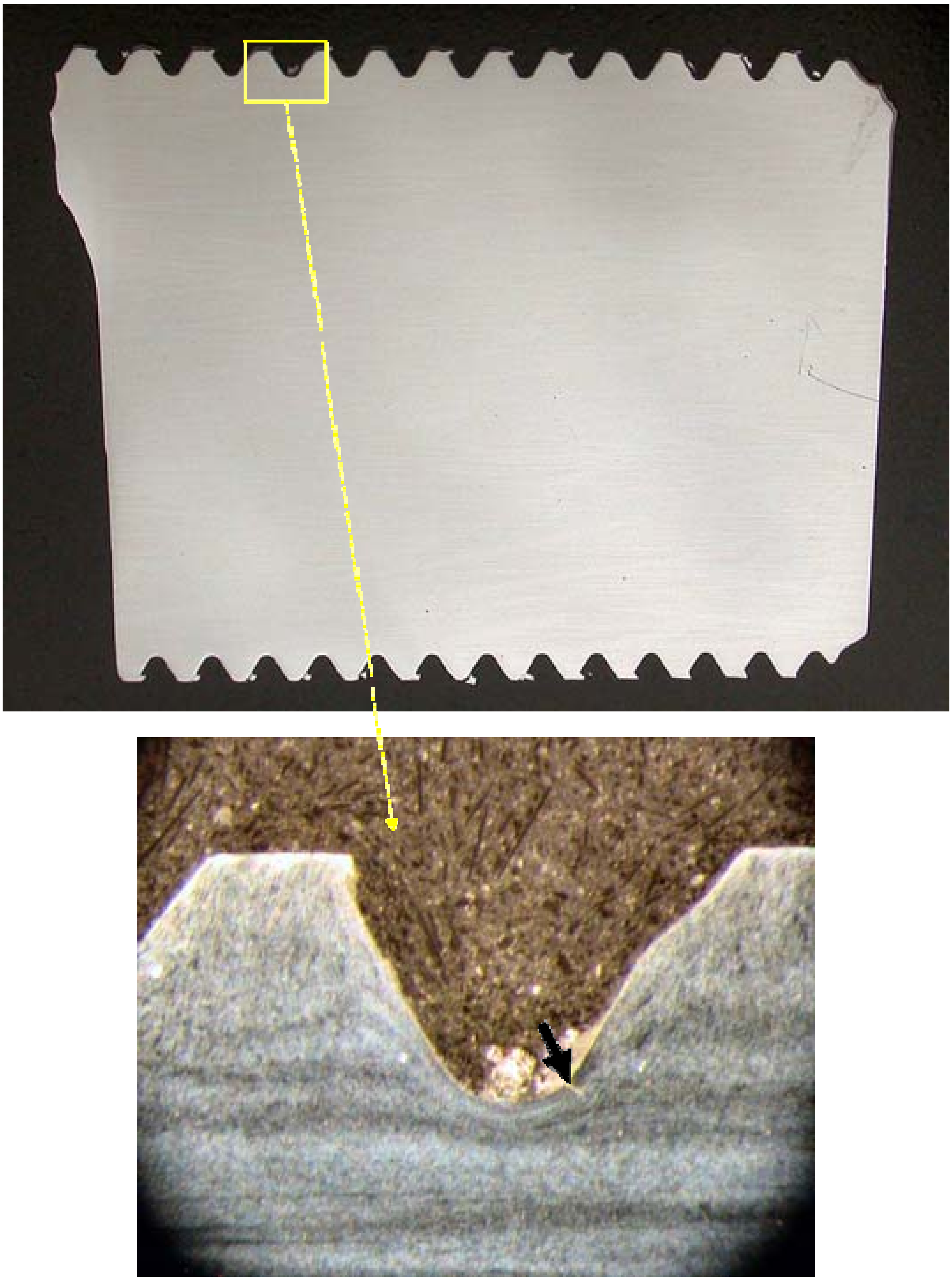

Figure 22: Minute crack in thread bottom.

26

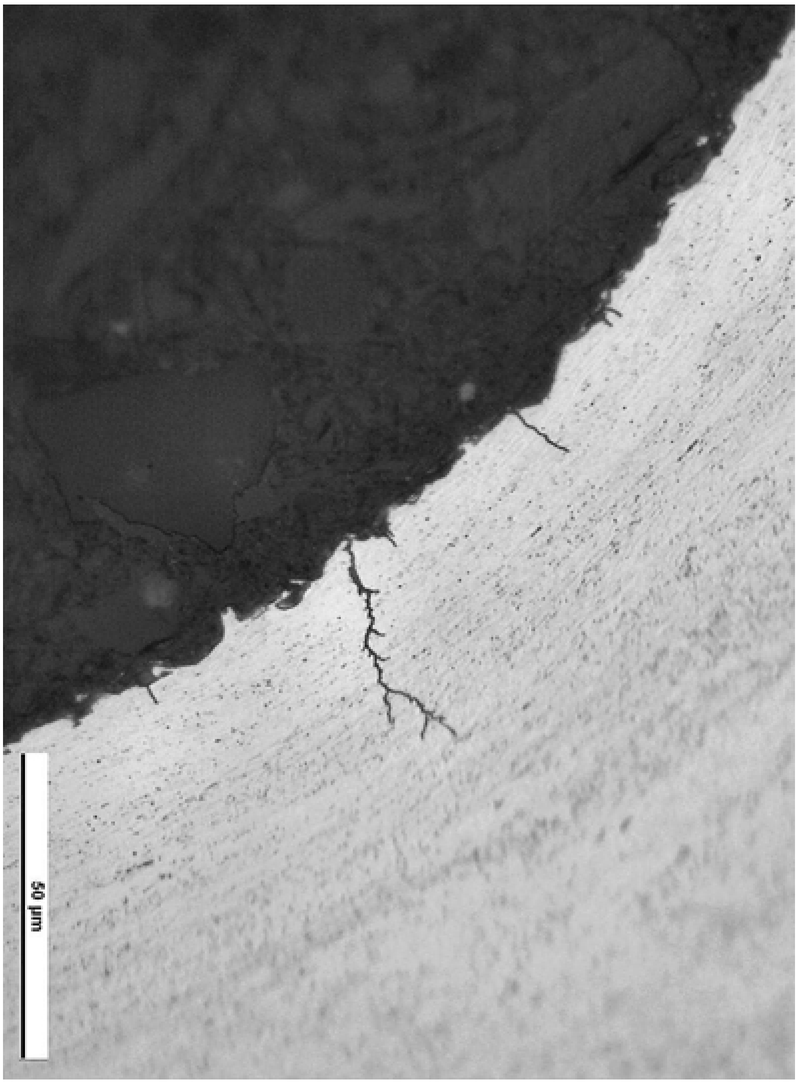

Figure 23: Example of crack in thread bottom.

Figure 24: Example of crack in thread bottom.

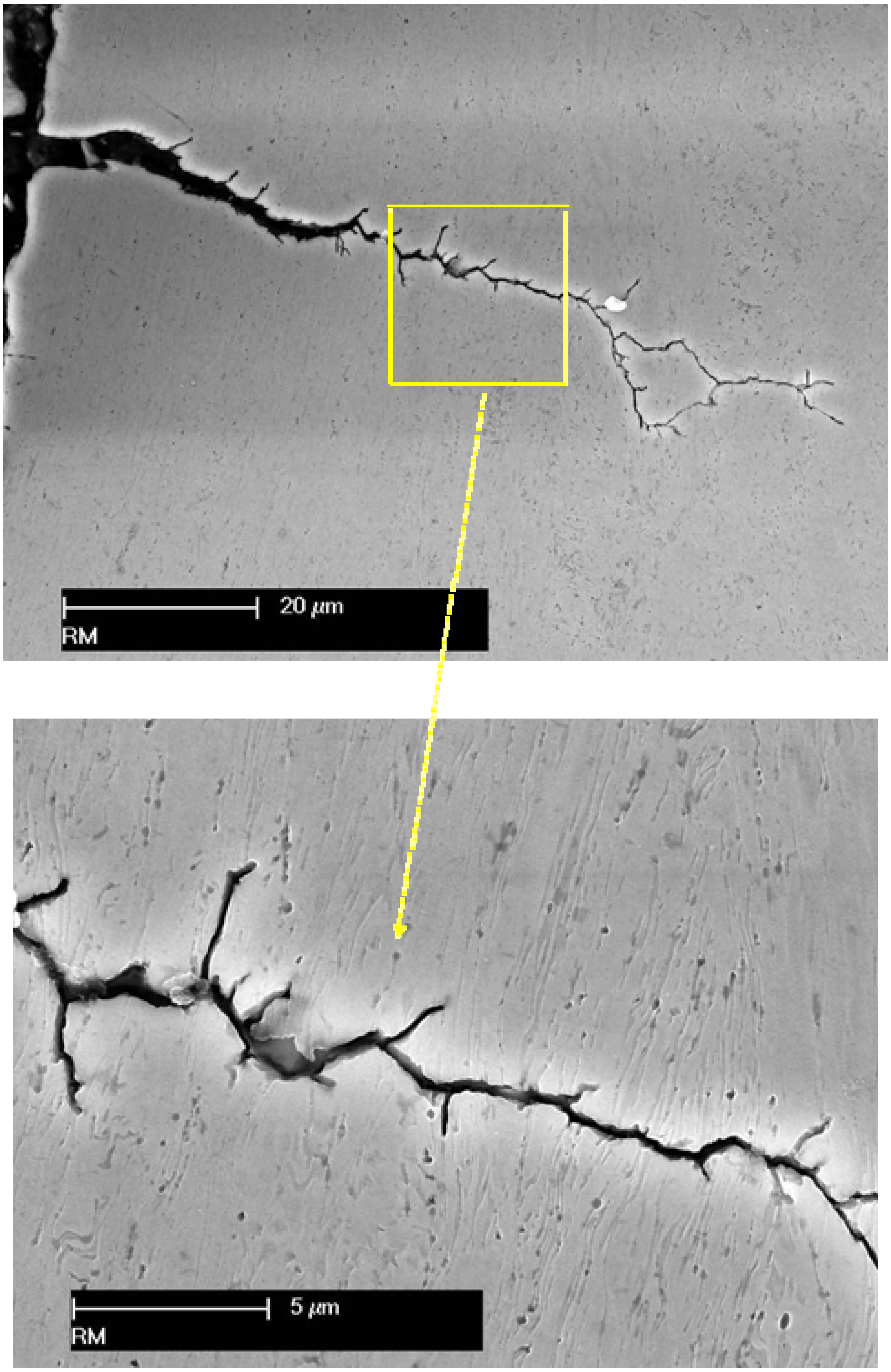

Figure 25: Higher magnifications of part of crack in Figure 24.

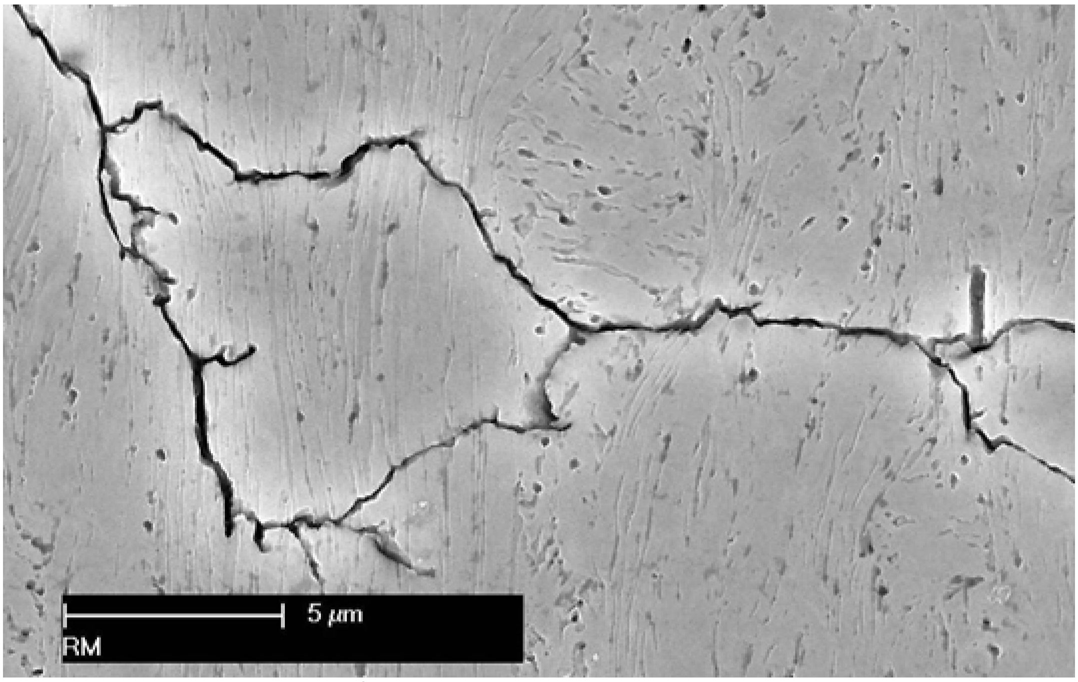

Figure 26: Higher magnification near crack tip.

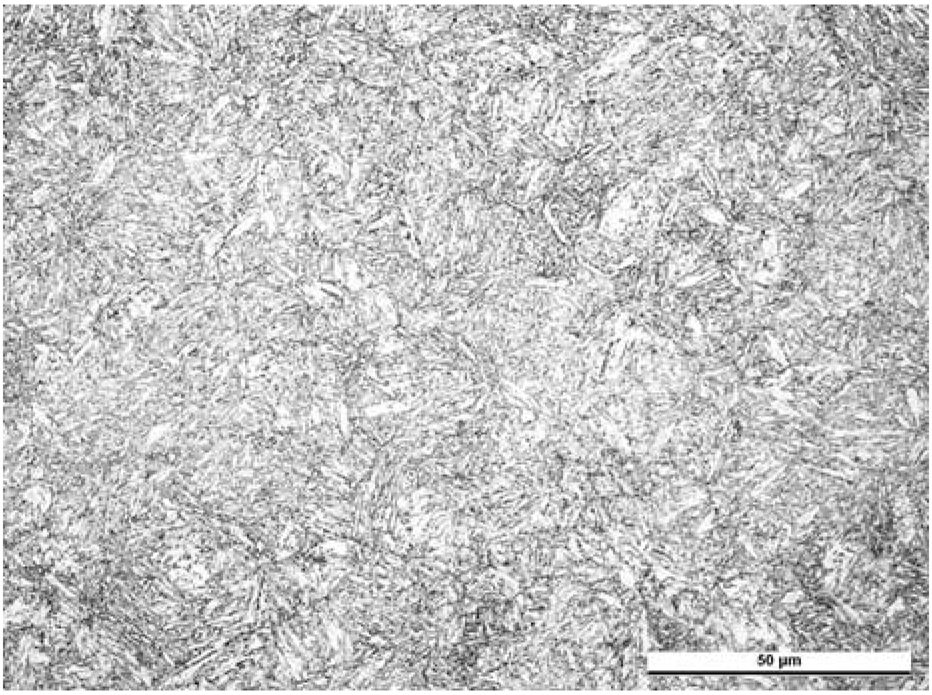

Figure 27: Microstructure of piston rod material featuring uniformly tempered matensite.

Figure 28: Microstructure of rod end material featuring uniformly tempered matensite.

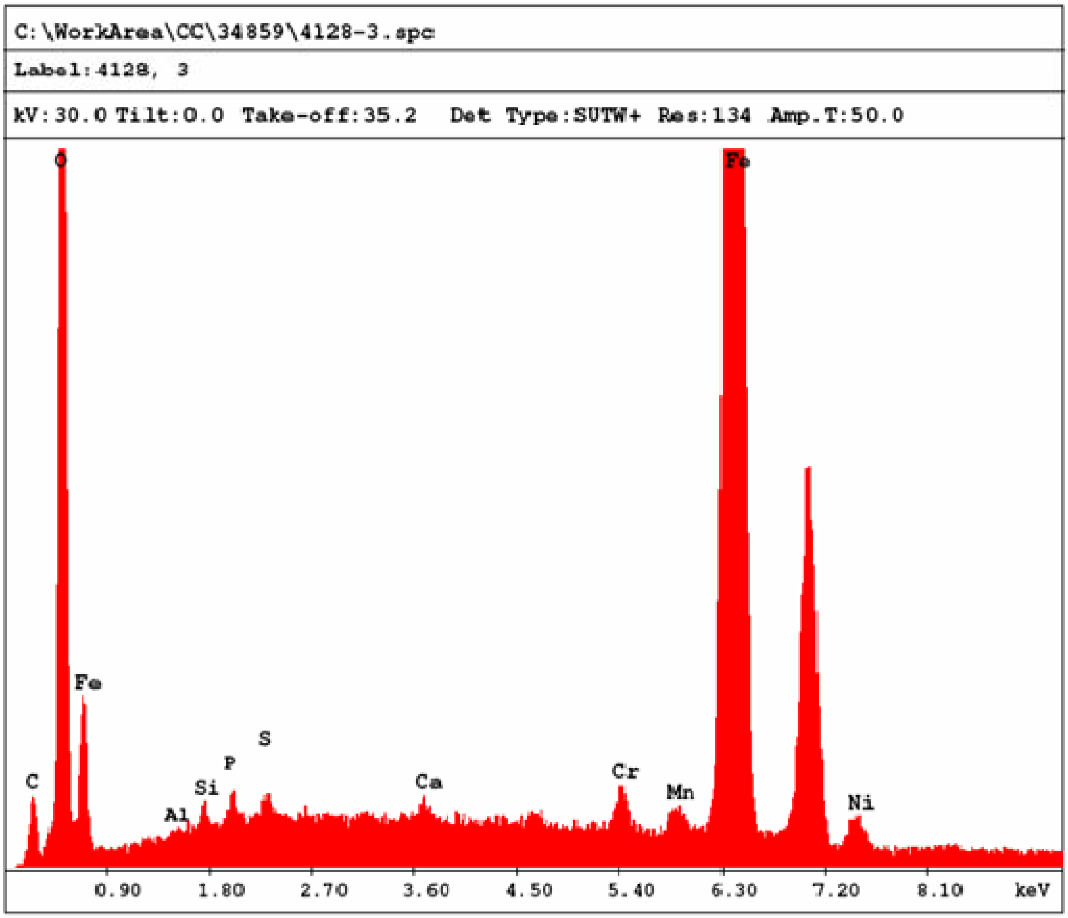

Figure 29: Energy dispersive x-ray analysis of corrosion products retrieved from piston rod threads.

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Figure 30: Rod end (as dismantled).

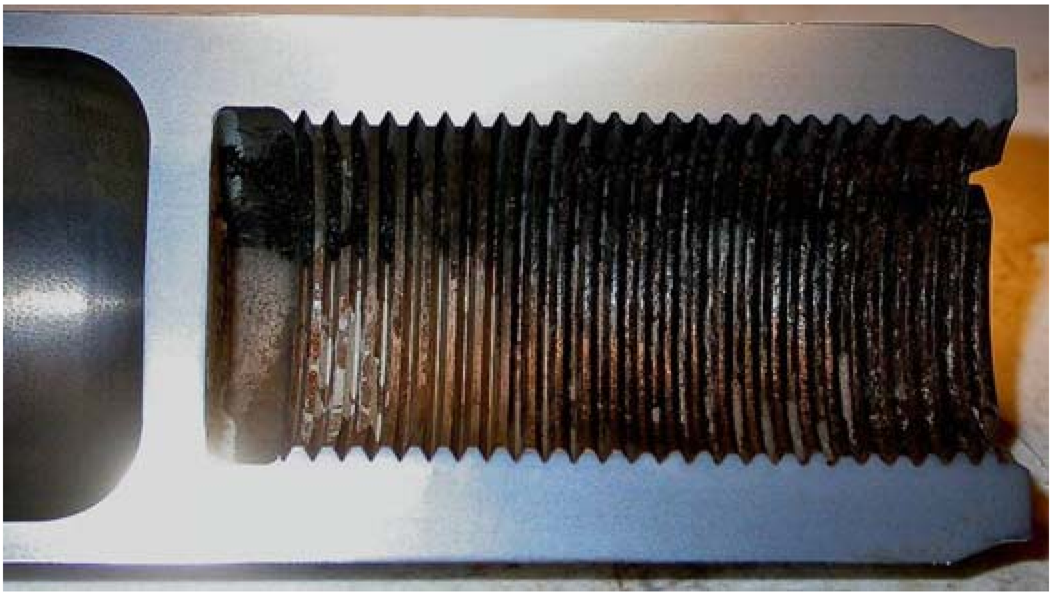

Figure 31: Part of sectioned piston rod (after cleaning prior to sectioning).

33

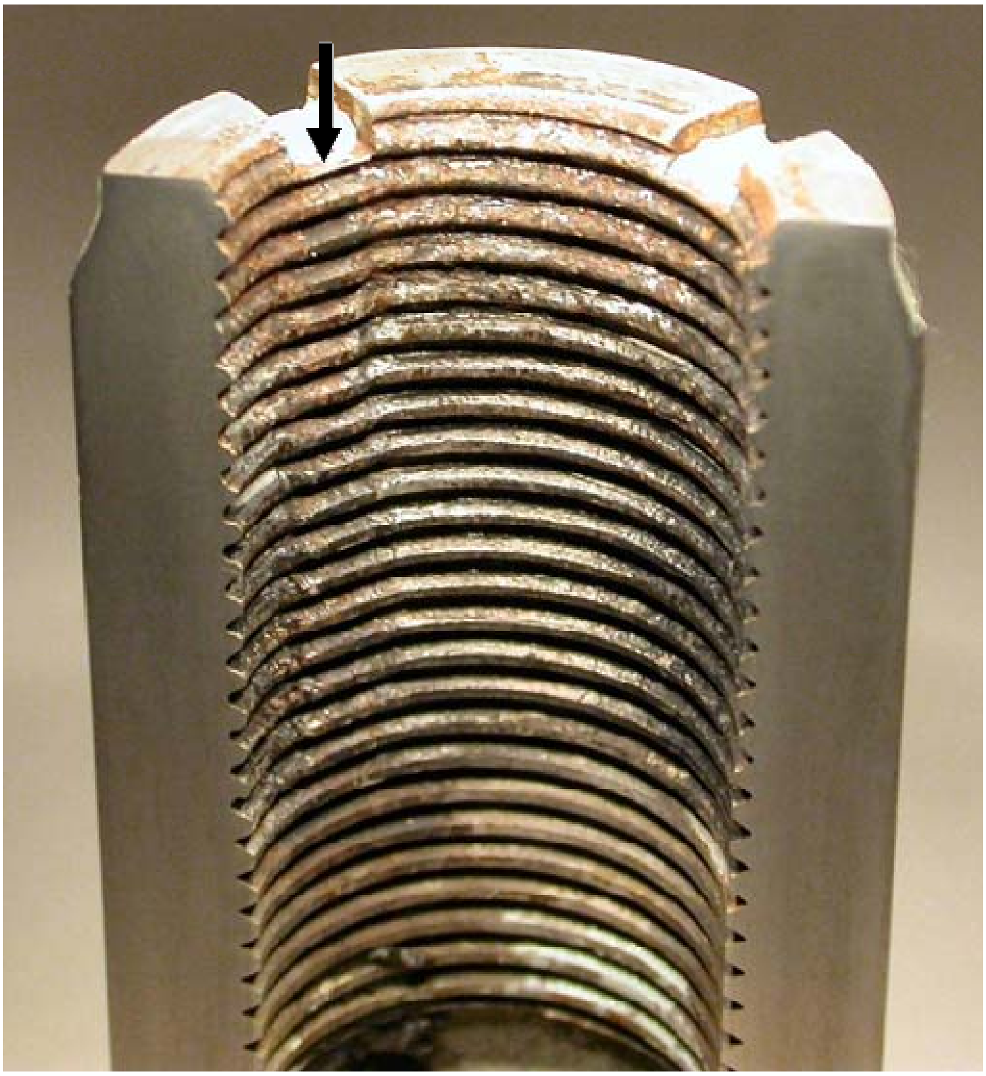

Figure 32: Overview of piston rod section showing less corrosion in the key way area (at arrow).

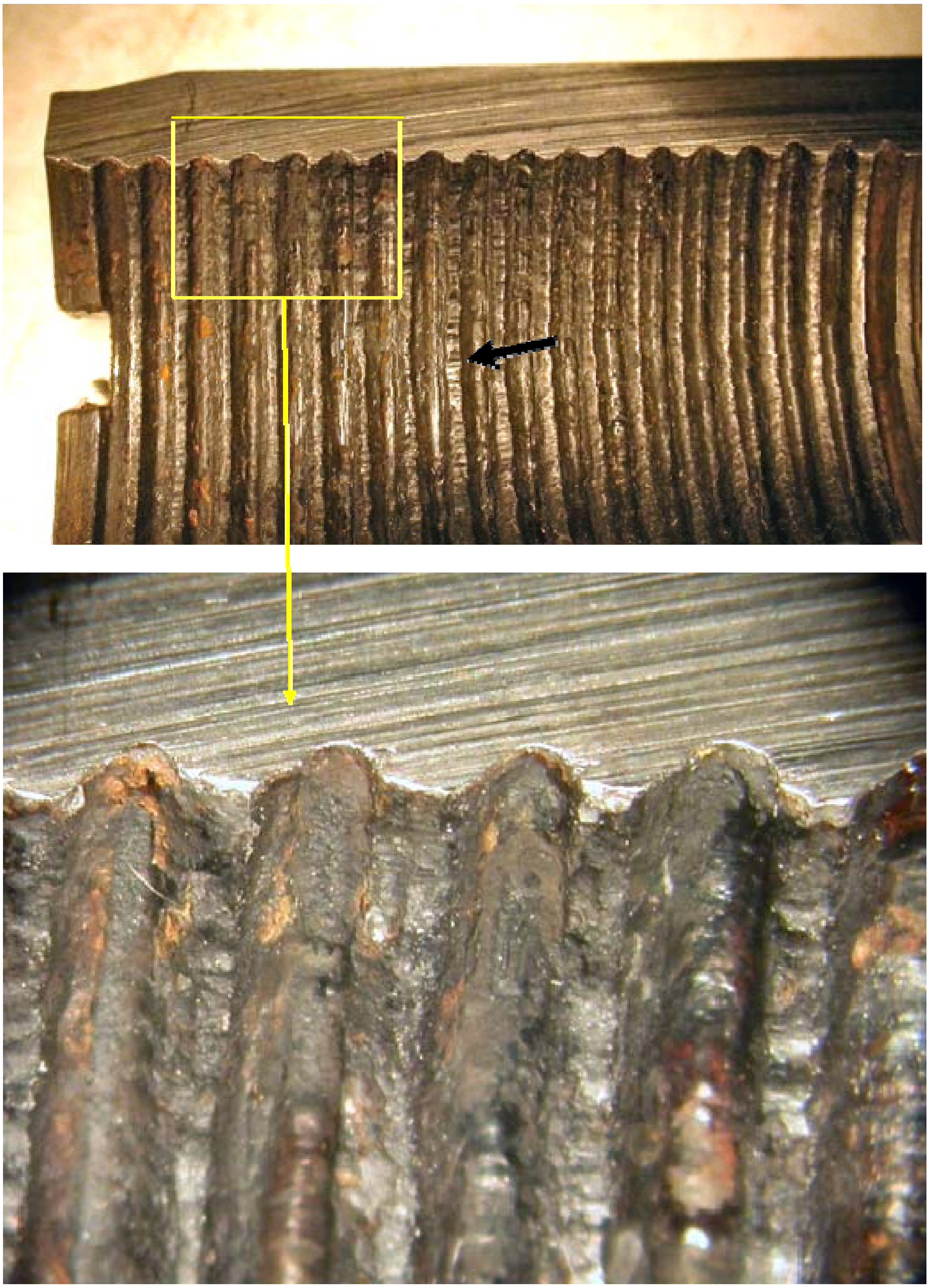

Figure 33: Corrosion attacks in piston rod threads. Note also the wear marks in thread top (example at arrow)

35

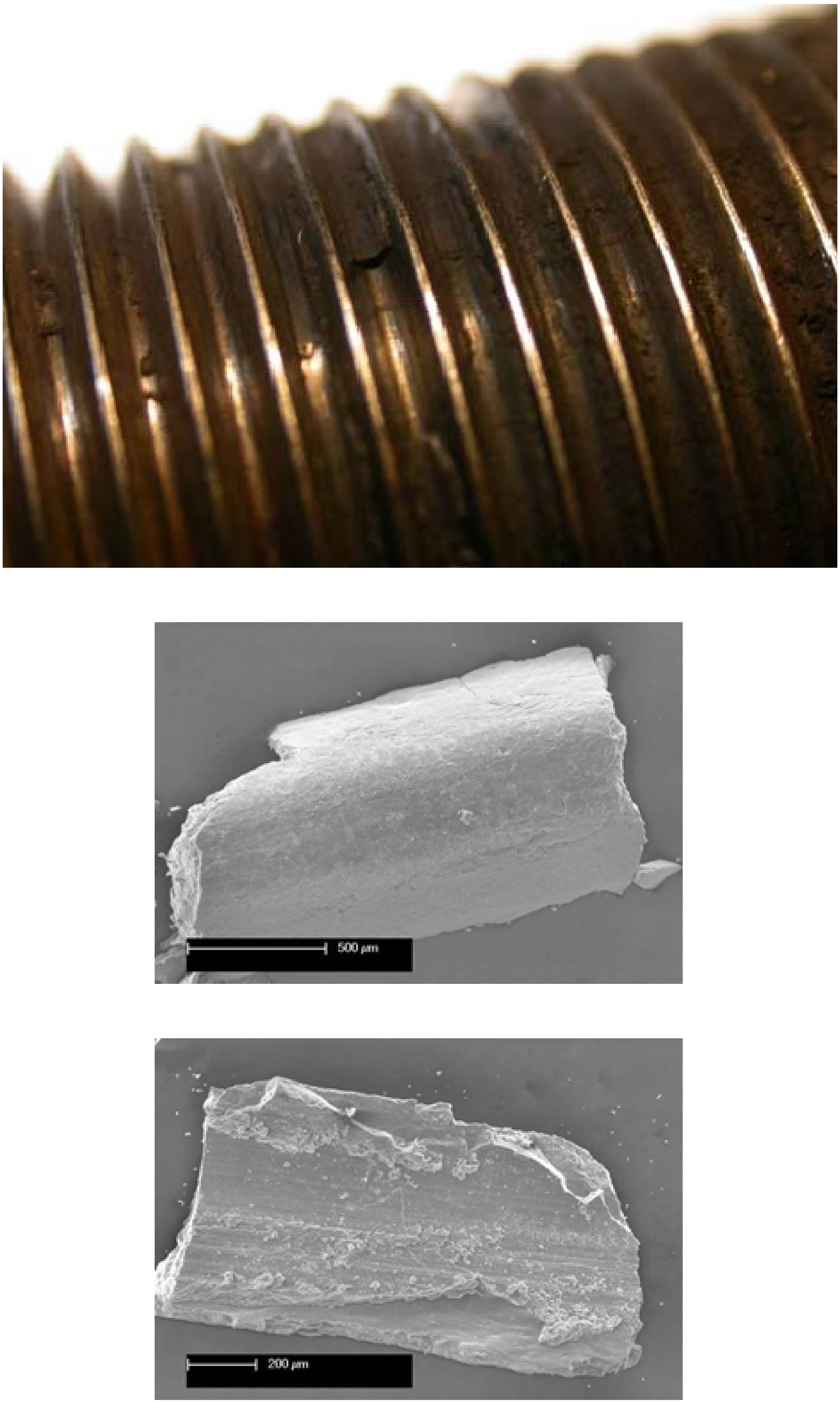

Figure 34: Left actuator piston rod end. The threads are partly filled with hard brittle scales that could be plied out easily. Bottom photos represent front and back sides of such plied-out scales.

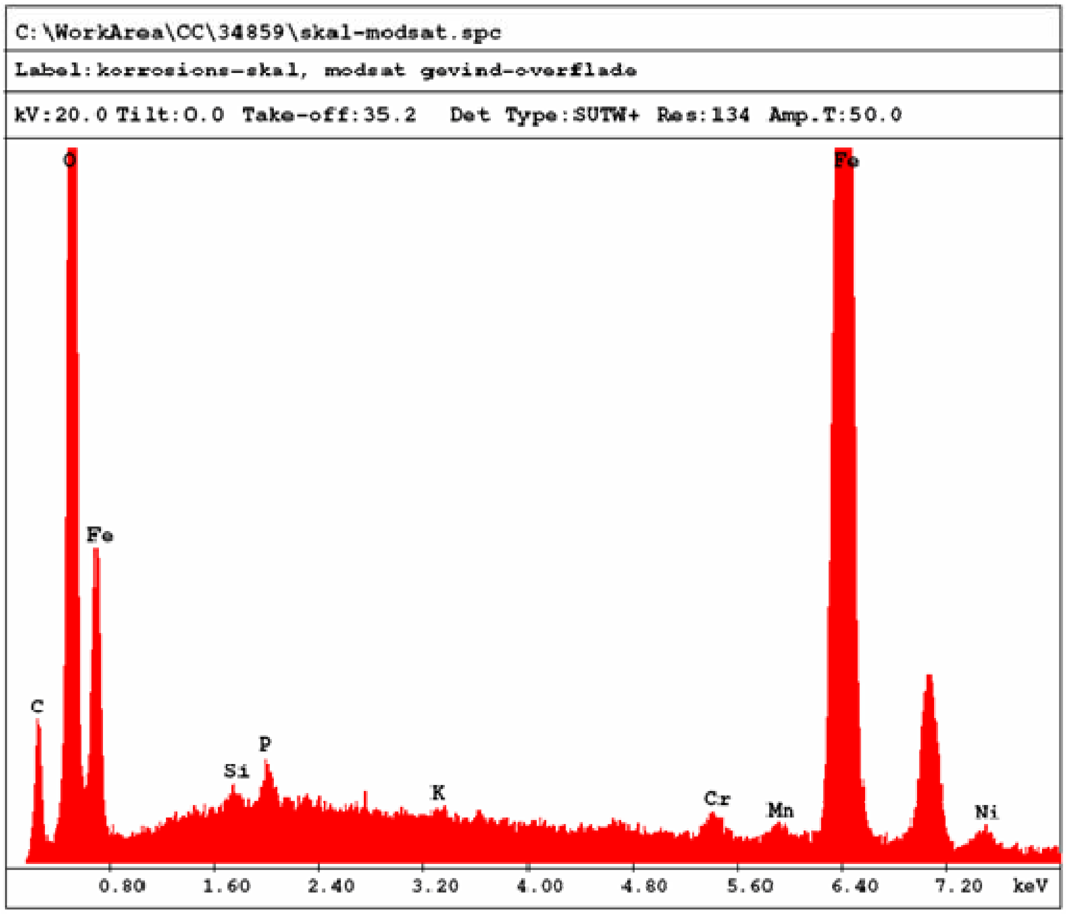

Figure 35: Energy dispersive x-ray analysis of brittle scales from rod end thread.

37

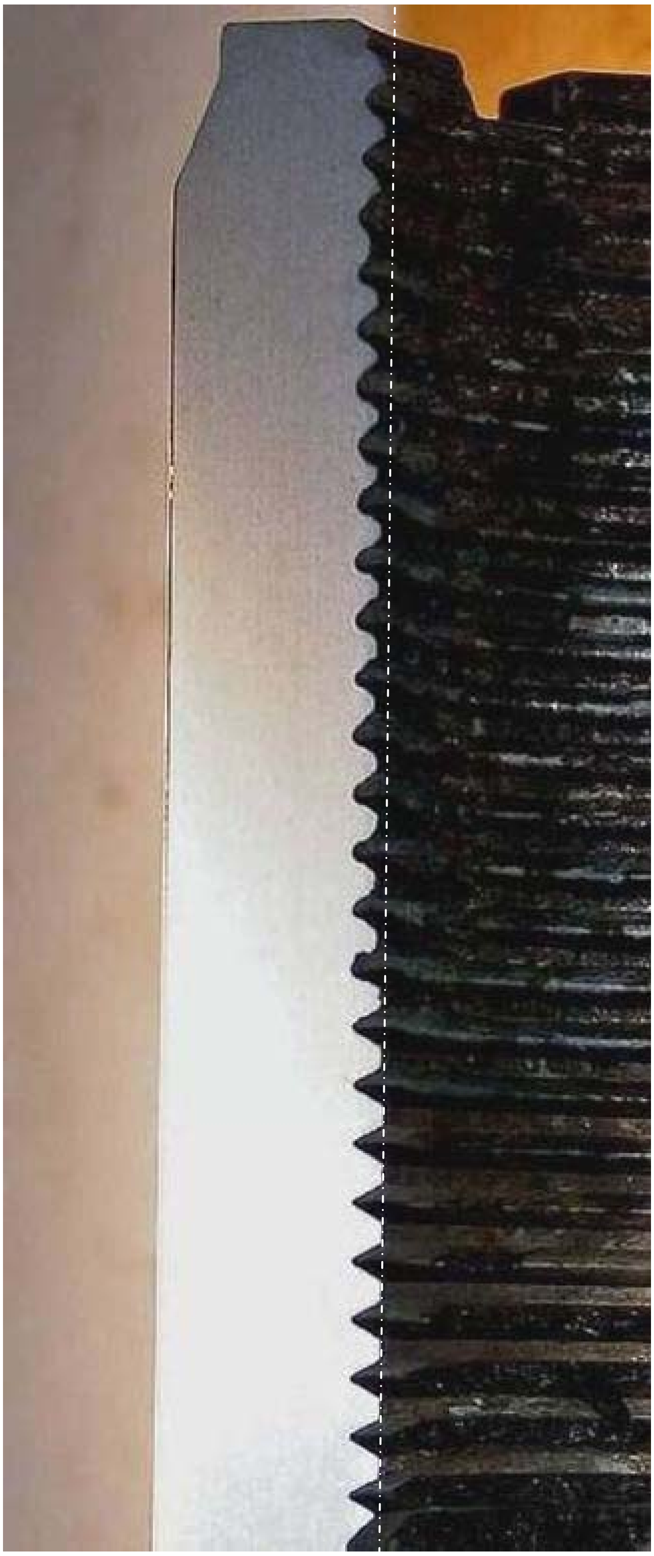

Figure 36: Longitudinal section of left actuator piston rod female thread showing distribution of corrosion along the threaded bore. The super imposed white line indicates the nominal thread top.

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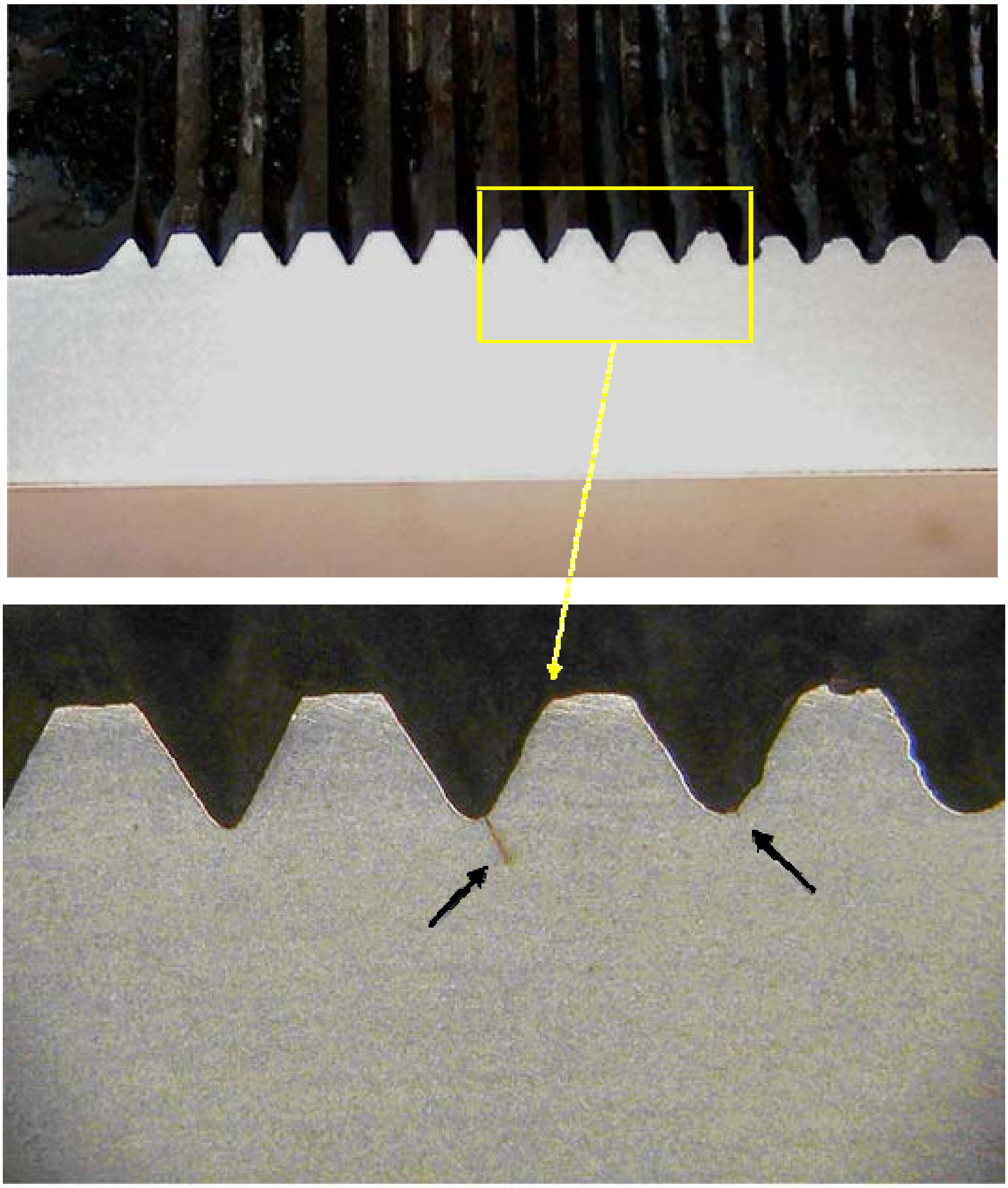

Figure 37: Left Retract Actuator Piston Rod. Small crack in last two engaged threads (at arrows).

39

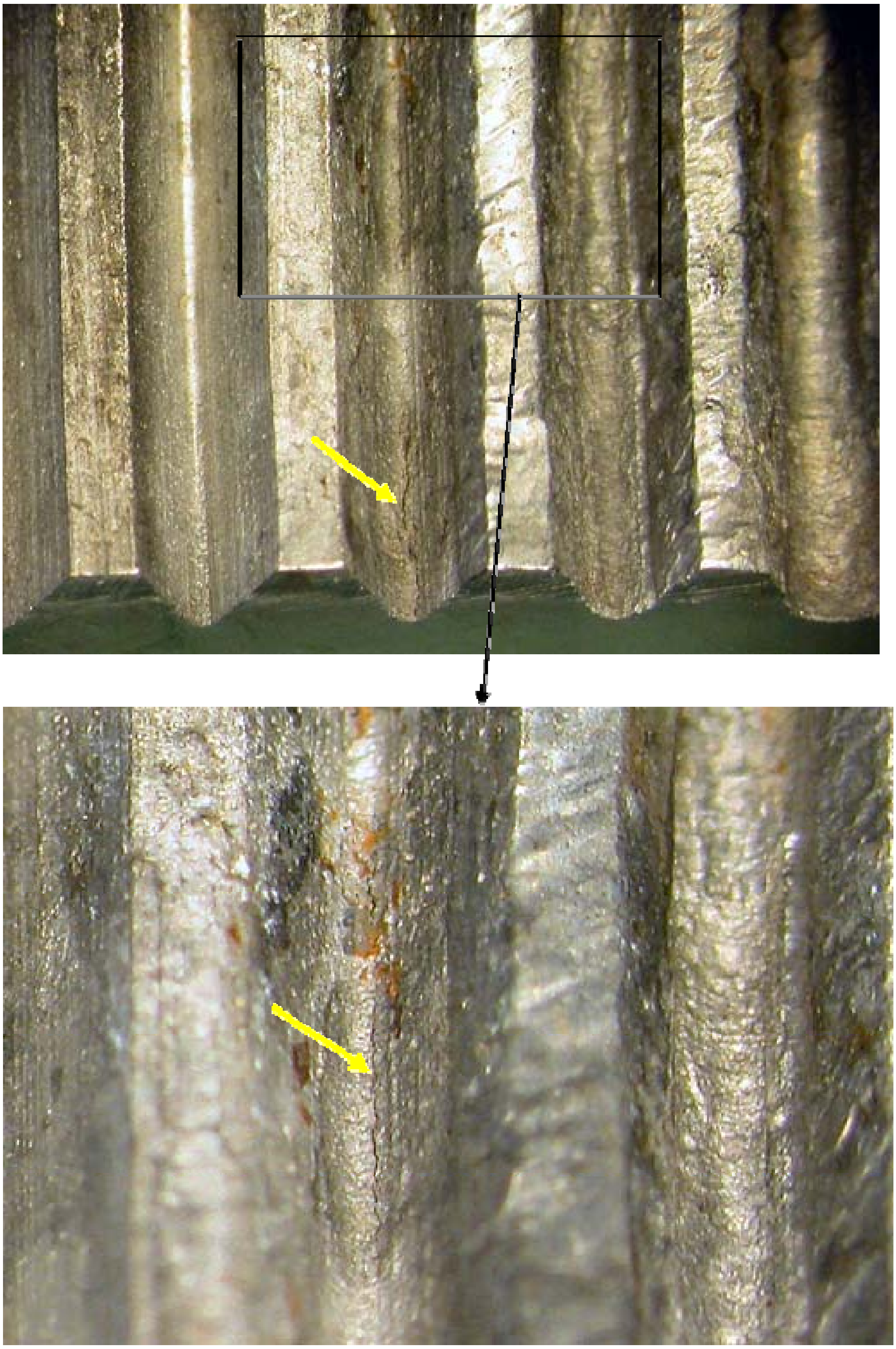

Figure 38: Light optical view of cracks in thread bottom of last engaged thread.

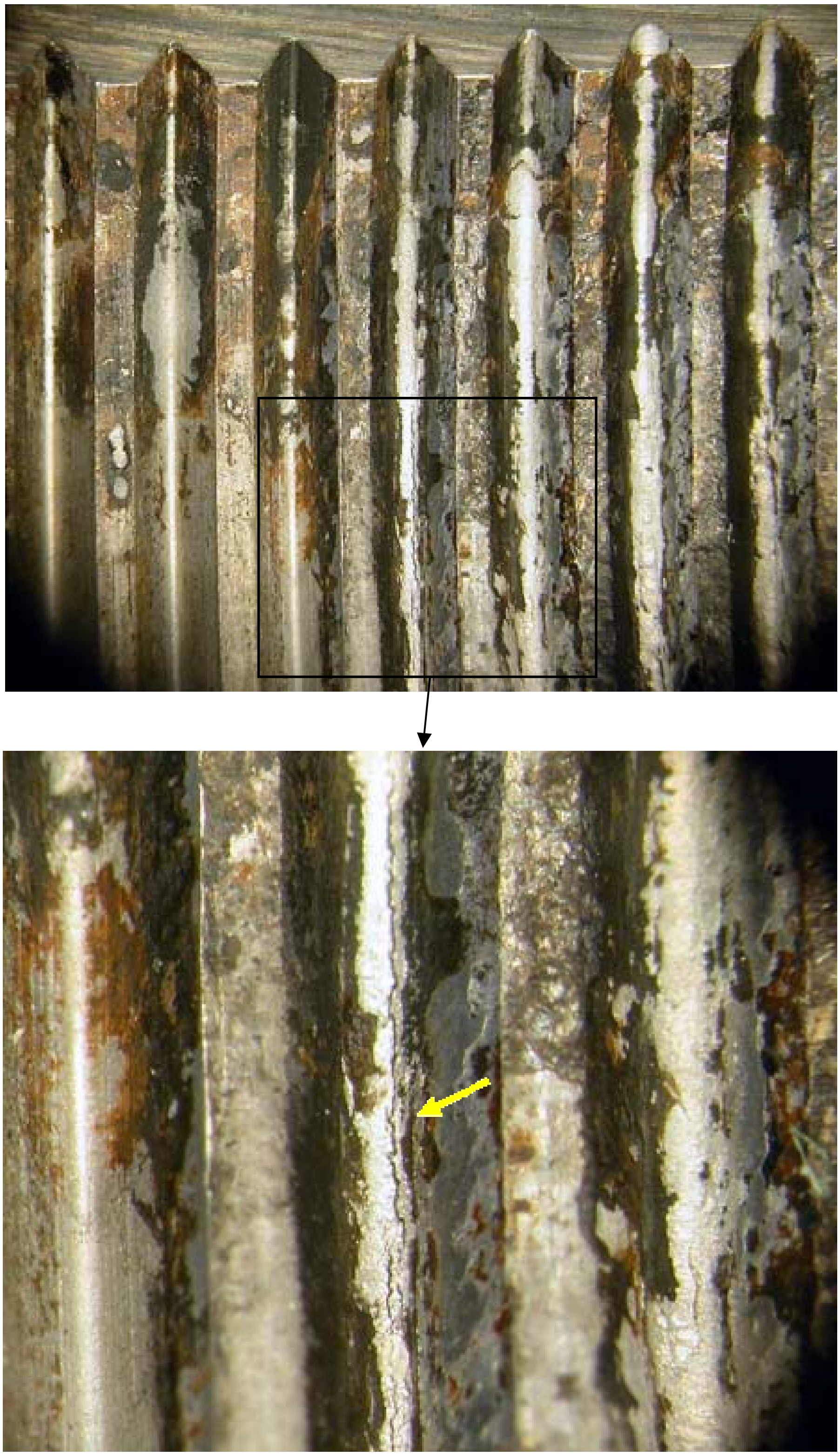

Figure 39: Light optical view of cracks in thread bottom of last engaged thread.

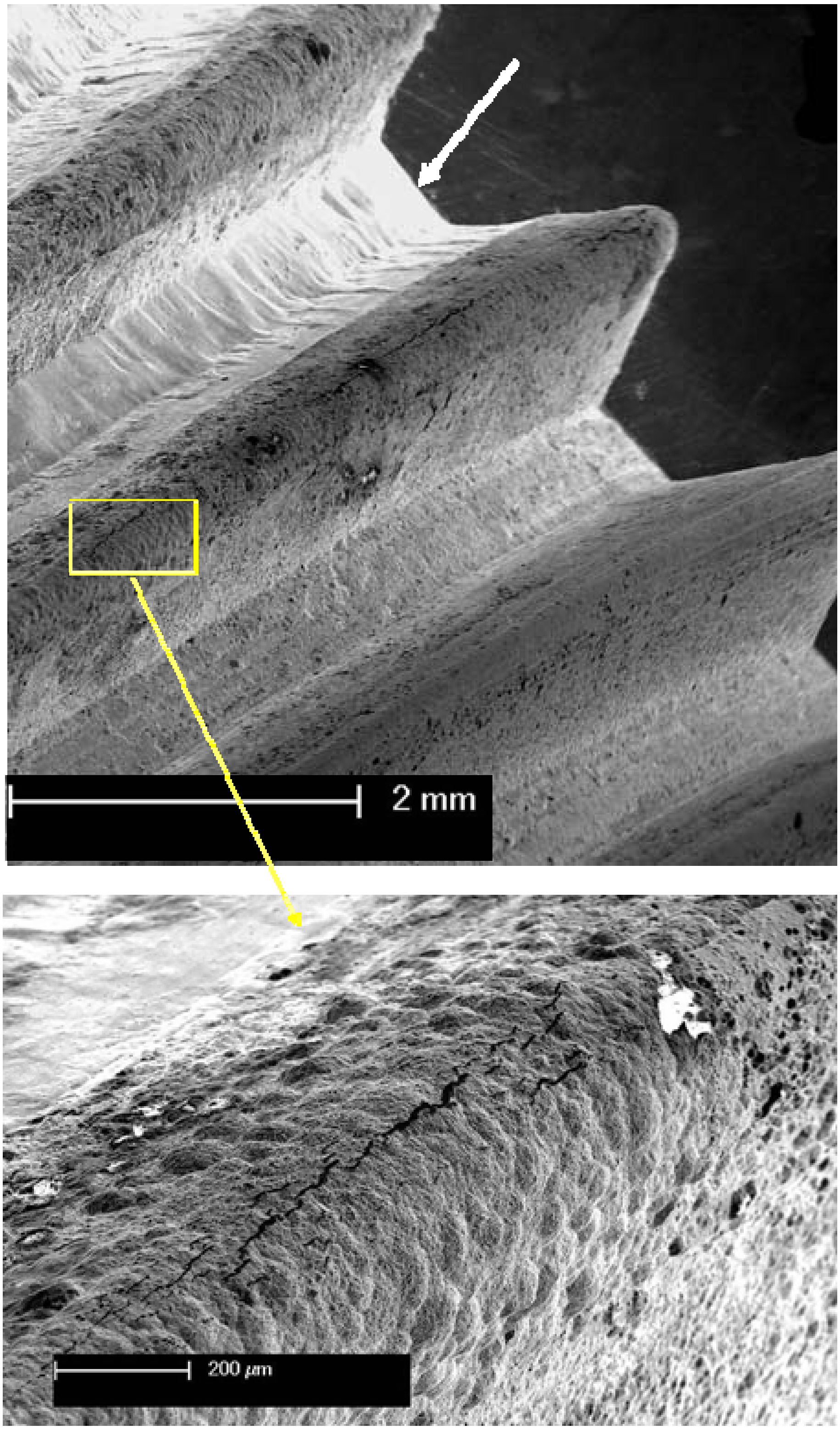

Figure 40: Scanning electron microscope images of cracks in last engaged thread. Note also the evidence of polishing wear in thread top at arrow in the top photo.

42

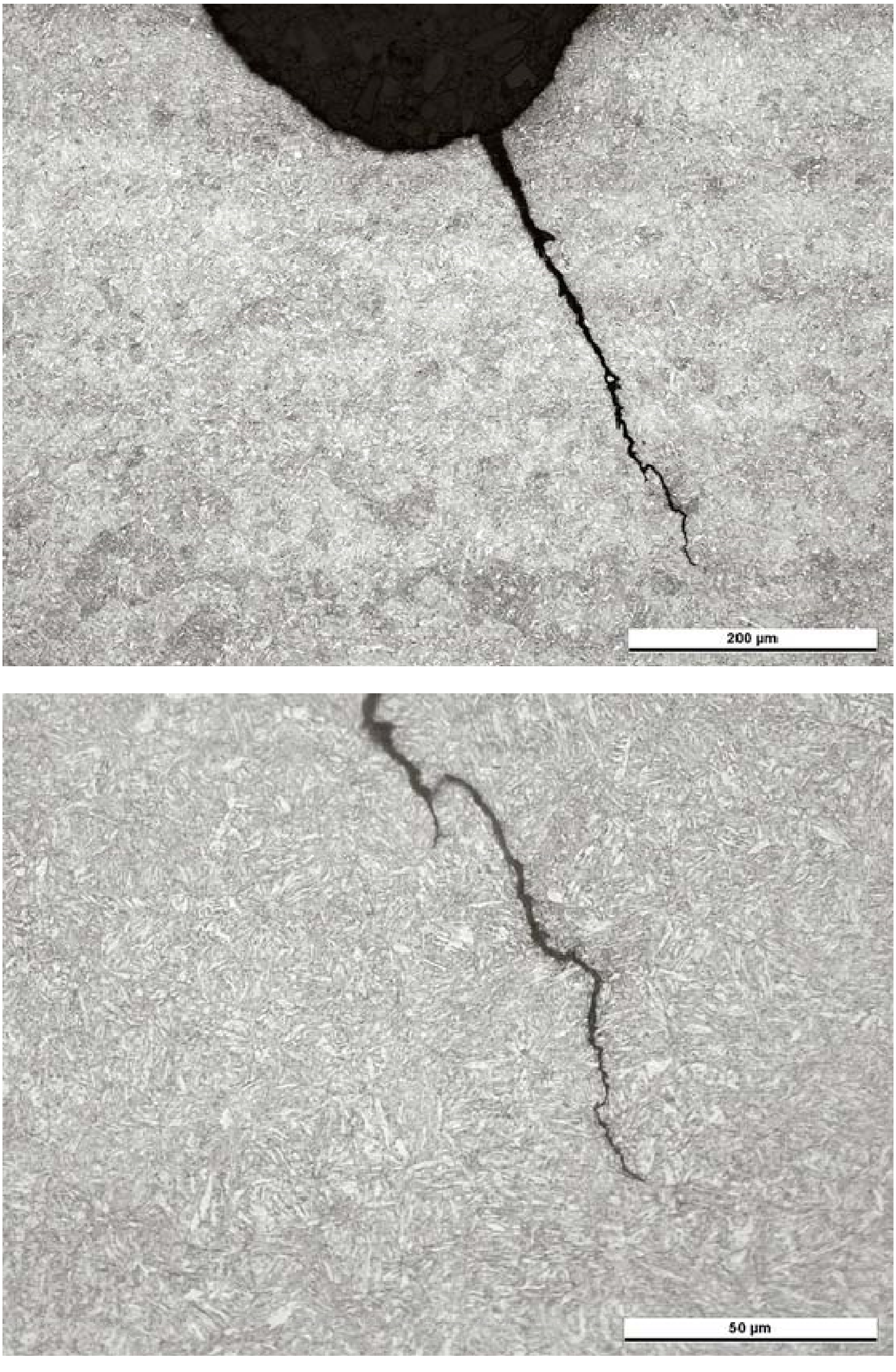

Figure 41: Metallographic section of crack in last engaged thread.

43

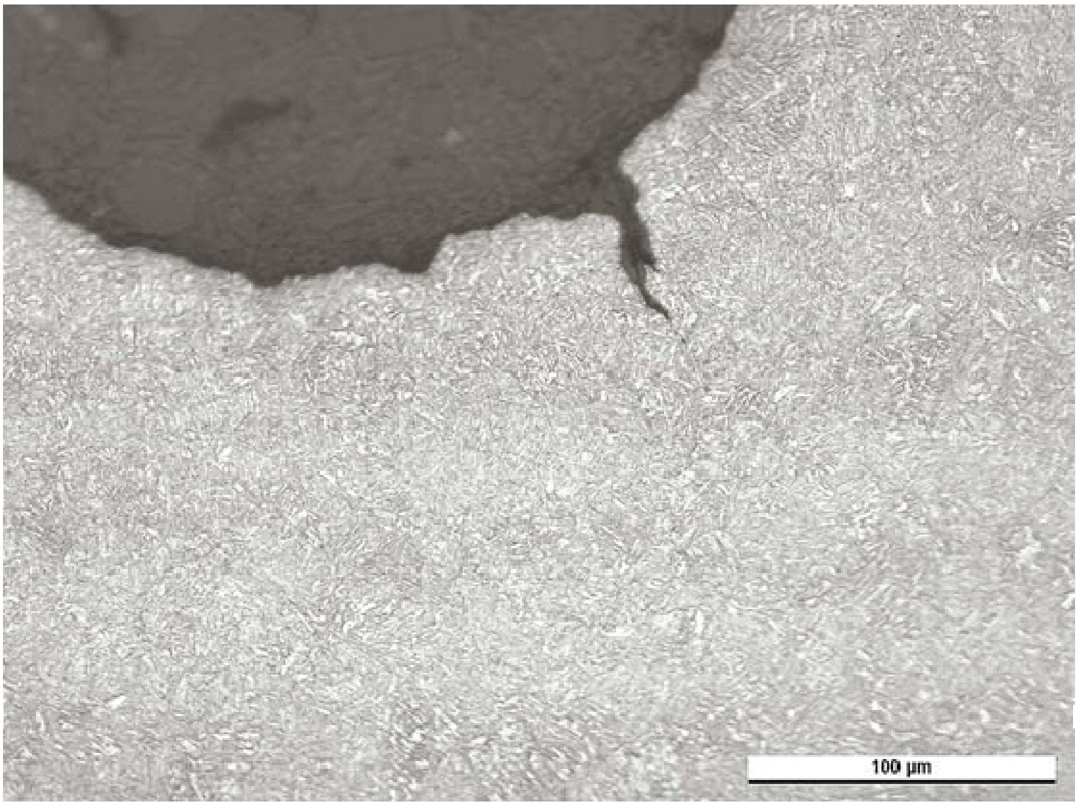

Figure 42: Metallographic section of crack in neighbour thread to last engaged thread.

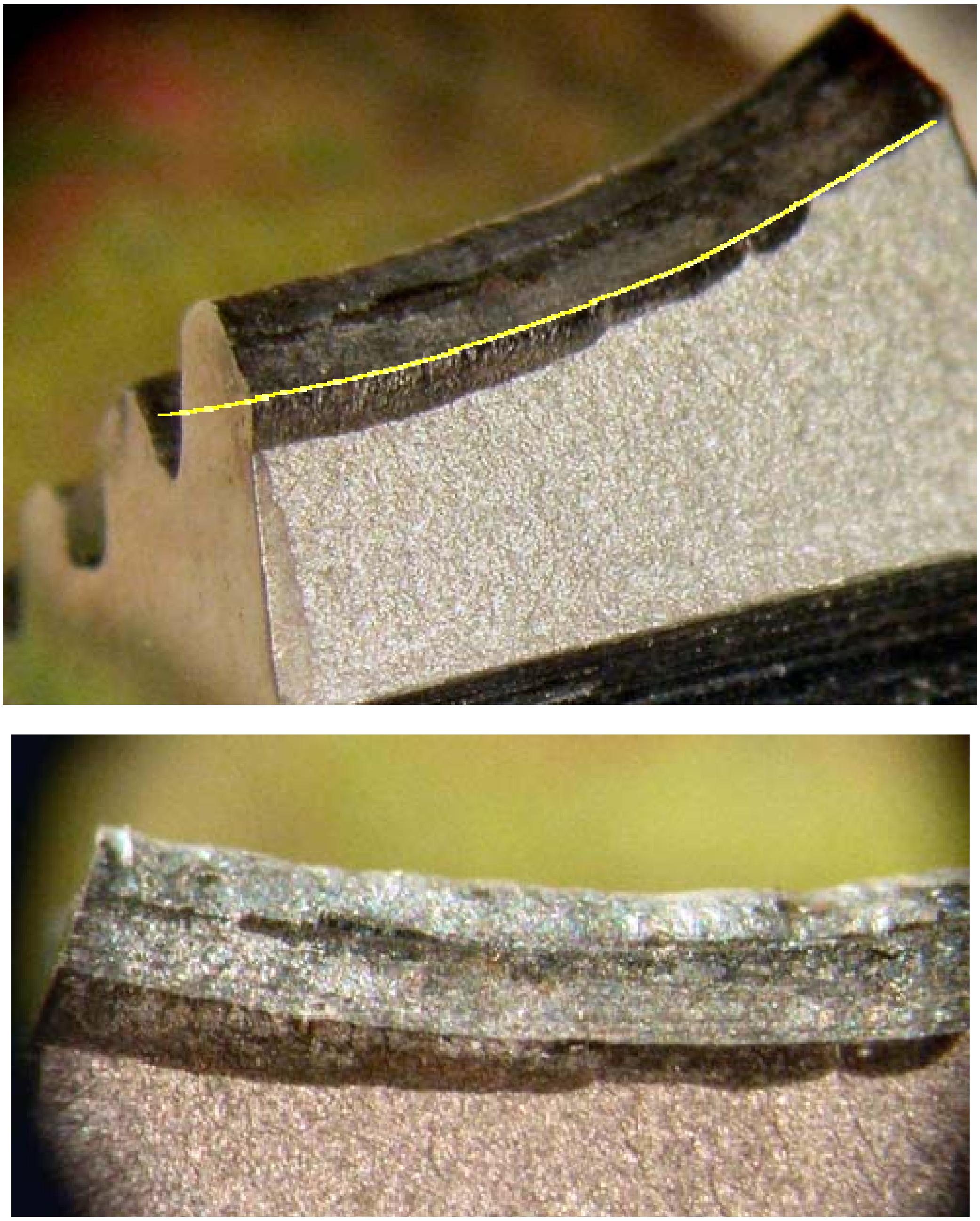

Figure 43: Free-laid crack surface. Yellow line indicates bottom of thread. The black occurring crack surface has the macroscopic appearance of fatigue cracking.

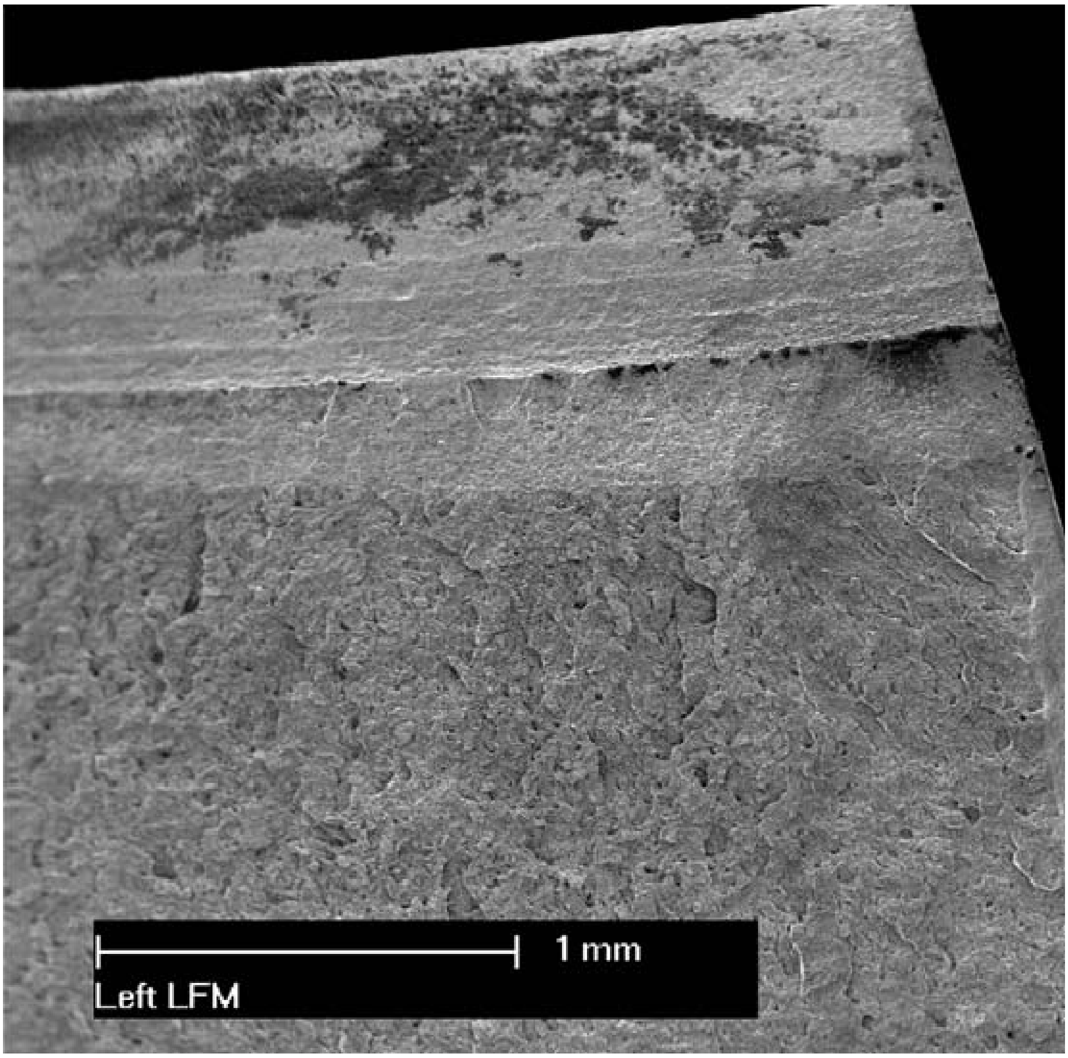

Figure 44: Scanning electron microscope image showing an overview of free-laid crack surface (opposite part to Figure 43).

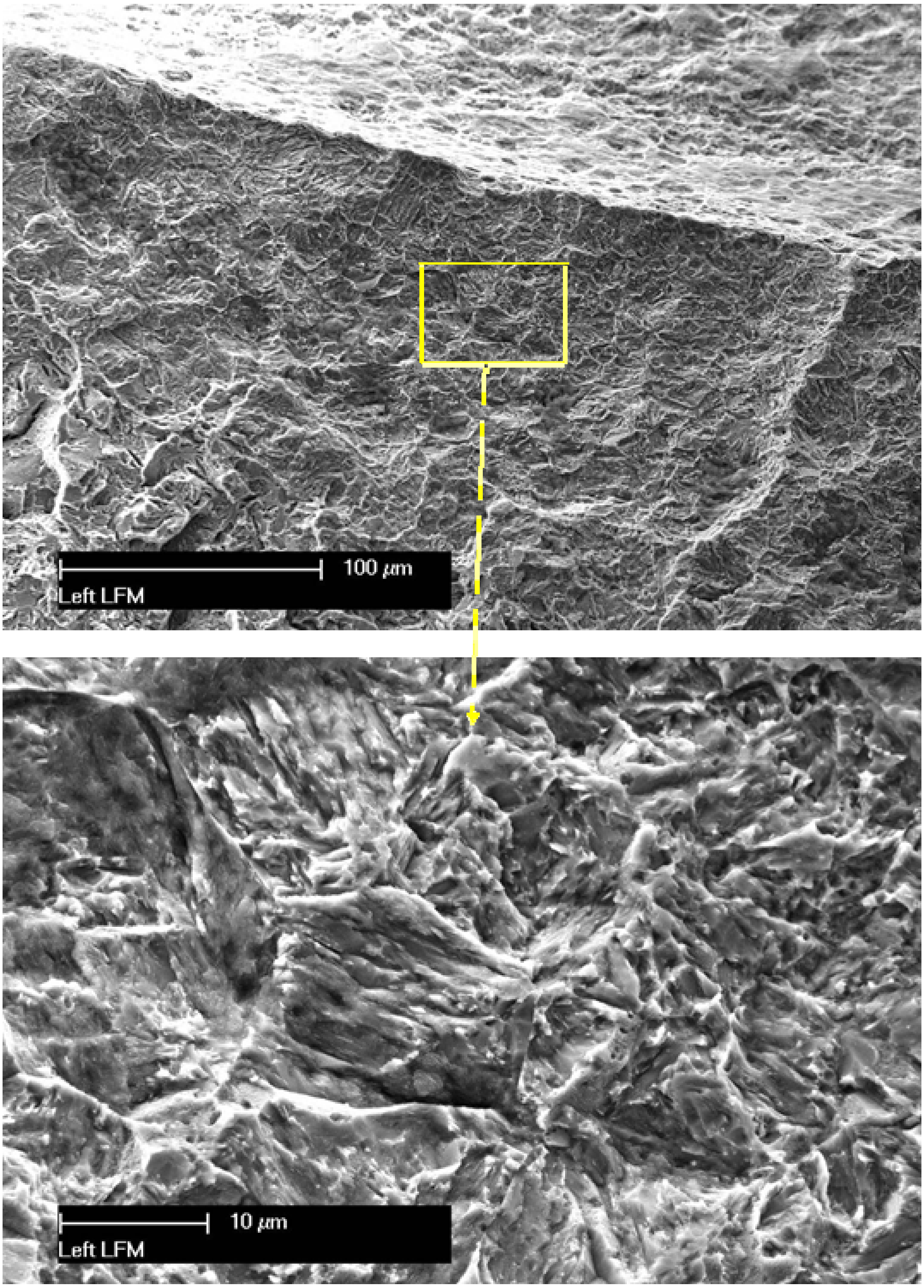

Figure 45: Typical area of crack near the surface. The appearance is typical of (low cycle) fatigue in high strength steel.

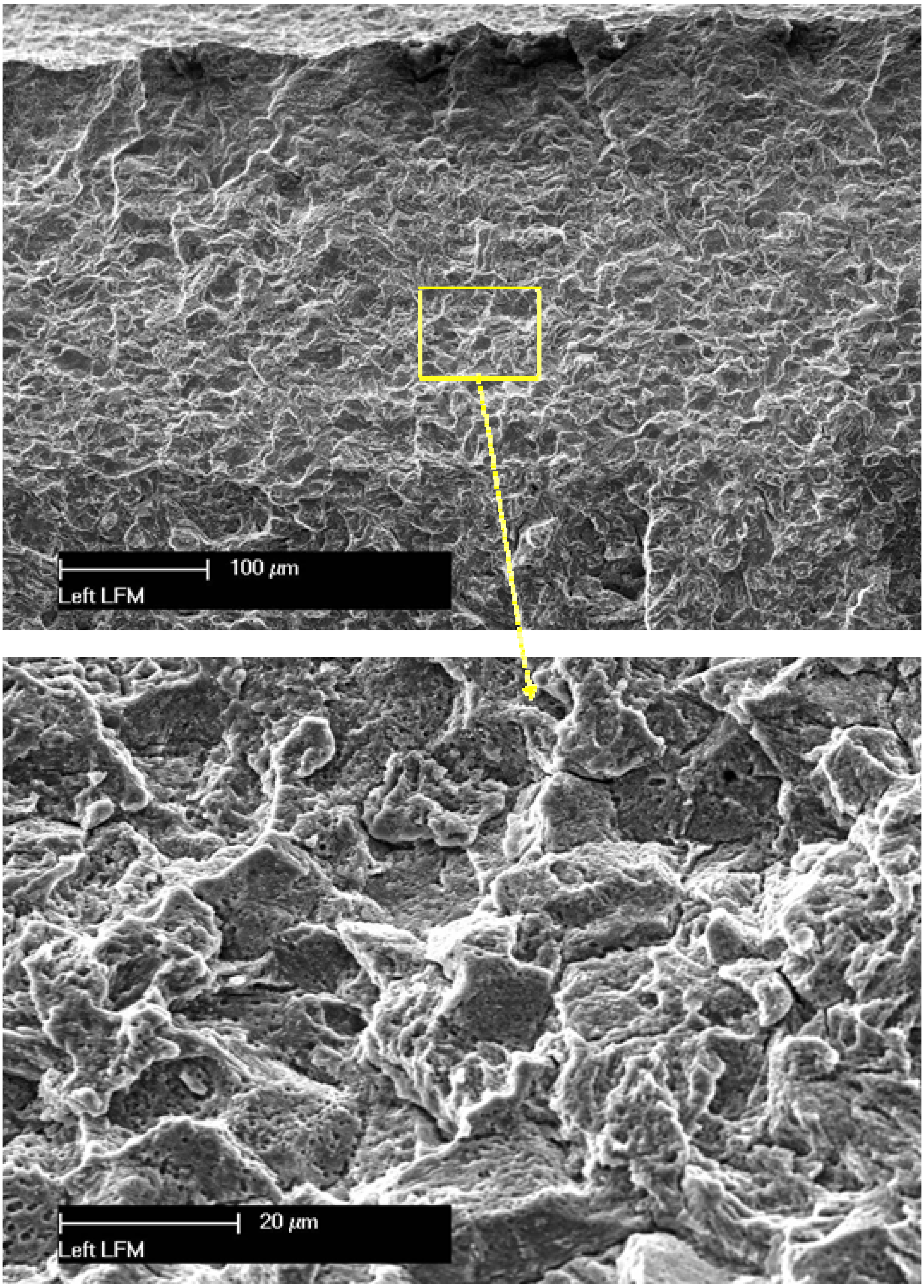

Figure 46: Scanning electron microscope images of crack surface at mid-depth of crack. A tendency towards intergranular cracking appears to be present.

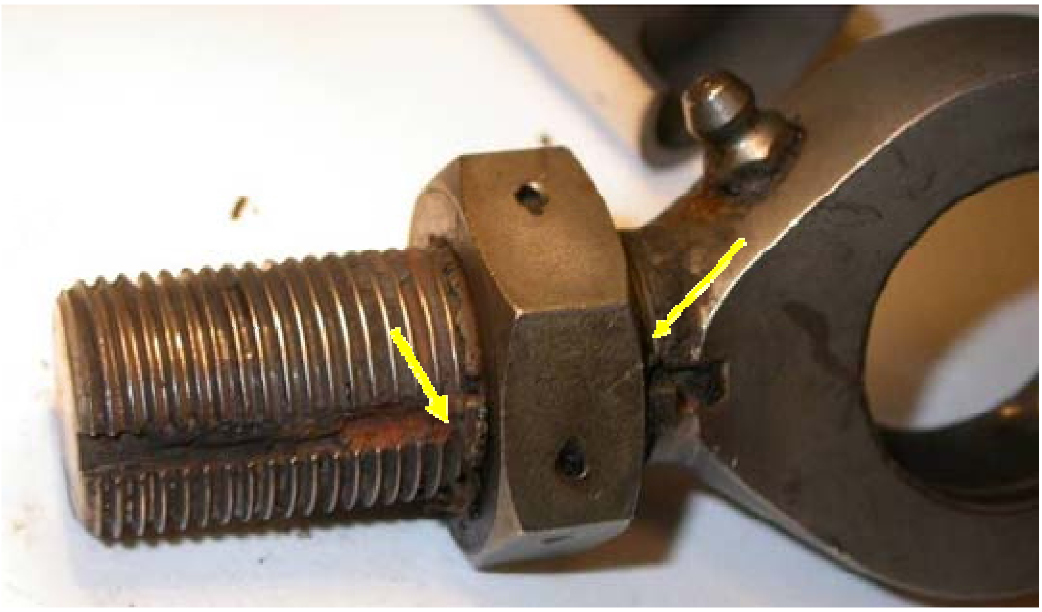

Figure 47: Sampling points for energy dispersive x-ray analysis.

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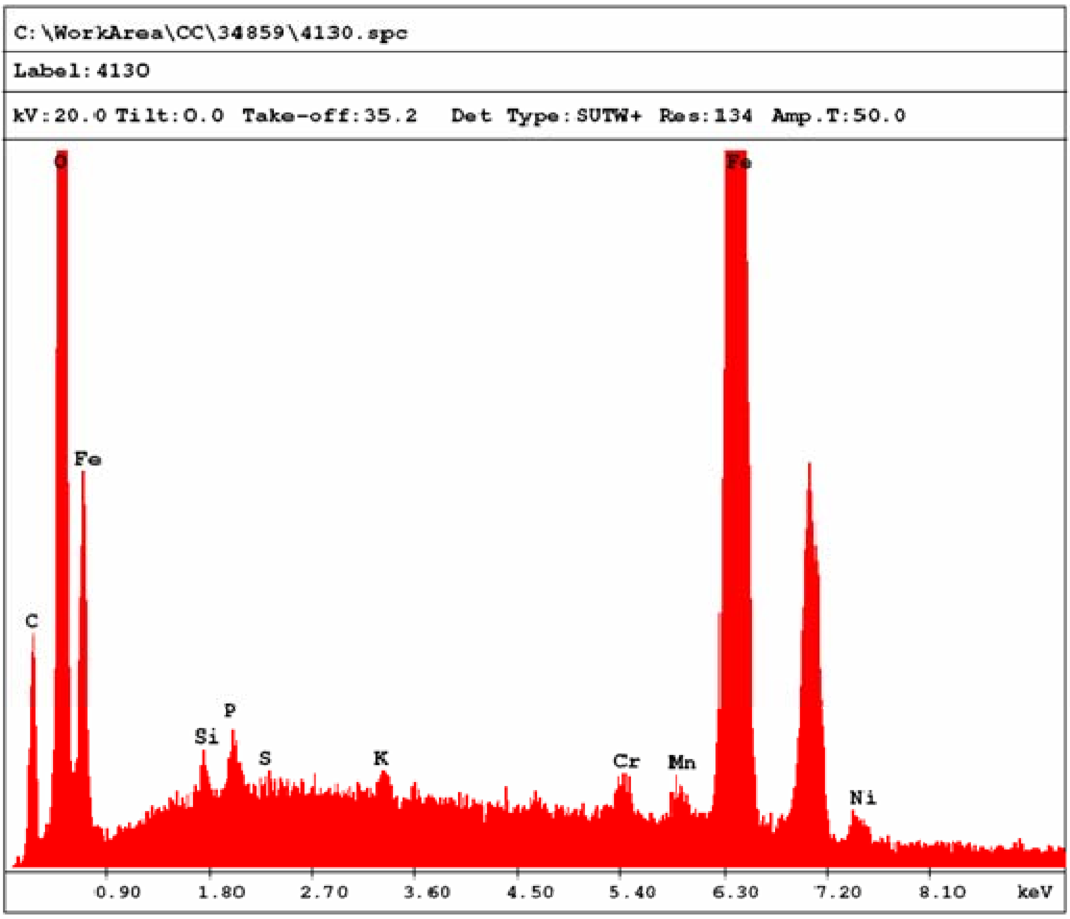


Figure 48: Energy dispersive x-ray analysis of corrosion products retrieved from key way in rod end.

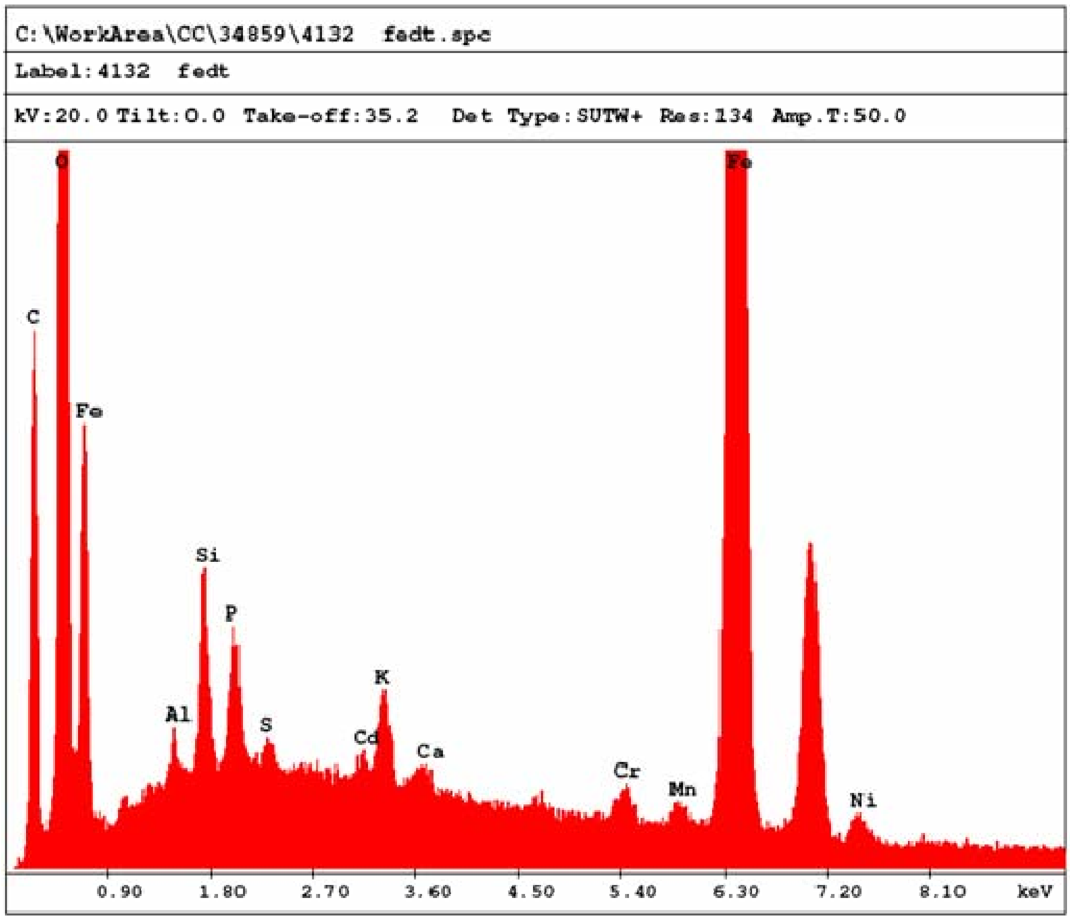


Figure 49: Energy dispersive x-ray analysis of grease compound retrieved from out side lock nut area in rod end.

51

Enclosure 1

Piston rod material

Analysis by Optical Emission Spectrometry

Division for Materials and Environment

**Performed using a SPECTROLAB S instrument according to ASTM E 415
With instrument specific modifications.**

Date 13-09-2007 Program FE-10
Sample No: CC/HPN
Case Id:
Sample Id:
Description: pipe

C	Si	Mn	P	S	Cr	Mo
%	%	%	%	%	%	%
0,42	0,31	0,73	0,004	0,002	0,88	0,25
Ni	Al	Co	Cu	Nb	Ti	V
%	%	%	%	%	%	%
1,80	0,070	0,047	0,035	0,002	0,004	0,012
W	Pb	Sn	Mg	As	Zr	Ce
%	%	%	%	%	%	%
0,013	0,001	0,007	0,0003	<0,001	0,001	<0,002
Se	B	Zn	Ta	Te	N	Fe
%	%	%	%	%	%	%
<0,002	<0,0002	0,002	<0,003	<0,001	0,004	95

Fe is calculated as difference

Signature

☐ Due to the size of the sample the analysis has been performed using mask.
Accordingly the results obtained has increased uncertainty compared to analysis under optimal conditions.

☐ Analysis has been performed after remelting of the sample.
Accordingly the results obtained has increased uncertainty compared to analysis of original solid material.

Enclosure 2

Rod end material

Analysis by Optical Emission Spectrometry

FORCE TECHNOLOGY

Division for Materials and Environment

Performed using a SPECTROLAB S instrument according to ASTM E 415
With instrument specific modifications.

Date 13-09-2007 Program FE-31
Sample No: CC/HPN
Case Id:
Sample Id:
Description: lifting eje

C	Si	Mn	P	S	Cr	Mo
%	%	%	%	%	%	%
0,032	0,056	0,070	0,007	0,003	12,6	2,18
Ni	**Al**	**Co**	**Cu**	**Nb**	**Ti**	**V**
%	%	%	%	%	%	%
8,7	1,03	0,028	0,051	0,005	0,016	0,021
W	**Pb**	**Sn**	**As**	**Se**	**B**	**Ce**
%	%	%	%	%	%	%
0,011	<0,0005	<0,001	0,001	0,011	<0,0001	0,012
N	**Fe**					
%	%					
0,008	75					

Fe is calculated as difference

Signature

☐ Due to the size of the sample the analysis has been performed using mask.
Accordingly the results obtained has increased uncertainty compared to analysis under optimal conditions.

☐ Analysis has been performed after remelting of the sample.
Accordingly the results obtained has increased uncertainty compared to analysis of original solid material.

Appendix C: Complain card

COMPLAINT CARD

Aircraft registration	Work order number	Flight number	Log sequence	Date
LN-RDK	WO0454621			2007-06-03

HPS: RDK WO0454621 PMS: LN-RDKWO0454621

COMPLAINT

Status Closed **BIT code**

Description

During Line check found rod end on r/h mlg. retraction actuator loose in piston end.

Complaint ATA	Zone	Ref.to WO	Station
32-31		WO0453416	Omitted by the AIB DK

Action nbr: 1 **Doc. ref:** amm **Action ATA:**

found nut loose nut fastned and operational test of the main landing gear primary extension and retraction perf wo/rem.acc to amm 32-00-710-801.

Sta

SK

Omitted by the AIB DK

Da

070604 08:40:00

1(1)

Appendix D: Zonal inspection requirement manual

Q400 DASH 8 The Quiet One

PSM 1-84-7 — MAINTENANCE REQUIREMENTS MANUAL MRB REPORT — Transport Canada/FAA/JAA Approved

ZONAL INSPECTION PROGRAM

MAJOR ZONE 700 – LANDING GEAR

Task Number	Model/ Eff.	Task Code/ Task Title/ Task Description	Zones in Task	Interval	Prcluded Task No.
Z700-01E	ALL	GVI NOSE LANDING GEAR External General Visual Inspection of the Nose Landing Gear	711	A	320100-205 320100-208 322000A201, 322000E201
Z700-02E	ALL	GVI NOSE LANDING GEAR DOORS External General Visual Inspection of the Nose Landing Gear Doors	712, 713, 714, 715	C	
Z700-03E	ALL	GVI MAIN LANDING GEAR, LH External General Visual Inspection of the Main Landing Gear, LH	721	A	320100-205 320100-208 321000A201, 321000E201
Z700-04E	ALL	GVI MAIN LANDING GEAR, RH External General Visual Inspection of the Main Landing Gear, RH	731	A	320100-205 320100-208 321000A201, 321000E201
Z700-05E	ALL	GVI MAIN LANDING GEAR DOORS, LH External General Visual Inspection of the Main Landing Gear Doors, LH	722, 723, 724, 725	C	
Z700-06E	ALL	GVI MAIN LANDING GEAR DOORS, RH External General Visual Inspection of the Main Landing Gear Doors, RH	732, 733, 734, 735	C	

MRB REPORT – PART 1

3–700 Page 1

Nov 04/1999

Appendix E: Maintenance task card

WPID:	JOBSEQ:	CHTYP/PART:	ACREG/BOWID:

JOBCARDNAME: **EXTERNAL GVI OF THE MAIN LANDING GEAR, RH** JOBID:

ACTYP: **Q400** ACEFFCD: ACSNORG: ZONE: **731** ZONE: ZONE: JOBCARD: **FRQ067002**

SKILL: **MECH** SKILL: SKILL: SKILL: SKILL: TO rev:

ISSUED BY: ISSUE DATE: **2007-03-28** PAGE: **1** OF **5**

A/C REG.	JOBCARD NO. FRQ067002
ATTACH: ATTACH:	ATTACH: ATTACH:

AMM 1:	PAGEBLOCK:	CODE:	AMM 5:	PAGEBLOCK:	CODE:
AMM 2:	PAGEBLOCK:	CODE:	AMM 6:	PAGEBLOCK:	CODE:
AMM 3:	PAGEBLOCK:	CODE:	AMM 7:	PAGEBLOCK:	CODE:
AMM 4:	PAGEBLOCK:	CODE:	AMM 8:	PAGEBLOCK:	CODE:

COMPNO:	OUTSN:	PN:	SNORG:	POS:
COMPNO:	INSN:	PN:	SNORG:	VER: 5
STATION:	DATE:	SIGNATURE:		

JOB ATTACHMENT: AMM 05-47-04-210-802-000-001

JOB ATTACHMENT: AMM 05-40-00-210-801-000-001

ITEM NO: 0670000401 0670000401

ZONE: 731 Main gear

Subject: GENERAL VISUAL INSPECTION (EXTERNAL) OF THE MAIN LANDING GEAR, RH

References:

Type	Document
AMM	05-47-04-210-802
MPD	Z700-04E
MPITEM	0670000401
MANUAL	MTCM:000-05-730-300

Appendix E continued: Maintenance task card

WPID:	JOBSEQ:	CHTYP/PART:		ACREG/BOWID: JOBID:	
ACTYP: Q400	ACEFFCD: ACSNORG:	ZONE: 731	ZONE: ZONE:	JOBCARD: FRQ067002	
ISSUED BY:	ISSUE DATE: 2007-03-28			TO rev:	PAGE: 2 OF 5

DI *PERF.*

TASK 05-47-04-210-802

General Visual Inspection of the Main Landing Gear, RH (MRB #Z700-04E)

1. **General**
   A. The maintenance procedure that follows is for the general visual inspection of the main landing gear (MLG). These procedures are applicable to the right MLG assembly.

2. **Job Set-Up Information**
   A. Tools & Equipment
      (1) Pin, NLG Door Ground Lock
      (2) Pin, MLG Door Ground Lock

   B. Reference Information

REFERENCE	DESIGNATION
AMM05-40-00-210-801	MRB Inspection Requirements for a Zonal Inspection
AMM12-00-01-860-801	Standard Aircraft Configuration for Maintenance
AMM32-00-00-840-801	Open and Lock the Landing Gear Doors
AMM32-00-00-840-802	Unlock and Close the Landing Gear Doors

3. **Job Set-Up**
   _____ A. Make sure that the aircraft is in the standard configuration for maintenance (Refer to AMM12-00-01-860-801).

   _____ B. Open the MLG doors (Refer to AMM32-00-00-840-801).

   WARNING: YOU MUST INSTALL THE LOCKPINS IN THE DOOR MECHANISMS OF THE MLG AND NLG. THE DOOR MECHANISMS CAN ACCIDENTALLY CLOSE THE LANDING GEAR DOORS. THIS CAN CAUSE INJURIES TO PERSONS AND DAMAGE TO THE EQUIPMENT.

   _____ _____ C. Install the safety locks on the MLG doors.

4. **Procedure**
   Ref. Fig. 1
   _____ A. Do an external general visual inspection of the main landing gear (MLG) as follows:
      (1) Examine the zone 731 (Refer to AMM05-40-00-210-801).

5. **Close Out**
   _____ A. Remove all tools, equipment, and unwanted materials from the work area.

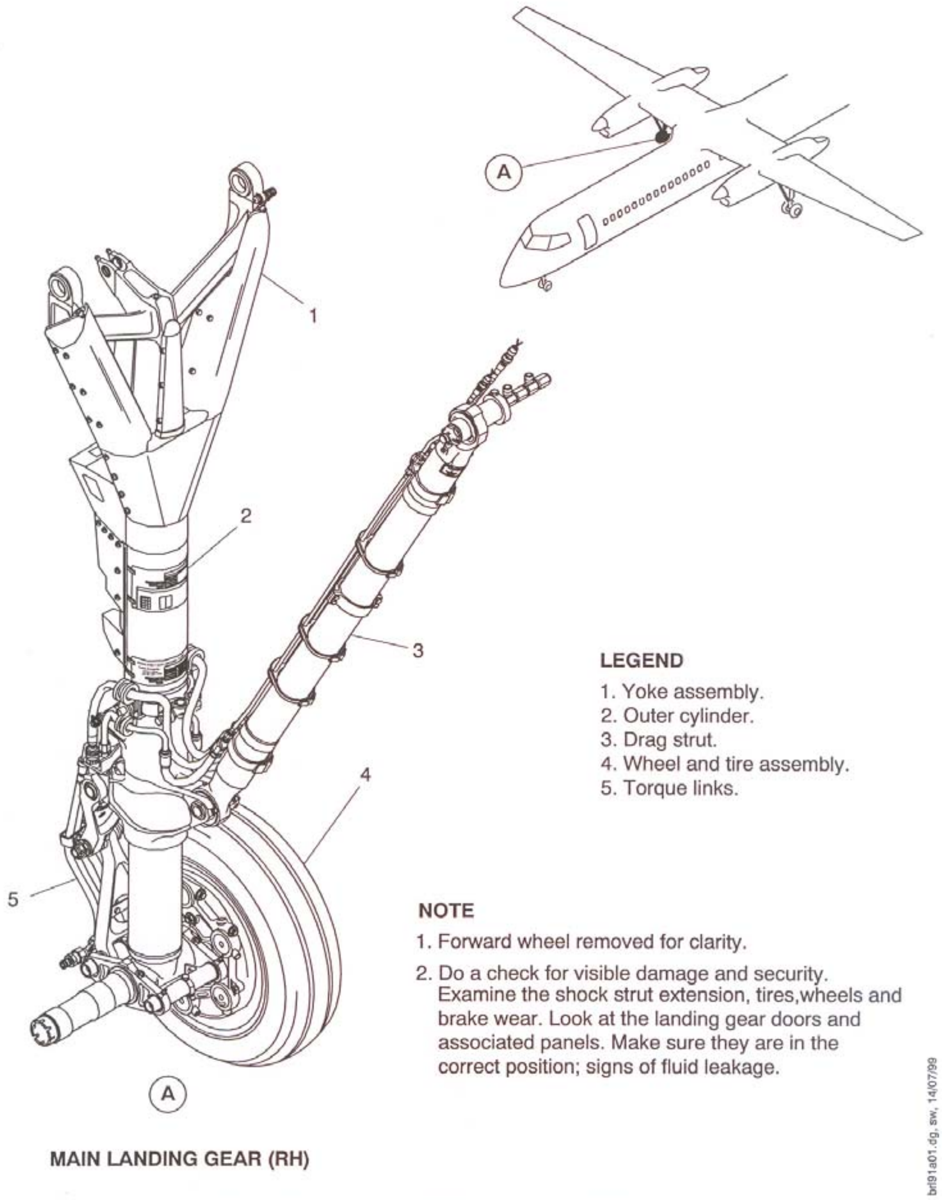
   _____ _____ B. Remove the safety locks on the MLG doors.

   WARNING: BE CAREFUL WHEN YOU REMOVE THE LOCKPINS OF THE MAIN LANDING GEAR. THE LANDING GEAR DOORS CAN OPERATE. THIS CAN CAUSE INJURIES TO PERSONS AND DAMAGE TO THE EQUIPMENT.

   C. Close the MLG doors (Refer to AMM32-00-00-840-802).

Appendix E continued: Maintenance task card

					ACREG/BOWID:
WPID:		JOBSEQ:	CHTYP/PART:		JOBID:
ACTYP: Q400	ACEFFCD:	ACSNORG:	ZONE: 731	ZONE:	ZONE: JOBCARD: FRQ067002
ISSUED BY: (		ISSUE DATE: 2007–03–28			TO rev: PAGE: 3 OF 5



LEGEND

1. Yoke assembly.
2. Outer cylinder.
3. Drag strut.
4. Wheel and tire assembly.
5. Torque links.

NOTE

1. Forward wheel removed for clarity.
2. Do a check for visible damage and security. Examine the shock strut extension, tires,wheels and brake wear. Look at the landing gear doors and associated panels. Make sure they are in the correct position; signs of fluid leakage.

Figure 1: Gear, Main Landing (RH) – Inspection/Check

Appendix E continued: Maintenance task card

					ACREG/BOWID:	
WPID:	JOBSEQ:	CHTYP/PART:			JOBID:	
ACTYP: Q400	ACEFFCD:	ACSNORG:	ZONE:	ZONE:	ZONE:	JOBCARD: FRQ067002
					TO rev:	
ISSUED BY:		ISSUE DATE: 2007-03-28				PAGE: 4 OF 5

DI *PERF.*

TASK 05-40-00-210-801

MRB Inspection Requirements for a Zonal Inspection

1. **General**
   A. This maintenance procedure is for the general visual inspection requirements for a zonal inspection as necessary by the Maintenance Review Board (MRB).

   The Zonal Inspection Program is a procedure by which the aircraft is examined on a scheduled basis. The program makes sure that all systems, power plants, components, installations and structures receive sufficient inspection for correct installation and general condition.

2. **Explanation**
   A. The aircraft consists of areas divided (internally and externally) into major zones, major sub-zones and zones in accordance to ATA Specification 100. The Task Number identifies the major zone and is followed by a sequence number in the zone (e.g. Z200-02, Z200-03, etc.). The letter 'E' after the sequence number identifies an external inspection (e.g. Z200-01E). Zonal tasks include one or more than one zone, for inspection purposes.

   To find zone, access panel and aircraft station data, refer to the Aircraft Maintenance Manual (AMM) PSM 1-84-2, Chapter 6, Dimensions and Areas.

3. **Zonal Inspection**
   A. Zonal Inspections are General Visual Inspections (GVI). The only inspection aids necessary are a flashlight and an inspection mirror. You must remove the seats, carpets, fairings, doors, access/trim panels in the zone, as necessary, to complete the Zonal Inspection. You must sufficiently lift the insulation material to do the structural inspection when necessary. Do the Zonal Inspection within arms-reach distance.

   NOTE: The MRB Report Section 3, Zonal Inspection Program requirements, specified here, are given as an inspection aid only. If there is a difference between manuals, use the Maintenance Requirements Manual, PSM 1-84-7.

4. **Job Set-Up Information**
   A. Tools & Equipment
      (1) Commercially AvailableLight Source
      (2) Mirror

5. **Job Set-Up**
   A. If necessary, remove the applicable access panels, fairings or doors.

   B. Sufficiently lift the insulation material to do the structural inspection when necessary.

6. **Procedure**
   A. Do a general visual inspection of the zonal area(s) as follows:
      (1) Examine the equipment, the structure, all connectors and control cables, as applicable, for:

      NOTE: Use a mirror and light source as inspection aids when necessary.

      (a) Cleanliness. Make sure the area is clean.
      (b) Damage, cracks, deterioration of protection treatment and corrosion.
      (c) Signs of wear, chafing, dents, loose or damaged fasteners, distortion, fouling, bowing scoring and fraying.
      (d) Correct installation of control rods, pulleys, wiring harnesses, electrical bonding, ground studs and tubing.

Appendix E continued: Maintenance task card

						ACREG/BOWID:	
WPID:		JOBSEQ:	CHTYP/PART:			JOBID:	
ACTYP: Q400	ACEFFCD:	ACSNORG:	ZONE:	ZONE:	ZONE:	JOBCARD: FRQ067002	
						TO rev:	
ISSUED BY:		ISSUE DATE: 2007–03–28					PAGE: 5 OF 5

DI PERF.

(e) Correct installation of connectors and backshells. Make sure that no red witness bands are visible.

(f) Correct installation of those connectors and backshells with other forms of L/HIRF protection.

(g) Signs of fluid leakage, overheating and unusual discoloration.

(h) The correct operation of the drain holes. Make sure that the drain holes are clean, not blocked, and that the area is not moist.

(i) Examine the access panels, fairings or doors removed for access.

(2) Examine the applicable composite structure/material for:

(a) Cleanliness. Make sure the area is clean.

(b) Discoloration because of overheating.

(c) Do a "tap" test to examine the composite structure for signs of delamination.

(d) Foreign matter, signs of scratches, crazing, cracks, blisters, dents, orange peeling, pitting, air bubbles, porosity, resin–rich and resin–poor areas, and wrinkles.

(e) Correct installation of control rods, pulleys, wiring harnesses, electrical bonding and tubing

(f) The correct operation of the drain holes. Make sure that the drain holes are clean, not blocked, and that the area is not moist.

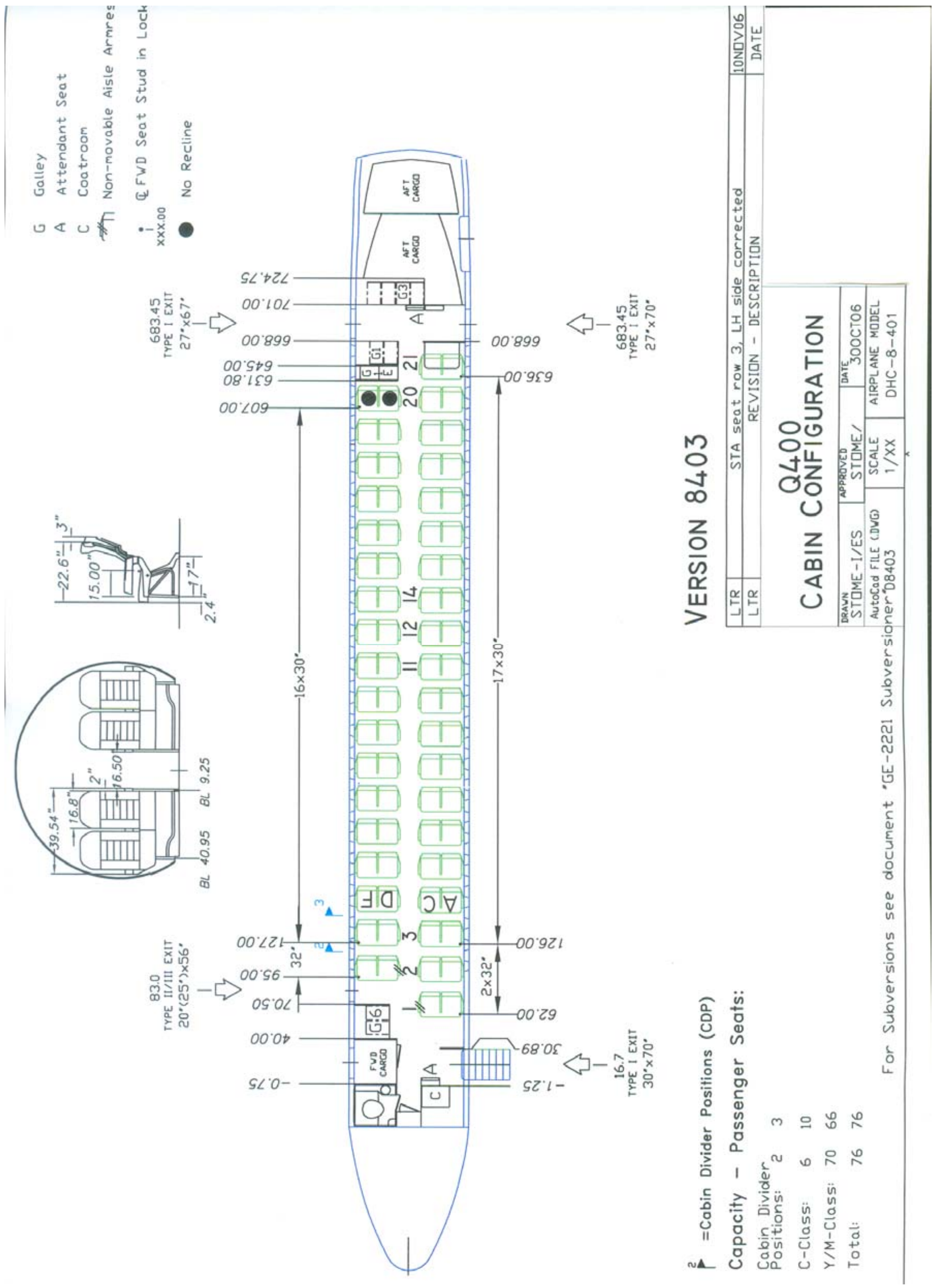
7. Close Out

A. Remove all tools, equipment, and unwanted materials from the work area.

B. Install the insulation material lifted for access.

C. Install the applicable access panels, fairings or doors removed for access.

Appendix F: Cabin layout



Appendix G: Operators quick reference handbook (QRH)

Q400 The Quiet One

DHC-8-400

LANDING GEAR

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Appendix G continued: Operators quick reference handbook (QRH)

Q400 The Quiet One

LANDING GEAR

[redacted]

DHC-8-400

ALTERNATE LANDING GEAR EXTENSION
("LDG GEAR INOP" Caution Light.)

Landing Considerations:

- Landing Gear cannot be retracted.
- Nosewheel steering will be inoperative.

- Airspeed.. 185 KIAS (max)
- L/G Inhibit switch.. Inhibit
- Landing Gear selector.. Down
- Landing Gear Alternate Release door .... Open
- Main Gear Release handle .... Pull Fully Down
- Landing Gear Alternate Extension door.................................... Open

Note: *IF LEFT and/or RIGHT green gear locked down Advisory Lights do not illuminate, insert Hydraulic Pump handle in socket and operate until LEFT and RIGHT green gear locked down Advisory Lights illuminate.*

- Nose Gear Release handle.................................... Pull Fully Up

Note: *Leave Landing Gear Alternate Release and Extension Doors fully open and L/G Inhibit switch at Inhibit.*

- Gear-Locked-Down indicator .... On/Check/Off
- Anti-Skid.. Test

Note: *If alternate landing gear extension procedures fails, proceed to QRH page 14.2.*

After Landing:

As soon as possible after engine shutdown:

- Ground Locks.. Install

Page: 14.1 Effective:16.Sep 2005

Q400 The Quiet One

DHC-8-400

LANDING GEAR

[redacted]

LANDING GEAR INDICATOR MALFUNCTION

IF any of the Green gear-locked-down Advisory Lights fail to illuminate:

- Landing Gear Alternate Extension Door .... Open
- Gear-Locked-Down Indicator .... On/Check/Off
- Landing Gear Alternate Extension Door .... Close

LANDING GEAR DOOR MALFUNCTION

Illumination Of Amber Door Open Advisory Light With Landing Gear Up

- Airspeed .... 185 KIAS (Max)
- Flap 0

IF amber Door open advisory light remains illuminated:

- Landing Gear selector .... Down

IF amber Door open advisory light remains illuminated:

- Landing Gear selector .... Leave Down
- Airspeed .... 185 KIAS (Max)
- Complete flight with landing gear down.

IF amber Door open advisory light is out:

- Landing Gear selector .... Up

IF amber Door open advisory light illuminates:

- Airspeed .... 185 KIAS (Max)
- Complete flight with amber Door open advisory light illuminated.

Illumination Of Amber Door Open Advisory light with Landing Gear Down

- Airspeed .... 185 KIAS (Max)
- Complete flight with landing gear down.

Q400 The Quiet One

DHC-8-400

LANDING GEAR

[redacted]

GEAR RETRACTION FAILURE

- Check L/G Inhibit switch .... Normal
- Check Landing Gear Alternate Release Door .... Closed
- Check Landing Gear Alternate Extension Door .... Closed
-

•If normal and closed positions:
•Landing Gear selector .... Down
•Airspeed .... 185 KIAS (max)
•Land at nearest suitable airport
•
•If NOT normal and / or closed positions:
•Landing Gear selector .... Down
•L/G Inhibit switch .... Normal
•Landing Gear Alternate Release Door .... Close
•Landing Gear Alternate Extension Door .... Close
•Landing Gear selector .... Up

UNSAFE GEAR-INDICATION AFTER GEAR-UP SELECTION

- Landing Gear selector .... Down
- Airspeed .... 185 KIAS (max)
- Land at nearest suitable airport

"INBD ANTI-SKID" and/or "OUTBD ANTI-SKID" (Caution Light)

- Anti-Skid .... On

Landing Considerations:

- Use Manual Technique for braking (see note below)

Landing Distance Factor and V_{REF}				
Cond:	NON ICING		ICING	
Flaps	Factor	V_{REF} +	Factor	V_{REF} +
0	2.65	0	3.75	0
5	2.65	0	3.75	0
10	2.05	0	2.90	0
15	1.90	0	2.65	0
35	1.70	0	2.25	0

Note: ***Manual Technique*** *- for maximum deceleration, brakes should be applied intermittently with momentary release at about 1 second intervals.*

Caution: *Excessive brake application can result in skidding and tire failure.*

Q400 The Quiet One

LANDING GEAR

[redacted]

DHC-8-400

"NOSE STEERING"
(Caution Light)

- Steering Handle .... Center

IF Caution Light remains illuminated:

- Nose Steering .... Off

Landing Considerations:

- Land at an airport with minimum crosswind.

Note: *Taxi using differential braking and power.*

"WT ON WHEELS"
(Caution Light)

- No crew action req'd

Caution: *Landing Gear may not retract.*

Note: *Caution Light may extinguish after landing, however rectification will be required prior to next flight.*

I

"TOUCHED RUNWAY"
(Warning Light)

- Do Not Start APU
- Advice ATC for Runway Inspection

Note: *Continued flight operations require maintenance approval.*

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Appendix G continued: Operators quick reference handbook (QRH)

Q400 The Quiet One

DHC-8-400

EMERGENCY LANDING, FORCED LANDING, EMERGENCY EVACUATION

[redacted]

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Appendix G continued: Operators quick reference handbook (QRH)

Q400 The Quiet One

DHC-8-400

EMERGENCY LANDING, FORCED LANDING, EMERGENCY EVACUATION

EMERGENCY LANDING
(Both Engines Operating)

If possible ensure no passengers are seated in the plane of the propellers.

- GPWS CB (A1 & B1 - Avionics CB Panel) .... Pull
- Emergency Lights .... On
- Auto/Man/Dump .... Dump
- ELT .... On
- Shoulder Harness .... Lock
- FD DOOR LOCK .... Un-Lock

Landing Gear Extended:

- Proceed with normal approach.

Landing Considerations:

When aeroplane comes to a stop:

- Emerg Brake .... On
- Condition Levers .... Fuel Off
- T- Handles .... Pull
- Battery Master .... Off
- Evacuate airplane

Landing Gear Retracted:

Landing Considerations:

- Flap .... 35°
- Maintain V_{REF} until immediately prior to flare.
- DO NOT exceed 6° nose up during flare.
- Touch down with minimum speed and minimum rate of descent without stalling.

After ground contact:

- Condition Levers .... Fuel Off
- T- Handles .... Pull
- Battery Master .... Off

When aeroplane comes to a stop:

- Evacuate aeroplane

(cont'd on next page)

Appendix G continued: Operators quick reference handbook (QRH)

Q400 The Quiet One

DHC-8-400

EMERGENCY LANDING, FORCED LANDING, EMERGENCY EVACUATION

[redacted]

EMERGENCY LANDING

(Both Engines Operating) (cont'd)

Ditching:

- Landing Gear .... Up
- Condition Levers .... Max
- Bleed Air 1 and 2 .... Off
- Flap .... 35°
- ELT .... On

Landing Considerations:

- In rolling swell surface conditions attempt to ditch along and parallel to the crests as much into wind as swell line permits. In other water surface conditions land into wind.
- Maintain V_{REF} until immediately prior to flare.
- Commence flare to achieve zero vertical velocity immediately prior to water contact.
- Maintain pitch attitude of 10° nose up.
- Touch down with minimum speed and minimum rate of descent without stalling.
- A transient nose-up pitching motion may result following touchdown. Overcorrection of this tendency could result in porpoising or nosing in.

After water contact:

- Condition Levers .... Fuel Off
- T- Handles .... Pull
- Battery Master .... Off

When aeroplane comes to a stop:

- Evacuate aeroplane

Note: *After completion of the ditching run, the aeroplane will float with one wing in the water. The upper portion of the right forward emergency exit and the airstair door should be used for evacuation. The airstair door ditching dam must be in place prior to opening the door.*

Warning: ***DO NOT*** *open the Aft Doors or the lower portion of the right forward emergency exit.*

Page: 8.2 Effective:01.Jul 2002

Q400 The Quiet One

DHC-8-400

EMERGENCY LANDING, FORCED LANDING, EMERGENCY EVACUATION

[redacted]

FORCED LANDING
(Both Engines Inoperative)

- Hyd #3 Isol Vlv .... Open

Landing Considerations:

- Flap .... 0 (if possible)
- Condition Levers .... Fuel Off
- Alternate Feather (if req'd) .... FTHR
- Main, Aux & Stby Batteries .... Off
- Battery Master .... On

Note: *With Flap 0, landing gear retracted, propellers feathered and zero wind, 2.5 nautical miles can be travelled for every 1000 feet of altitude loss.*
All Hydraulic (except for elevator control), pneumatic, and non-essential electrical services will be inoperative.

- FASTEN BELT .... On
- Emergency Lights .... On
- ELT .... On
- Shoulder Harness .... Lock

Select Appropriate Landing Considerations:

- Gear Extended .... Below
- Gear Retracted .... Page 8.4
- Ditching .... Page 8.4
- FD DOOR LOCK .... Un-Lock

Landing Gear Extended:

Landing Considerations:

- Extend landing gear using ALTERNATE LANDING GEAR EXTENSION procedure (page 14.1). Allow sufficient time for alternate gear extension.
- Extending landing gear will steepen glide angle and decrease glide distance.
- Land into wind, maintaining V_{REF} until immediately prior to flare.
- Commence flare to achieve zero vertical velocity immediately prior to ground contact
- DO NOT exceed 6° nose up during flare
- Touch down with minimum speed and minimum rate of descent without stalling.

After touchdown:

- Battery Master .... Off
- Emerg Brake .... Apply Intermittently

When aeroplane comes to a stop:

- Evacuate aeroplane

Page: 8.3 Effective: 15.Dec 2003

Appendix G continued: Operators quick reference handbook (QRH)

Q400 The Quiet One

DHC-8-400

EMERGENCY LANDING,
FORCED LANDING,
EMERGENCY EVACUATION

[redacted]

FORCED LANDING
(Both Engines Inoperative) (cont'd)

Landing Gear Retracted:

Landing Considerations:

- Maintaining V_{REF} until immediately prior to flare.
- Commence flare to achieve zero vertical velocity immediately prior to ground contact
- DO NOT exceed 5° nose up during flare
- Touch down with minimum speed and minimum rate of descent without stalling.

When aeroplane comes to a stop:

- Battery Master.. Off
- Evacuate aeroplane

Ditching:

- Landing Gear .... Up
- ELT .... On

Landing Considerations:

- In rolling swell surface conditions attempt to ditch along and parallel to the crests as much into wind as swell line permits. In other water surface conditions land into wind.
- Maintain V_{REF} until immediately prior to flare.
- Commence flare to achieve zero vertical velocity immediately prior to water contact
- Maintain pitch attitude of 10° nose up.
- Touch down with minimum speed and minimum rate of descent without stalling.
- A transient nose-up pitching motion may result following touchdown. Overcorrection of this tendency could result in porpoising or nosing in.

After water contact:

- Battery Master.. Off

When aeroplane comes to a stop:

- Evacuate aeroplane

Note: *After completion of the ditching run, the aeroplane will float with one wing in the water. The upper portion of the right forward emergency exit and the airstair door should be used for evacuation. The airstair door ditching dam must be in place prior to opening the door.*

Warning: ***DO NOT*** *open the Aft Doors or the lower portion of the right forward emergency exit.*

Page: 8.4 Effective:01.Jul 2002

Appendix G continued: Operators quick reference handbook (QRH)

Q400 The Quiet One

DHC-8-400

EMERGENCY LANDING, FORCED LANDING, EMERGENCY EVACUATION

[redacted]

ON GROUND EMERGENCIES

- Emerg Brake .... On
- Power Levers .... Disc
- Condition Levers .... Fuel Off
- T- Handle (affected engine) .... Pull
- Tank Aux Pump (affected engine) .... Off

IF Fire:

- Extg switch .... Fwd Btl
  - Wait up to 30 secs, if fire persists:
- Extg switch .... Aft Btl

IF Evacuation Requiered:

ANNOUNCE: "EMERGENCY, OPEN SEAT BELT GET OUT"

- FASTEN BELT .... Off
- Emergency Lights .... On
- Evacuation signal .... On
- AC/DC Ext Pwr and APU .... Off
- Battery Master .... Off

IF EVACUATION IS NOT REQUIERED:

ANNOUNCE "CABIN CREW AND PASSENGER KEEP YOUR SEATS"

EMERGENCY OPENING OF FLIGHT COMPARTMENT DOOR (FLIGHT COMPARTMENT DOOR JAMMED)

- Unlock and push or step down on bottom hinge pin.
- Unlock and pull down upper hinge pin.
- Unlock and lift middle hinge pin.
- Push flight compartment door at hinge side

Note: It may require a large force to open the flight compartment door

- Rotate the flight compartment door counter clockwise and stow agains the lavatory

Note: Upon forcing the flight compartment door open, it may fall straight aft and lay flat on the cabin floor.

Page: 8.5 Effective:20.Jun 2004

4.21 ALTERNATE LANDING GEAR EXTENSION

4.21.1 LANDING GEAR MALFUNCTION (ILLUMINATION OF LDG GEAR INOP CAUTION LIGHT), OR PARTIAL LOSS OF NO. 2 HYDRAULIC SYSTEM QUANTITY (ILLUMINATION OF #2 HYD ISO VLV CAUTION LIGHT) OR LOSS OF NO. 2 HYDRAULIC SYSTEM PRESSURE (ILLUMINATION OF #2 ENG HYD PUMP CAUTION LIGHT)

1. Maximum airspeed – 185 kt IAS.
2. L/G DOWN SELECT INHIBIT SW – INHIBIT.

NOTE

If LDG GEAR INOP caution light was out, it will illuminate when the L/G DOWN SELECT INHIBIT SW is selected to INHIBIT.

3. LANDING GEAR lever – DN (if lever not previously selected to DN).
4. LANDING GEAR ALTERNATE RELEASE door – Open fully.
5. MAIN L/G RELEASE handle – Pull fully down. Check L DOOR and R DOOR amber doors open and LEFT and RIGHT green locked down advisory lights illuminate.

NOTE

Gear release handle loads may exceed those experienced during practice extensions.

6. LANDING GEAR ALTERNATE EXTENSION door – Open fully.

NOTE

If LH and/or RH green gear locked down advisory lights do not illuminate, insert hydraulic pump handle in socket and operate until LH and RH green gear locked down advisory lights illuminate.

7. NOSE L/G RELEASE handle – Pull fully up. Check N DOOR amber doors open and NOSE green gear locked down advisory lights illuminate.

NOTE

Gear release handle loads may exceed those experienced during practice extensions.

8. LANDING GEAR ALTERNATE RELEASE and LANDING GEAR ALTERNATE EXTENSION doors – LEAVE FULLY OPEN.
9. L/G DOWN SELECT INHIBIT SW – Leave at INHIBIT.

CAUTION

Landing gear cannot be retracted following extension by alternate extension procedure.

CAUTION

Nosewheel steering is inoperative following extension by alternate extension procedure.

10. ANTI SKID switch – TEST.

After landing:

11. Ground locks – Install main gear safety lock pins and engage nose gear lock as soon as possible after engine shutdown.

4.21.2 LANDING GEAR INDICATOR MALFUNCTION

If any of the primary green gear locked down advisory lights fail to illuminate:

1. LANDING GEAR ALTERNATE EXTENSION door – Open.
2. GEAR LOCKED DOWN INDICATOR LIGHT switch – ON. Check for illumination of appropriate gear locked down alternate light.
3. LANDING GEAR ALTERNATE EXTENSION door – Close.

4.21.3 LANDING GEAR DOOR MALFUNCTIONS

4.21.3.1 ILLUMINATION OF AMBER DOOR OPEN ADVISORY LIGHT WITH LANDING GEAR UP

1. Maximum airspeed – 185 KIAS.
2. FLAPS lever – 0°.

If amber DOOR open advisory light remains illuminated:

3. LANDING GEAR lever – DN.

If amber DOOR open advisory light remains illuminated:

4. LANDING GEAR lever – Leave DN. See paragraph 4.21.3.2.

If amber DOOR open advisory light out:

5. LANDING GEAR lever – UP.

If amber DOOR open advisory light illuminates:

6. Maximum airspeed – 185 KIAS.
7. Complete flight with amber DOOR open advisory light illuminated.

4.21.3.2 ILLUMINATION OF AMBER DOOR OPEN ADVISORY LIGHT WITH LANDING GEAR DOWN

1. Maximum airspeed – 185 KIAS.
2. Complete flight with landing gear down.

Appendix I: Extract from flight data recorder (FDR)

A/C REG.: LN-RDK REC/CASSETTE NO.: 5604 DATE REMOVED: 09SEP07

ACMS VOL/FILE : <no volname>/q:\prod\dardata\0709130Q.RDK

ACMS OPERATOR: PROFILE USED: 12 - Hard Landing RATE: 1 SEC FRAME: 22914

144	1	1650	130	16	127	24	545	541	137	10		11
Date YYMMDD	GMT HH:MM:S(	Press Alt F 1013 hF Feet	Radio alt. Feet	Hdg LH (degr)	Gnd. Speed Knots	CAS LH (kts)	Landing Gear Handle	Landing Gear Nose	Ldg. Gear Main	Vert. G	Lat. G	Long. G
90907		1672	1806	278	197	198				0.96	0.07	-0.07
		1654	1827	276	196	198	Retract			0.98	0.09	-0.06
	13:00:54	1630	1781	275	195	198		Up	Up	0.99	0.09	-0.05
		1612	1774	274	195	197				1.01	0.10	-0.06
90907		1588	1746	273	194	196				1.09	0.11	-0.05
		1562	1717	271	193	193	Retract			1.12	-0.00	-0.04
	13:00:58	1542	1651	270	193	193		Up	Up	1.09	0.06	-0.04
		1524	1634	269	192	193				1.11	-0.00	-0.07
90907		1512	1611	269	192	192				1.14	-0.03	-0.16
		1506	1591	269	191	193	Extend			1.08	0.12	-0.18
	13:01:02	1490	1588	267	190	191		Transit	Transit	1.07	-0.00	-0.17
		1480	1562	266	188	191				1.09	0.08	-0.19
90907		1490	1547	266	187	189				0.93	-0.05	-0.21
		1466	1517	265	185	187	Extend			1.04	-0.05	-0.20
	13:01:06	1444	1506	265	184	189		DWNLCK	Transit	0.98	0.05	-0.20
		1416	1480	264	182	186				1.00	0.06	-0.18
90907		1394	1453	264	181	185				1.05	0.06	-0.16
		1378	1426	264	179	184	Extend			1.02	0.04	-0.16
	13:01:10	1342	1405	264	178	182		DWNLCK	Transit	1.07	-0.01	-0.15
		1322	1391	263	177	180				1.07	0.04	-0.13
90907		1302	1425	264	175	177				1.04	0.09	-0.13
		1286	1378	264	174	177	Extend			1.03	0.07	-0.13
	13:01:14	1258	1380	263	173	174		DWNLCK	Transit	1.08	0.04	-0.12
		1244	1333	263	171	173				1.08	0.04	-0.11
90907		1224	1315	263	170	172				1.09	0.07	-0.09

Appendix I continued: Extract from flight data recorder (FDR)

90907		2962	RANGE	267	173	173				1.11	0.12	0.23
		2954	RANGE	265	173	173	Extend			1.16	0.12	0.25
	13:07:54	2958	RANGE	263	173	173		DWNLCK	Transit	1.14	0.09	0.25
		2974	RANGE	261	174	173				1.10	0.15	0.23
90907		2972	RANGE	259	174	171				1.04	0.10	0.21
		2970	RANGE	256	175	171	Retract			1.11	0.07	0.24
	13:07:58	2968	RANGE	254	176	171		Transit	Transit	1.12	-0.02	0.24
		2960	RANGE	253	176	173				1.08	0.11	0.25
90907		2962	RANGE	252	176	172				1.04	0.10	0.25
		2970	RANGE	251	177	173	Retract			1.02	0.07	0.23
	13:08:02	2976	RANGE	250	178	175		Up	Transit	0.97	0.07	0.21
		2964	RANGE	249	179	175				1.06	0.08	0.25
90907		2960	RANGE	249	179	174				1.07	0.09	0.25
		2958	RANGE	248	179	176	Retract			1.07	0.09	0.23
	13:08:06	2960	RANGE	248	180	176		Up	Transit	1.04	0.10	0.23
		2964	RANGE	248	180	176				0.98	0.09	0.21
90907		2966	RANGE	247	181	178				1.00	0.09	0.21
		2966	RANGE	247	181	179	Retract			0.98	0.08	0.21
	13:08:10	2970	RANGE	247	181	180		Up	Transit	1.05	0.10	0.21
		2966	RANGE	247	182	180				1.06	0.08	0.21
90907		2956	RANGE	247	182	179				1.11	0.10	0.23
		2964	RANGE	247	182	179	Retract			1.02	0.11	0.21
	13:08:14	2966	RANGE	247	183	181		Up	Transit	1.03	0.16	0.21
		2960	RANGE	246	183	180				1.06	0.16	0.21
90907		2962	RANGE	245	184	179				1.06	0.17	0.22
		2976	RANGE	245	184	181	Retract			0.93	0.12	0.18
	13:08:18	2972	RANGE	243	185	183		Up	Transit	1.03	0.23	0.20
		2966	RANGE	242	186	181				1.05	0.18	0.20
90907		2956	RANGE	240	187	179				1.16	0.22	0.22
		2940	RANGE	237	187	181	Retract			1.21	0.25	0.23
	13:08:22	2938	RANGE	235	187	181		Up	Transit	1.18	0.18	0.22
		2946	RANGE	233	187	180				1.13	0.16	0.20
90907		2962	RANGE	232	187	181				1.00	0.14	0.16
		2966	RANGE	230	187	181	Retract			1.04	0.13	0.18
	13:08:26	2964	RANGE	229	187	182		Up	Transit	1.04	0.11	0.18
		2968	RANGE	228	187	182				1.02	0.10	0.16

Appendix I continued: Extract from flight data recorder (FDR)

90907		2990	RANGE	320	172	173				1.11	0.04	0.27
		2990	RANGE	323	172	173	Retract			1.10	0.06	0.28
	13:09:42	2990	RANGE	325	173	173		Up	Transit	1.09	0.05	0.27
		2990	RANGE	328	173	174				1.07	0.04	0.27
90907		2990	RANGE	331	174	174				1.09	0.05	0.27
		2990	RANGE	333	175	175	Retract			1.09	0.05	0.27
	13:09:46	2990	RANGE	336	175	175		Up	Transit	1.12	0.05	0.27
		2990	RANGE	339	176	176				1.10	0.06	0.26
90907		2992	RANGE	341	176	176				1.09	0.05	0.26
		2992	RANGE	344	177	176	Retract			1.09	0.04	0.25
	13:09:50	2992	RANGE	347	177	176		Up	Transit	1.11	0.06	0.26
		2992	RANGE	350	178	176				1.10	0.06	0.26
90907		2990	RANGE	352	179	176				1.11	0.05	0.25
		2992	RANGE	355	179	176	Extend			1.11	0.06	0.26
	13:09:54	2992	RANGE	358	180	176		Up	Transit	1.11	0.06	0.26
		2990	RANGE	1	180	176				1.12	0.05	0.26
90907		2990	RANGE	4	181	176				1.12	0.06	0.26
		2992	RANGE	6	182	176	Extend			1.11	0.05	0.25
	13:09:58	2992	RANGE	9	183	177		Up	Transit	1.11	0.05	0.26
		2994	RANGE	12	183	177				1.10	0.05	0.25
90907		2994	RANGE	15	184	177				1.10	0.05	0.25
		2994	RANGE	17	184	177	Extend			1.10	0.06	0.25
	13:10:02	2994	RANGE	20	185	178		Up	Transit	1.11	0.06	0.25
		2992	RANGE	23	186	178				1.11	0.07	0.25
90907		2992	RANGE	25	187	178				1.10	0.05	0.24
		2994	RANGE	28	187	178	Extend			1.09	0.06	0.25
	13:10:06	2992	RANGE	31	188	178		Up	Transit	1.11	0.05	0.25
		2994	RANGE	34	189	178				1.10	0.06	0.24
90907		2990	RANGE	36	189	178				1.12	0.05	0.25
		2988	RANGE	39	190	178	Extend			1.12	0.06	0.25
	13:10:10	2990	RANGE	42	191	179		Up	Transit	1.12	0.07	0.25
		2990	RANGE	45	192	179				1.11	0.08	0.24
90907		2992	RANGE	47	192	180				1.10	0.07	0.23
		2990	RANGE	50	193	180	Extend			1.11	0.07	0.23
	13:10:14	2988	RANGE	53	194	180		Up	Transit	1.15	0.06	0.22
		2992	RANGE	55	194	180				1.09	0.05	0.20

Appendix I continued: Extract from flight data recorder (FDR)

90907		3002	RANGE	58	195	180				1.02	0.07	0.17
		2994	RANGE	60	195	180	Extend			1.05	0.05	0.18
	13:10:18	2992	RANGE	62	195	180		Up	Transit	1.05	0.07	0.18
		2988	RANGE	63	195	179				1.06	0.07	0.18
90907		2988	RANGE	65	195	180				1.05	0.09	0.18
		2986	RANGE	66	196	181	Extend			1.09	0.05	0.18
	13:10:22	2982	RANGE	67	196	181		Up	Transit	1.06	0.09	0.18
		2986	RANGE	68	195	181				1.00	0.09	0.16
90907		2988	RANGE	68	195	180				1.01	0.07	0.16
		2988	RANGE	68	195	180	Extend			0.99	0.06	0.15
	13:10:26	2982	RANGE	69	195	180		Up	Transit	1.02	0.09	0.17
		2976	RANGE	69	195	181				1.07	0.09	0.18
90907		2980	RANGE	70	195	180				1.03	0.05	0.17
		2984	RANGE	70	195	180	Extend			0.98	0.05	0.16
	13:10:30	2982	RANGE	70	195	180		Up	Transit	0.97	0.05	0.15
		2978	RANGE	71	195	180				1.00	0.05	0.14
90907		2972	RANGE	71	195	180				1.04	0.06	0.16
		2970	RANGE	71	195	179	Extend			1.04	0.04	0.16
	13:10:34	2972	RANGE	72	195	178		Up	Transit	1.02	0.04	0.16
		2970	RANGE	72	195	179				1.00	0.02	0.15
90907		2966	RANGE	73	195	179				1.02	0.04	0.15
		2964	RANGE	74	195	179	Extend			1.01	0.02	0.14
	13:10:38	2962	RANGE	76	195	179		Up	Transit	1.05	0.05	0.16
		2960	RANGE	77	195	179				1.05	0.07	0.16
90907		2958	RANGE	78	195	179				1.04	0.07	0.16
		2958	RANGE	79	195	179	Extend			1.03	0.06	0.16
	13:10:42	2958	RANGE	79	195	179		Up	Transit	1.01	0.05	0.15
		2958	RANGE	80	195	179				1.00	0.07	0.14
90907		2958	RANGE	81	195	179				1.01	0.07	0.15
		2958	RANGE	81	195	178	Extend			1.01	0.06	0.16
	13:10:46	2960	RANGE	81	194	178		Transit	Transit	1.00	0.06	0.16
		2962	RANGE	82	194	178				1.01	0.06	0.15
90907		2964	RANGE	82	194	178				1.00	0.08	0.14
		2964	RANGE	83	194	177	Extend			1.00	0.09	0.15
	13:10:50	2964	RANGE	83	194	177		Transit	Transit	1.02	0.07	0.15
		2962	RANGE	83	194	177				1.01	0.06	0.15

Appendix I continued: Extract from flight data recorder (FDR)

90907		2964	RANGE	83	193	176				0.99	0.07	0.14
		2962	RANGE	83	193	177	Extend			1.00	0.07	0.14
	13:10:54	2958	RANGE	84	193	176		DWNLCK	Transit	1.00	0.08	0.15
		2956	RANGE	84	193	176				1.01	0.07	0.15
90907		2954	RANGE	84	193	176				1.02	0.08	0.16
		2954	RANGE	84	192	176	Extend			1.01	0.11	0.16
	13:10:58	2952	RANGE	84	192	176		DWNLCK	Transit	1.01	0.11	0.16
		2952	RANGE	83	192	175				1.01	0.10	0.16
90907		2950	RANGE	82	191	175				1.02	0.09	0.16
		2950	RANGE	82	191	175	Extend			1.02	0.09	0.16
	13:11:02	2952	RANGE	81	191	175		DWNLCK	Transit	1.01	0.07	0.16
		2952	RANGE	81	190	175				1.00	0.06	0.16
90907		2952	RANGE	80	190	174				1.00	0.07	0.16
		2952	RANGE	80	189	174	Extend			1.00	0.07	0.16
	13:11:06	2952	RANGE	80	189	173		DWNLCK	Transit	1.00	0.06	0.15
		2952	RANGE	79	189	173				1.01	0.07	0.17
90907		2950	RANGE	79	189	173				1.02	0.07	0.17
		2952	RANGE	79	189	172	Extend			1.01	0.07	0.16
	13:11:10	2952	RANGE	79	188	172		DWNLCK	Transit	1.02	0.07	0.17
		2952	RANGE	78	188	173				1.01	0.07	0.16
90907		2952	RANGE	78	188	173				1.01	0.08	0.16
		2954	RANGE	78	187	173	Extend			1.00	0.07	0.16
	13:11:14	2952	RANGE	78	187	172		DWNLCK	Transit	1.03	0.06	0.16
		2950	RANGE	78	187	171				1.03	0.08	0.18
90907		2954	RANGE	78	186	171				1.02	0.07	0.17
		2952	RANGE	78	186	170	Extend			1.02	0.07	0.18
	13:11:18	2952	RANGE	78	186	169		DWNLCK	Transit	1.01	0.09	0.17
		2958	RANGE	78	185	169				0.99	0.11	0.18
90907		2954	RANGE	77	185	168				1.02	0.07	0.18
		2942	RANGE	77	185	168	Extend			1.17	0.06	0.22
	13:11:22	2950	RANGE	76	185	167		DWNLCK	Transit	1.10	0.07	0.21
		2962	RANGE	76	185	166				0.96	0.09	0.17
90907		2970	RANGE	76	184	167				0.95	0.09	0.16
		2962	RANGE	76	184	167	Extend			0.98	0.07	0.18
	13:11:26	2956	RANGE	76	184	166		DWNLCK	Transit	1.08	0.06	0.19
		2960	RANGE	75	184	167				1.04	0.04	0.18

Appendix I continued: Extract from flight data recorder (FDR)

90907		0	19	264	109	119				1.09	0.04	0.05
		-8	14	264	109	117	Extend			1.11	-0.05	0.05
	13:57:06	-12	8	264	109	119		DWNLCK	Transit	1.10	0.06	0.05
		-16	3	265	109	118				1.06	0.04	0.02
90907		-20	1	265	109	116				1.26	0.23	-0.30
		-10	RANGE	265	108	115	Extend			1.14	-0.15	-0.36
	13:57:10	-18	RANGE	265	107	114		DWNLCK	Transit	1.37	-0.20	-0.20
		-10	RANGE	263	105	109				1.31	RANGE	-0.46
90907		0	RANGE	261	103	108				1.19	-0.71	RANGE
		-4	RANGE	261	98	102	Extend			1.13	-0.86	-0.79
	13:57:14	-10	RANGE	260	94	95		DWNLCK	Transit	1.23	-0.91	-0.89
		-10	RANGE	260	88	91				1.14	-0.73	-0.66
90907		-12	RANGE	261	82	84				1.37	-1.00	-0.67
		-22	RANGE	264	76	76	Extend			1.64	-0.65	-0.82
	13:57:18	-26	RANGE	271	70	69		DWNLCK	Transit	1.43	-0.21	-0.82
		-8	RANGE	281	64	63				1.62	RANGE	-0.80
90907		0	RANGE	298	57	55				1.50	0.56	RANGE
		0	RANGE	312	46	46	Extend			1.40	-0.23	-0.88
	13:57:22	-6	RANGE	323	35	0		DWNLCK	Transit	1.43	0.66	RANGE
		-14	RANGE	334	24	0				1.28	0.75	-0.92
90907		-12	RANGE	339	11	0				1.11	-0.53	RANGE
		-16	RANGE	340	2	0	Extend			0.98	-0.46	0.06
	13:57:26	-16	RANGE	340	0	0		DWNLCK	Transit	0.98	-0.46	0.06
		-16	RANGE	340	0	0				0.98	-0.46	0.05
90907		-16	RANGE	340	0	0				0.98	-0.46	0.05
		-16	RANGE	340	0	0	Extend			0.98	-0.46	0.07
	13:57:30	-16	RANGE	340	0	0		DWNLCK	Transit	0.98	-0.45	0.05
		-16	RANGE	340	0	0				0.98	-0.45	0.05
90907		-16	RANGE	340	0	0				0.98	-0.46	0.06
		-16	RANGE	340	0	0	Extend			0.99	-0.45	0.06
	13:57:34	-16	RANGE	340	0	0		DWNLCK	Transit	0.98	-0.45	0.06
		-16	RANGE	340	0	0				0.98	-0.45	0.06
90907		-16	RANGE	340	0	0				0.98	-0.46	0.06
		-16	RANGE	340	0	0	Extend			0.98	-0.45	0.05
	13:57:38	-16	RANGE	340	0	0		DWNLCK	Transit	0.98	-0.45	0.06
		-16	RANGE	340	0	0				0.98	-0.46	0.06

Appendix I continued: Extract from flight data recorder (FDR)

90907		-16	RANGE	340	0	0				0.98	-0.46	0.06
		-16	RANGE	340	0	0	Extend			0.98	-0.45	0.06
	13:57:42	-16	RANGE	340	0	0		DWNLCK	Transit	0.98	-0.45	0.07
		-16	RANGE	340	0	0				0.98	-0.46	0.06
90907		-16	RANGE	340	0	0				0.98	-0.45	0.05
		-16	RANGE	340	0	0	Extend			0.98	-0.46	0.06
	13:57:46	-16	RANGE	340	0	0		DWNLCK	Transit	0.98	-0.45	0.06
		-16	RANGE	340	0	0				0.98	-0.46	0.05
90907		-16	RANGE	340	0	0				0.98	-0.45	0.06
		-16	RANGE	340	0	0	Extend			0.98	-0.46	0.06
	13:57:50	-16	RANGE	340	0	0		DWNLCK	Transit	0.98	-0.46	0.06
		-16	RANGE	340	0	0				0.98	-0.45	0.06
90907		-16	RANGE	340	0	0				0.98	-0.46	0.06
		-16	RANGE	340	0	0	Extend			0.98	-0.45	0.05
	13:57:54	-16	RANGE	340	0	0		DWNLCK	Transit	0.98	-0.46	0.05
		-16	RANGE	340	0	0				0.98	-0.46	0.06