



NATIONAL TRANSPORTATION SAFETY BOARD

Office of Aviation Safety - Central Region

Investigation Summary and Findings

PILOT STATEMENT SUMMARY

About 10 minutes into the flight the pilot noticed a No. 2 engine twist grip light which illuminated momentarily then extinguished. Shortly after he noticed a CAD caution light which also illuminated for a second and then extinguished. He then heard a strange noise from the No. 2 engine but noted that all engine parameters were normal. He elected to abort the flight and return to Sioux Falls airport. In the turn back to the airport he noticed a glow in his night vision goggles and about the same time the No. 2 fire light illuminated. He activated both fire bottles and secured the No. 2 engine and proceeded with a single engine approach and landing at Sioux Falls airport with without further incident. After landing it was apparent that there was a large amount of oil on the engine deck and down the side of the helicopter.



Figure 1 – No. 2 engine compartment damaged by fire

No. 2 ENGINE INFORMATION

The Arriel 1E2 engine, s/n 47069, was installed on the accident helicopter, N911MK EC145 s/n 9218. The helicopter was initially examined in Sioux Falls, SD, by Airbus and Safran Helicopter Engines (SHE; formerly Turbomeca) under the supervision of an FAA inspector. The No. 2 engine was sent to the SHE factory in Grand Prairie, Texas, for examination. During the engine examination and disassembly, the gas generator rear bearing was found damaged in several pieces. The individual bearing pieces were subsequently examined by the SHE laboratory in Bordes, France.

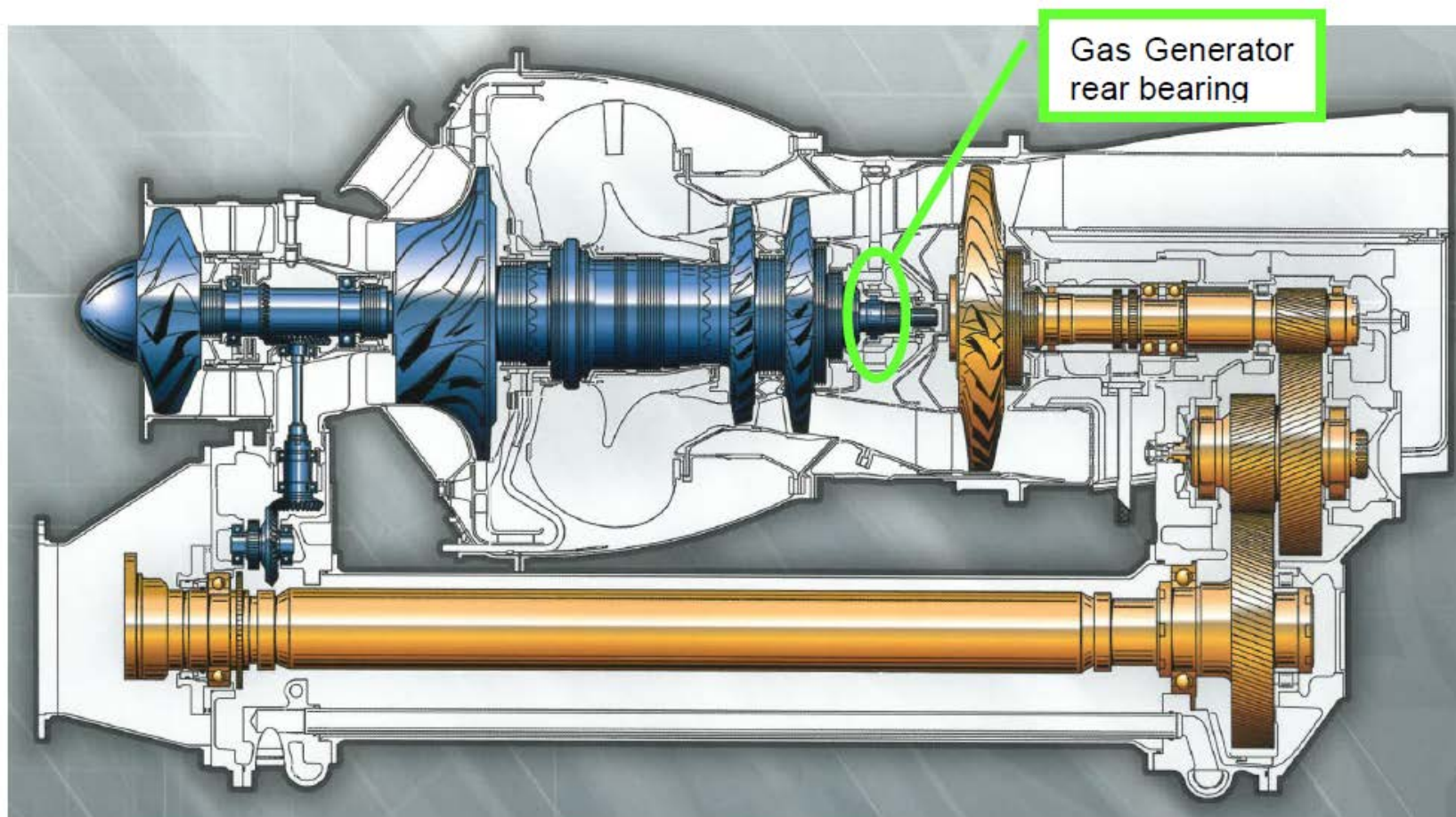


Figure 2 – Engine profile diagram with rear bearing location noted

ENGINE OIL SYSTEM REQUIREMENTS, MAINTENANCE, AND INSPECTIONS**Arriel 1 E2 Approved and Recommended Engine Oils**

The Arriel 1 E2 engine maintenance manual (EMM), TASK 71-00-02-940-801-A01 titled FUEL – LUBRICANTS AND SPECIAL PRODUCTS), provides tables of recommended and authorized fuels and lubricants for the engine; SUB-TASK 71-00-02-940-002-A01 titled LUBRICANTS deals with the engine oils. The oil tables provide the various differing kinematic viscosities and different categories. The viscosity range listed is from 3cSt to 7.5 cSt at 100°C and the categories are standard, corrosion inhibiting, and high thermal stability (HTS). Based on the oil type selected, there are temperature limitations and differing oil drain frequency requirements. In the NOTES section it states:

The oil type stipulated for normal use is the 5cSt fluid synthetic oil specified under the heading “RECOMMENDED OILS” and “NORMAL USE”. The oils mentioned under the heading “AUTHORIZED USE” can be used but are not recommended, unless otherwise specified.

According to the operator, the accident engines were serviced with Mobil Jet II oil. The Arriel 1 E2 EMM lists Mobile Jet II as a “NORMAL USE” standard approved synthetic oil with 5cSt rating with no restriction on the oil draining frequency associated with its use but with the following engine start operational limitation: Use 5cst oil with NATO code 0-156 [Mobil Jet II is designated at NATO symbol of 0-156] for normal use in ambient temperature between -30°C and +50°C (-22°F to 122°F).

Turbomeca SL No. 1642/96/Arriel/25, 2nd issue, dated May 15, 1996, (was the most current version of the SL at the time of the accident) stated that under certain operating temperature condition the use of 7.5cSt oil is better than 5cSt oil in reducing carbon formation.

The operator's maintenance logbooks revealed the following completed tasks in Table 1:

Date	TSN	TSO (Mo3)	Task	Done by	Remarks
26 Jan. 2017	6198	2603	Event		
27 Dec. 2016	6146	2551	Periodic check (EMM) <u>400 hr</u> - Inspect oil filter - Inspect rear bearing's Elect. Mag Plug	Operator	No record available of inspection result
14 Dec. 2016	6114	2519	Oil analysis (SOAP)	Operator	No record available of analysis
22. Oct 2016	5988	2393	Periodic check (EMM) <u>800 hr</u> - Oil system drain - Inspect strainer of rear bearing's Elect. Mag Plug <u>1200 hr</u> - Remove and clean oil scavenge tube	Operator	No record available of inspection result
25 Jul. 2016	5815	2220	Periodic check (EMM) <u>600 hr</u> Permeability check rear bearing ass'y	Operator	No record of permeability test result No trend analysis possible
23 Jun. 2016	5739	2144	Periodic check (EMM) <u>400 hr</u> - Inspect oil filter - Inspect rear bearing's Elect. Mag Plug	Operator	No record available of inspection result
21 May 2016	5637	2042	- Oil system rinse - Permeability check rear bearing ass'y	Operator	Checks done because oil tank's sight glass was cloudy and dark. Permeability test result: 100 ml No trend analysis reported.

Table 1 – EMM Module 3 tasks completed by the operator

Table 2 provides a list of pertinent oil system or Module M03 inspection requirements to detect or prevent clogged oil scavenge lines and the task frequencies based on the engine configuration from the CHAPTER 5 SCHEDULED INSPECTIONS REQUIREMENT TASK 05-20-00 unless otherwise noted. All the TU's listed in the applicability column had been incorporated into both engines at the time they were installed on the accident helicopter.

TABLE 2: PERTINENT OIL SYSTEM AND MODULE M03 TASKS				
EMM TASK DESCRIPTION	TASK NUMBER	INTERVAL (FLIGHT HOURS +TOLERANCE) R = REQUIRED OP = OPTIONAL	APPLICABILITY	NOTES
Inspection of oil level in tank	Engine Installed Refer to Helicopter Manual	Before each flight (R)	ALL	This agrees with the MBB-BK 117 C-2 FM preflight check (R)
Visually examine the engine and the engine floor for leakage TASK 05-20-10-201-804-A01	Engine Installed	After last flight daily (R)	ALL	MBB-BK 117 C-2 FM allows before first flight (R)
Visually check that there are no	Engine Installed	After last flight daily	ALL	MBB-BK 117 C-2 FM allows before first flight

TABLE 2: PERTINENT OIL SYSTEM AND MODULE M03 TASKS				
EMM TASK DESCRIPTION	TASK NUMBER	INTERVAL (FLIGHT HOURS +TOLERANCE) R = REQUIRED OP = OPTIONAL	APPLICABILITY	NOTES
leaks on the rear bearing oil ducts TASK 05-20-10-201-804-A01		(R)		(R)
Examine the visual blocker indicator of the oil filtering element TASK 05-20-10-201-804-A01	TASK 72-61-00-900-803-A01 Engine Installed	After last flight daily (R)	ALL	MBB-BK 117 C-2 FM allows before first flight (R)

TABLE 2: PERTINENT OIL SYSTEM AND MODULE M03 TASKS				
EMM TASK DESCRIPTION	TASK NUMBER	INTERVAL (FLIGHT HOURS +TOLERANCE) R = REQUIRED OP = OPTIONAL	APPLICABILITY	NOTES
Inspection and replacement of the oil filtering element TASK 05-20-10-201-840-A01	TASK 72-61-00-900-802-A01 Engine Installed or Removed	400+40 (R) ¹	Post TU 232	If particles present, check if particles per TASK 71-02-07-280-802-A01
Inspection and cleaning of the electrical magnetic plugs at oil outlet TASK 05-20-10-201-840-A01	TASK 79-38-00-210-801-A01 Engine Installed or Removed	400+40 (R) Every 12+1 months	ALL	If particles present, check particles per TASK 71-02-07-280-802-A01

¹ The inspection frequency was every 150 hours+15 hours for Pre TU 232.

TABLE 2: PERTINENT OIL SYSTEM AND MODULE M03 TASKS				
EMM TASK DESCRIPTION	TASK NUMBER	INTERVAL (FLIGHT HOURS +TOLERANCE) R = REQUIRED OP = OPTIONAL	APPLICABILITY	NOTES
Inspection of the rear bearing (for clogging)	TASK 72-43-10-280-801-A01	600+50	Post TUs 274, 281, 283, and 284*	Perform drain flow test, greater than 50 milliliters is acceptable, otherwise check for clogging
TASK 05-20-10-201-850-A01	Engine Installed	(R) ²		

² The inspection frequency was every 100 hours+10 hours for Pre TUs 274, 281, 283, and 284 incorporation.

TABLE 2: PERTINENT OIL SYSTEM AND MODULE M03 TASKS				
EMM TASK DESCRIPTION	TASK NUMBER	INTERVAL (FLIGHT HOURS +TOLERANCE) R = REQUIRED OP = OPTIONAL	APPLICABILITY	NOTES
Oil draining TASK 05-20-10-201-855-A01	TASK 79-00-00-610-801-A01 Engine Installed	800+80 (R) Every 24+2 months	No use ROYCO 560, ASTO 560 and ETO 2370 type oils ³ Avera McKennan uses Mobile Jet II	Use lubes per TASK 71-00-02-940-801-A01
Inspection/check of oil scavenge line strainer of gas generator rear bearing TASK 05-20-10-201-855-A01	TASK 79-38-00-210-801-A01 Engine Installed or Removed	800+80 (R) ⁴	Post TUs 274, 281, 283, and 284*	If particles view in comparison with TASK 71-02-07-280-802-A01

³ If these oils are used the drain interval is 400 hours+40 hours or every 12 months+1 month.

⁴ The inspection frequency was every 100 hours+10 hours for Pre TUs 274, 281, 283, and 284 incorporation.

TABLE 2: PERTINENT OIL SYSTEM AND MODULE M03 TASKS				
EMM TASK DESCRIPTION	TASK NUMBER	INTERVAL (FLIGHT HOURS +TOLERANCE) R = REQUIRED OP = OPTIONAL	APPLICABILITY	NOTES
Cleaning of the rear bearing of the free turbine nozzle guide vane (NGV)	TASK 72-43-10-100-801-A01 Engine Removed	1,200+50 (OP)	Post TUs 274, 281, 283, and 284*	Descale per TASK 71-00-02-940-801-A01. Decarbonize orifices with drill bit
Removal, cleaning and installation of the oil-scavenge line TASK 05-20-10-201-865-A01	TASK 72-43-00-610-801-A01 Engine Installed or Removed	1,200+50 (OP)	Post TUs 274, 281, 283, and 284*	Clean with de-scaler and decarbonize with drill bit

TABLE 2: PERTINENT OIL SYSTEM AND MODULE M03 TASKS				
EMM TASK DESCRIPTION	TASK NUMBER	INTERVAL (FLIGHT HOURS +TOLERANCE) R = REQUIRED OP = OPTIONAL	APPLICABILITY	NOTES
Make sure the three hollow struts for the passage of the rear bearing oil tubes are serviceable TASK 05-20-10-201-865-A01	TASK 72-43-10-210-801-B01 Engine Installed or Removed	1,200+50 (OP)	Post TU 281	Insert 1.68 mm (0.067 inch) diameter rod into hole – acceptable, otherwise replace union(s)

* Turbomeca issued SB 292 72 0215 titled M03 MODULE (GAS GENERATOR) MODIFICATION OF REAR BEARING. INCORPORATION OF MODIFICATIONS TU 274 - 281 - 283 - 284 originally issued on May 5, 1997, with the most current revision being update No. 3 issued on April 2002. The purpose of TU 274 was to improve the mechanical strength of the free turbine nozzle guide vane deflector by changing the material of the deflector and installing an adjusting washer thus preventing the formation of a crack which can result in rubbing of the free turbine disk requiring engine removal. It should be noted that TU 274 does not impact the rear bearing lubrication and was included due to mechanical reason with the other TU that do impact the rear bearing lubrication. The purpose of TUs 281, 283, and 284 were to improve cooling of the gas generator rear bearing and reduce the formation of coke deposits in that area. TU 281 increased lubrication jet diameter of the gas generator rear bearing from 1mm to 2mm (0.04 to 0.08 inch) and added a jet on the oil supply union. TU 283 added a chamfer to inside of the oil scavenge line to facilitate oil scavenging, and silver plated of the seal. TU 284 increased area of the passageway of the oil scavenge channel in the gas generator rear bearing housing from 6mm to 8mm (0.24 to 0.32 inch).

Gas Generator Rear Bearing Inspections

The permeability flow check of the rear bearing TASK 72-43-10-280-801-A01 titled REAR BEARING – FREE TURBINE NOZZLE-GUIDE-VANE ASSEMBLY INSPECTION AND CHECK SPECIAL PROCEDURE provides instructions for collecting and trending the amount of oil from the rear bearing oil scavenge line to assess if it is obstructed. A NOTE in the rear bearing inspection instructions stated that “The inspection of the rear bearing (for clogging) is a trend monitoring task. The quantity of oil collected during successive inspection is an indicator of rear bearing clogging.” However, when reviewing this inspection task requirement the operator, it was discovered that the inspection was used as a measure of engine serviceability (acceptability) and the data was not archived to be used for trending purposes.

Following the introduction of the TU 281 modification, the permeability inspection was maintained to assess whether the rear bearing chamber was sufficiently lubricated, and if the oil scavenge line was obstructed. Review of the EMM found no specific inspection of the oil vent line or oil vent line drain for clogging. According to SHE, the rear bearing oil scavenge line has sufficient capability to handle all the scavenge oil plus any vent air/oil mist (breather air) in the event that the oil vent line or oil vent line drain becomes clogged. A clogged rear bearing oil scavenge line reduces or prevents oil from being scavenged from the bearing compartment and returned to the oil tank. This results in several detrimental conditions such as: 1) elevated bearing temperatures from excess oil, 2) the inability to flush away containments such as dirt, metal particles, carbon, etc. that can cause premature bearing failure, 3) increase flow of oil and breather air through the vent line possibility causing carbon formation and blockage, and 4) increased bearing compartment pressure where the oil is forced past the labyrinth seals and ends up in the exhaust.

The rear bearing permeability inspection is conducted when the oil is hot, 60°C (140°F) or greater and the gas generator speed (N1) at 15% for 15 seconds. With the oil scavenge line removed, the oil is drained into a graduated cylinder until it stops. Below are the inspection criteria and additional actions:

- a) If the oil quantity collected is greater than 50 milliliters (ml) or 1.7 ounces (oz), compare it with the quantity collected during the last successful inspection. If this quantity is less than found during previous inspection, collect another sample. If the result is less than 50ml (1.7 oz) then perform b) below. If two successive inspections show a difference greater than 25% then perform inspection per step c) below. Record the inspection on the engine logbook page as well as the quantity collected and compare it with the last check.
- b) If the oil quantity collected is less than 30ml (1 oz), then the oil inlet and scavenge tubes and unions are inspected for clogging.
 - i. If lines or unions are clogged:
 1. Clean per TASK 72-43-00-610-801-A01 (the actual instructions do not reference the task to be performed, it states “clean”)
 2. Examine the rear bearing for clogging
 3. Retest
 4. If less than 50ml (1.7 oz) collected, clean rear bearing – this requires removal of module M03
 - ii. If tubes or unions are not clogged, clean rear bearing this requires removal of module M03

- iii. Drain oil system
- iv. Record the inspection and cleaning on the engine logbook page as well as the quantity collected
- c) If the oil quantity collected is less than 50ml (1.7 oz) but greater than 30ml (1 oz), then check for carbon particles in the strainer and oil filter
 - i. If particles found in strainer or oil filter, examine the oil inlet and scavenge tubes and unions of the rear bearing
 - 1. If tubes or unions are clogged same steps as b)i.
 - 2. If tubes or unions are not clogged, same as b)ii and b)iii.
 - ii. If strainer and oil filter clean
 - 1. Examine inlet and scavenge tubes and unions for clogging [no information is provided if found clogged, assume using the same procedures for clogged tubes or unions as specified in b)i. or c)i.]
 - 2. Do the next inspection after 25-hours of operation to have trend.
 - iii. Record the inspection and cleaning on the engine logbook page as well as the quantity collected

The EMM originally required the rear bearing inspection every 100 hours +10 hours. With the incorporation of TUs 274, 281, 283, and 284, the inspection frequency decreased to every 600 hours +50 hours. According to SHE, oil temperature comparison with different engines and different configurations, along with endurance testing of 770 accelerated mission testing (AMT) cycles and 215 continuous hours was used to validate the change. A 750 AMT cycle and 207 continuous hours endurance test was used to validate TU 283/284; no oil coking was detected. SHE decreased the inspection interval frequency progressively from 100 hours to greater than 450 hours and then to the current level of 600 hours in 2008 based on statistical analysis showing improvements. Several factors effect and encourage coke formation (See COKE FORMATION Section); namely multiple hot engine shutdowns or multiple post shutdown with high temperature from heat soak back from other components which was not part of the 750 AMT cycle.

COKE FORMATION

Coke formation occurs when the temperature of the oil resides at a temperature higher than the oil stability limit for a sufficient amount of time and this is influenced by several factors from oil type, operating condition, and part geometry. The Turbomeca SL No. 1642/96/Arriel/25 recommended the use of HTS oils to reduce the formation and accumulation of coke deposits. Although some oils perform well under one set of conditions they may perform poorly under others; therefore, engine manufacturers test and validate a variety of oils for use in their products as there is typically not one oil that excels in all conditions. Operational conditions such as hot engine shutdowns or post shutdown high temperature from heat soak back from other components can influence and promote coke formation; coke formation increases dramatically when oil is in contact with surfaces in exceed 300°C (572°F). Another operational influence is prolonged engine inactivity where the coke that has formed absorbed moisture that makes the coke more prone to shedding; shedding typically occurs after engine start. Although coke

formation is not desirable, if it does occur, it is better that it stays there instead of shedding and migrating. Coke shedding can result in obstruction of oil filters, oil passages, and orifices downstream.

The geometry of oil lines and bearing compartments can factor into coke formation and oil obstruction. Small diameter oil passages and lines as well as changes in oil flow path direction can reduce oil flow rate which increases the dwell time the oil may reside on a hot surface thus promote coke formation. Blockage of the oil passages from either accumulation of coke or shedding of coke can result in a similar increase in oil dwell time at higher than desired temperatures; small diameters (low volume) oil passages and lines are more prone to blockage than high volume. (ExxonMobil Corporation, 2016)

Turbomeca SL No. 1642/96/Arriel/25, 2nd issue, dated May 15, 1996, titled ARRIEL 1 – ALL VARIANTS OIL COKING IN THE GAS GENERATOR REAR BEARING HOUSING was the most current version of the SL at the time of the accident. The SL informed operators of cases where coke was observed in the rear bearing housing either on the oil jet or in the oil scavenge orifice and the potential results such as lack of lubrication leading to bearing deterioration and particles in the oil, or inadequate oil scavenging leading to oil bypassing the labyrinth seals into the exhaust creating smoke out the tailpipe. The SL discusses methods to detect and reduce the carbon formation such as the introduction of the gas generator rear bearing permeability flow check, recommend incorporation of TU 208 EMP, recommended a new engine stabilization procedure before shutdown (30 seconds at idle speed of $70\% \pm 2\%$ gas generator speed (N1)). The SL also stated that a study was initiated to reduce oil coking by relocating of the rear bearing oil jet to an area with reduced temperatures. As a result of that study, Turbomeca issued TU 28 that moved the lubricating jet from the bottom end of the oil supply duct into the union at the top of the duct.

ENGINE DECK FIRE DAMAGE AND OIL SPLATTER

Heat/fire damage was limited to rear end of No. 2 engine. Soot examination confirmed an oil based fire. Stains of liquid splatter were noted in the lower engine area. Heat/fire marks were noted on the lower part of hot section of No. 2 engine (see photo below).



Figure 3 – No. 2 engine deck fire damage

OIL SYSTEM EXAMINATION FINDINGS

There was a thin layer of coke at entry end of metal vent pipe with coke missing in one area (detached). No coke elsewhere. Scavenge pipe contained oil and debris. Vent tube was clear. Coked oil in the scavenge tube. Coked oil in oil supply tube near rear bearing housing.

The rear bearing's flexible cage shows corrosion on several arms. Cases of cage corrosion are very rare and are not systematically associated with bearing failures. Examination and comparison with the No. 1 engine flexible cage showed that dispersion with the surface treatment made the No. 2 cage more sensitive to corrosion. The bearing's lubrication hole was clear of obstruction.

The back plate displayed 3 distinct area of oil/coke splatter which lined up with the 3 horizontal tubes.

N911MK

Summary

Elastomer vent line

- Split in two positions. Opening was from inside going out.
- Outside surface with heat damage. Inside smooth. Contained oil and debris (associated with rear bearing).

3 Way Union

Total obstruction
Coke only



Shaft

- Axisymmetric wear of the 3 labyrinths
- Material transfer on the shaft due to a friction phenomenon with the inner race of the bearing.

Scavenge line

Presence of coked oil in scavenge pipe near magnetic plug

Strainer & swivel union

Total obstruction
Coke only

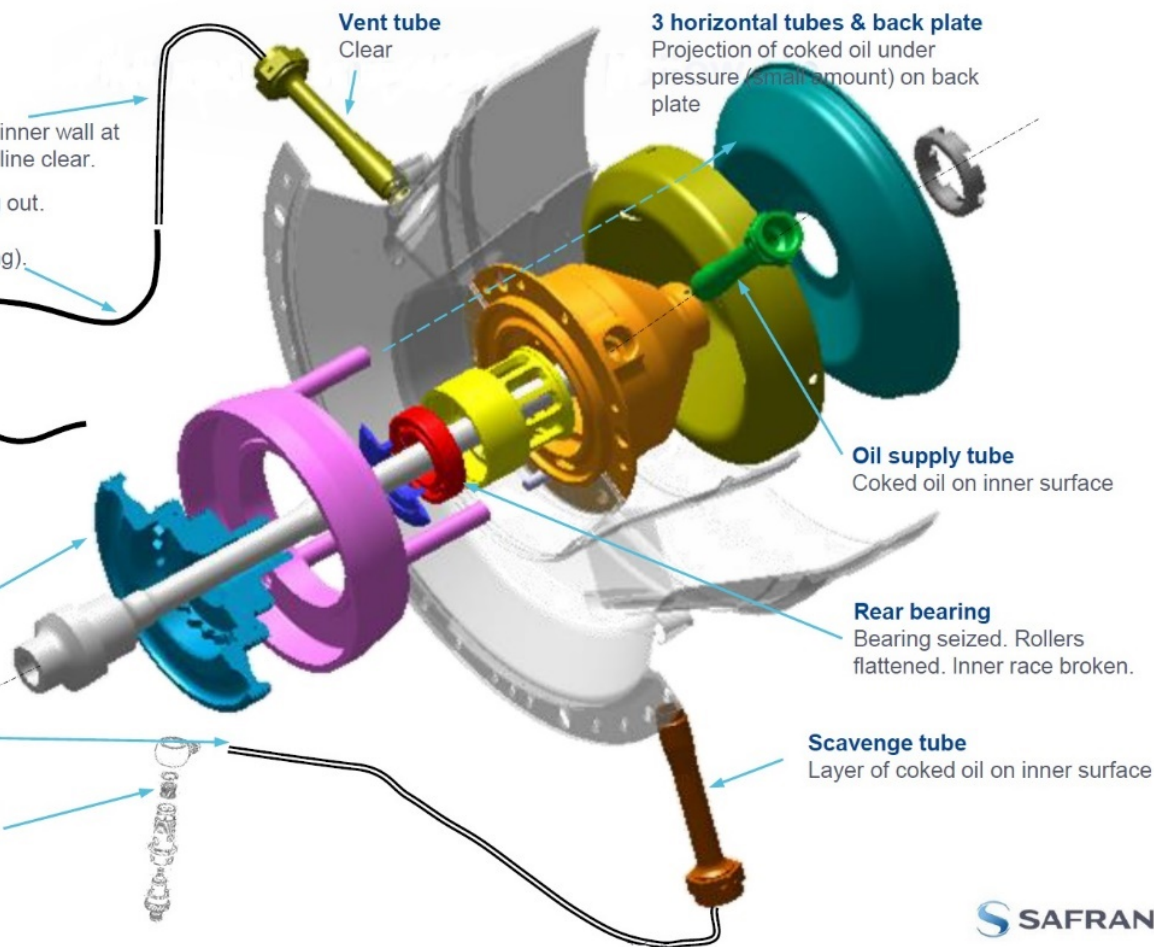


Figure 4 – Oil diagram with notes and labels

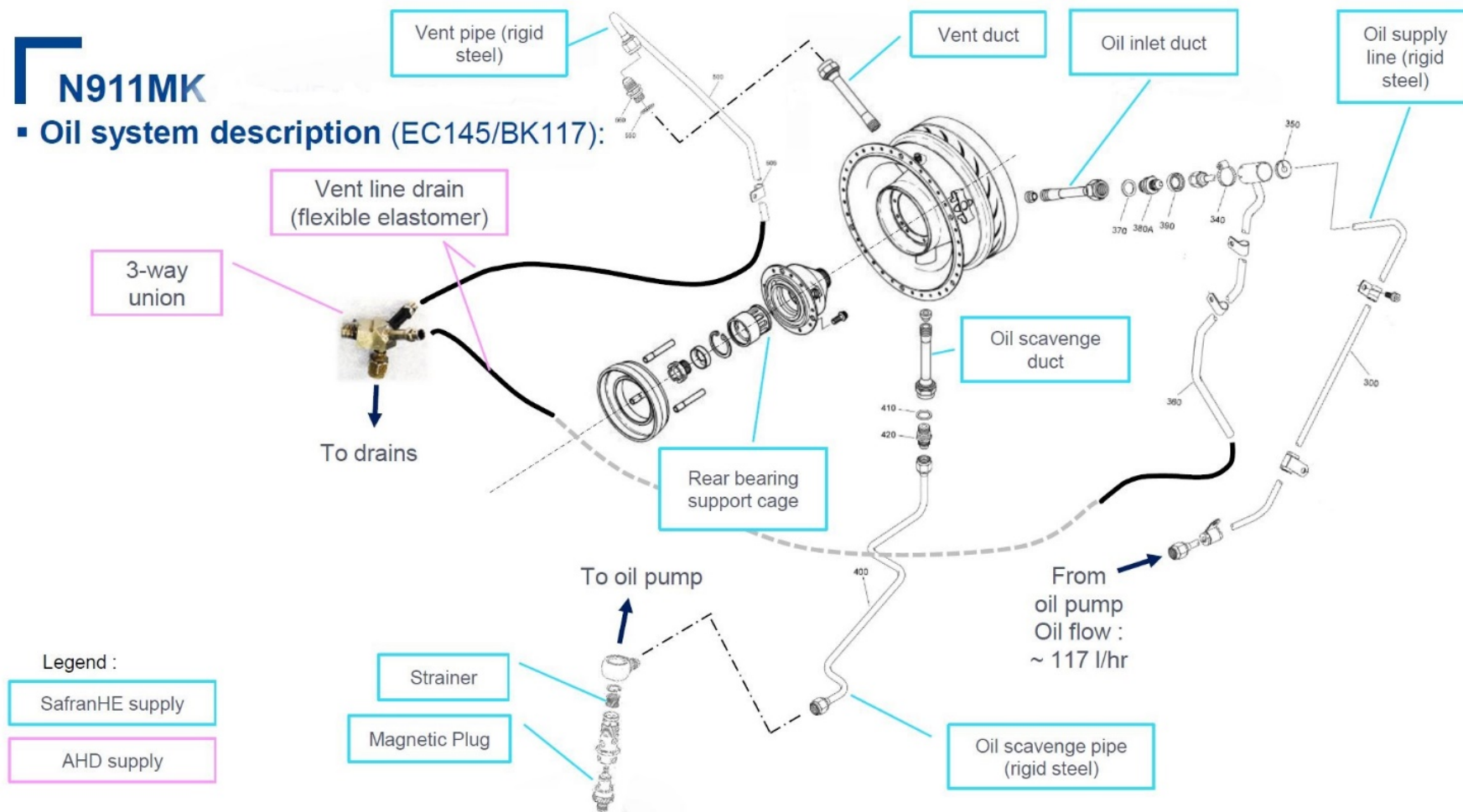
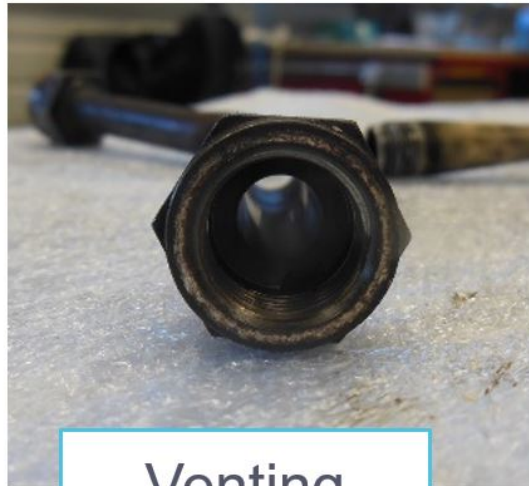


Figure 5 – Oil system description and diagram with notes



Oil supply



Venting



Scavenge

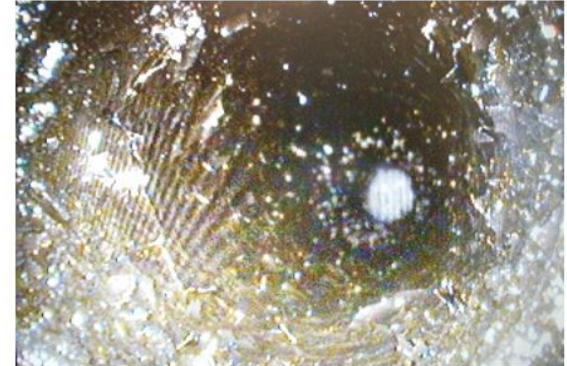
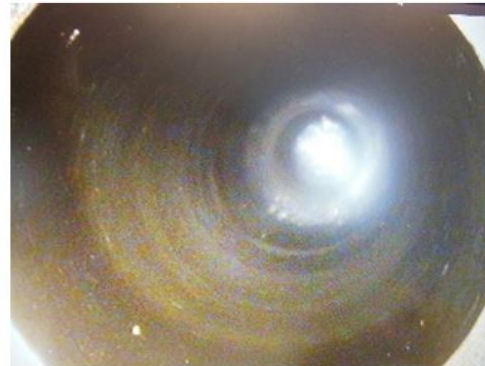
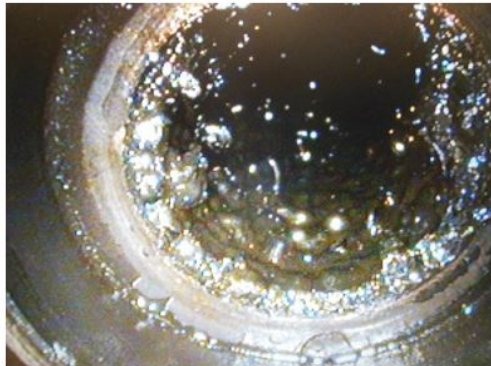


Figure 6 – Engine oil tubes with labels

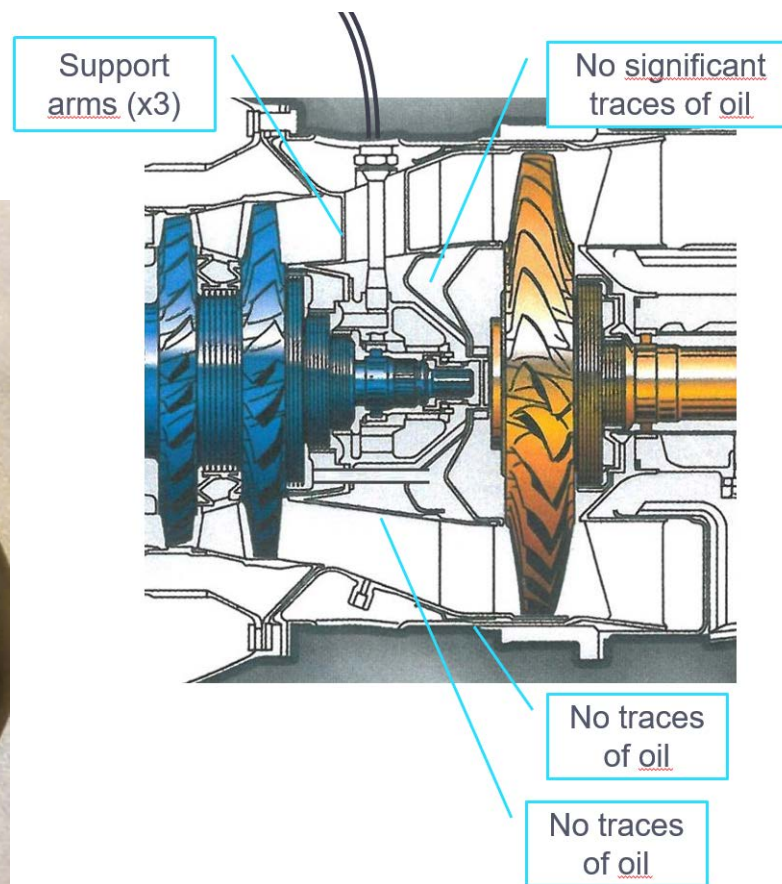


Figure 7/8 – Back plate with oil splatter from 3 horizontal tubes (L) and locations on diagram (R)



Figure 9/10/11 – Rear bearing strainer with coke buildup



Figure 12/13 – Flexible cage damage



Figure 14/15 – Coke on chip plug and strainer

DETAILED COMPONENT EXAMINATIONS

SHE examined the rear bearing components, scavenge line, magnetic plug, and rear bearing vent tube.

- Significant coking material was found in the rear bearing casing.
- The scavenge line was blocked with coke at the magnetic plug level. Significant coking was in the vent tube and contained no metallic debris.
 - The scavenge line's clogging with coking, which contained no metallic debris, led to oil overflowing from rear bearing casing.
- Corrosion of the rear bearing's flexible cage associated with dispersion with its surface treatment. Of note, cage corrosion is very rare and not usually associated with bearing failure.
- Rear bearing operated satisfactorily until its final moments of operation when it seized up in an excess of oil following the clogging of the scavenge line and until the pilot shut-down the engine.
- Evidence of the gas generator's spool (labyrinth lips and blade tips lightly worn) operating with a seized bearing. Differences between engines' parameters reported by pilot only after the engine shutdown. The engine parameters were normal until shutdown by pilot
- From 2000 to 2017 which included 22 million flight hours, there were 16 other instances of rear bearing coking with effect on operation have been identified with 13 of them detected with a low oil pressure indication and/or smoke at exhaust, 2 with a fire indication, and 1 with a magnetic chip light indication.
- No significant signs of oil in internal cavities.
- No evidence of oil exiting from rear bearing casing's support arms and through holes for oil pipes or T45 probes.
- No evidence of fire through or around the holes for oil pipes or T45 probes.
 - Note: N911MK incident is different from previous 2 known cases of fire under cowlings where the fire appeared to be caused by oil or hot air loaded with oil escaping through the holes designed for the oil pipes and T4 probes.
- All oil pipes and ducts were found in place, tightened, not broken and not cracked.
- No evidence of oil exiting from chaffing mark on oil pipe at front of the engine.
- Oil escaped from the rear bearing casing into the main air path and from the RE into the engine exhaust (no escape from the main air path to under the cowlings).
- Oil also escaped from the rear bearing casing into the vent line.
- Metallic vent pipe contained metallic debris, liquid oil and coking residue. No significant coking in tube & in metallic pipe.
 - No evidence of oil escaping outside the engine other than in the exhaust and in the rear bearing casing's vent line
- If the vent line and scavenge line are both blocked then:
 - Oil accumulates in the rear bearing area, oil does not return to the oil tank, oil overflows through labyrinths and horizontal tubes, then ends up in exhaust area and built up in the vent line

Rear Bearing Examination

The bearing was totally seized and could not rotate. All of the rollers, the cage, and the outer ring were stuck together. The rollers were flattened and did not protrude from the separating cage as they would normally. The separating cage and the flattened rollers showed circular scoring marks consistent with rubbing against the rotating inner race. The cage also exhibited numerous impact marks and indentations consistent with contact with other debris while rubbing with the rollers; the damage was also consistent with the rubbing and separation into several fragments of the inner race. The bearing's outer ring showed no indication of movement (rotation or displacement) against its support and was in good condition on the external surface. The fragments of the inner ring exhibited traces of rotational scoring and metal ripping at the race's surface, which was indicative of friction under a significant radial load. Several fragments showed rectangular imprints left by the flattening rollers. These imprints indicated that a significant sudden radial load was applied to the inner ring while it was still mounted on the shaft. The fragments exhibited blunted and rounded edges due to contact with surrounding parts or debris after the rupture of the bearing ring.



Figure 16 – No. 2 engine rear bearing damage



Figure 17 – Coke buildup in rear bearing casing

Rear bearing significant observations and findings

- Lack/insufficient lubrication
 - The investigation revealed that oil had overflowed from the bearing chamber. During the sequence of events, the pilot checked and found all engine parameters in the proper range. In particular, he did not mention any loss or drop of oil pressure.

- Excess of oil in chamber
 - The investigation revealed that oil had overflowed from the bearing chamber once the scavenge line was clogged. The bearing is designed to operate in an oil mist and not in an oil bath. The presence of liquid in the bearing chamber will provoke a resistance to the movement of the rollers. Prior to the clogging of the vent line, the bearing was still in satisfactory condition as no metallic debris were found in the scavenge line's strainer / magnetic plug assembly. The pilot did not report any change in engine parameters until he activated the fire pushbutton which in turn led to the activation of the fuel shut-off valve and to the engine shutdown. Therefore, the bearing operated satisfactorily until its final moments of operation in an excess of oil following the scavenge line's clogging and until the pilot shut-down the engine.
- Pollution of oil system
 - The bearing showed damage limiting the extent of the examination. All metallic components found in debris were indigenous to the rear bearing assembly and oil.
- Oil quality
 - The oil exhibited low levels of additives. Although unfavorable, it does not by itself explain the deterioration of the bearing.
- The bearing operated satisfactorily until the scavenge line was blocked with coking and the pilot shut down the engine.
- This event is the only case known to SHE (excluding cases where operational and/or maintenance issues were identified) where a gas generator rear bearing deterioration occurred following the scavenge line becoming completely blocked with coking.

Key factors for rear bearing coking

- Oil type and quality according to the type of operation performed by the operator
- The operator did not properly respect of the engine stabilization time before shut down sometimes combined with high cycle / hour ratio (typical of helicopter air ambulance operations)
- The operator did not respect the maintenance procedures (permeability checks records, trend analysis, strainer checks, stabilization time)
- The operator Misinterpreted the SHE engine maintenance instructions

Previous rear bearing coking mitigation efforts by SHE

Mitigating actions existing in Engine Maintenance Manual:

- Design modifications (released before 2000)
 - TU274: new material for rear plate
 - TU281: relocation of rear bearing's oil jet
 - TU283: modification of profile of inner diameter of oil scavenge duct
 - TU284: increase of diameter of oil scavenge orifice

- o Note: incident engine, s/n 47069, was fitted with the TU's above
- Maintenance documentation:
 - o EMM has been updated to include a "return to service task after storage" asking for inspection of mag plugs and strainers after a ground run. No periodical check is added.
 - o SL 1642: Oil coking in the Gas Generator rear bearing housing
 - o SL 2268: Aeroshell560 –Royco560 to require specific maintenance
 - o SL 2402: Restrictions of use of BP Turbo Oil 2380 (ETO 2380)
- Troubleshooting book:
 - o Intermittent illumination of the minimum oil pressure indication
 - o Smoke at the engine exhaust pipe

SUMMARY OF MATERIAL ANALYSIS BY SHE

- Soot from the combustion chamber casing (outer surface) contained phosphorus. The soot likely from the combustion of oil. No Sulphur found so the soot was not due to combustion of fuel. Soot is superficial, easily wiped off, fire of low intensity.
- Laterite on the HP Turbine. Laterite normally originates in the ambient air where the helicopter operates, this is a normal finding and is measured per the maintenance manual.
- Coke material and metallic debris in the rear bearing chamber. Coke typically forms due to the degradation of the oil. The large metallic debris is from the rear bearing material. Smaller debris was likely due to wear of other parts in the rear bearing assembly such as the rear bearing casing.
- Coke material in the scavenge tube. Coke typically forms due to the degradation of the oil.
- Coke material in the strainer. Coke typically forms due to the degradation of the oil.
 - o Note: there was no metallic debris found. Therefore, the coke accumulated before the degradation of the rear bearing.
- Coke in the three-way union. Coke typically forms due to the degradation of the oil.
 - o Note: there was no metallic debris found. Therefore, the coke accumulated before the degradation of the rear bearing.
- Coke and small metallic debris in the vent line. Coke typically forms due to the degradation of the oil. The metallic debris could not be identified but could be the result of the final deterioration in the rear bearing chamber with different components involved. Metallic debris was sent down the vent line.
- The oil sample analysis indicated that its additive content was low. Its viscosity was correct and the spectral analysis is inconclusive. There was high metallic content in the sample, but the sample was collected at the bottom of the tank.



Figure 18/19 – Exemplar Deck Fitting / 3-way union (L) - No. 2 deck fitting / 3-way union (R)



Figure 20/21 – No. 2 deck fitting opening for vent tube clogged with coke

FLEXIBLE VENT LINE

Airbus Helicopters Deutschland (AHD) components initially sent to and examined by SHE before they were sent to AHD, to include the flexible vent line and vent line's 3-way union.

- The vent line was found split open in two positions and the splits were from inside going out. The vent line contained liquid oil and coking residues, and metallic debris. No significant amount of coking.
- Vent line's 3-way union was clogged with coking. Coking material was found hard and compacted in the union's orifice and contained no metallic debris.
- AHD performed extensive testing of exemplar flexible vent lines. The performed tests showed that the damage to the vent line is most likely a result of low pressure and high heat when compared to different setups of pressure and temperature failure modes of sample tubes.

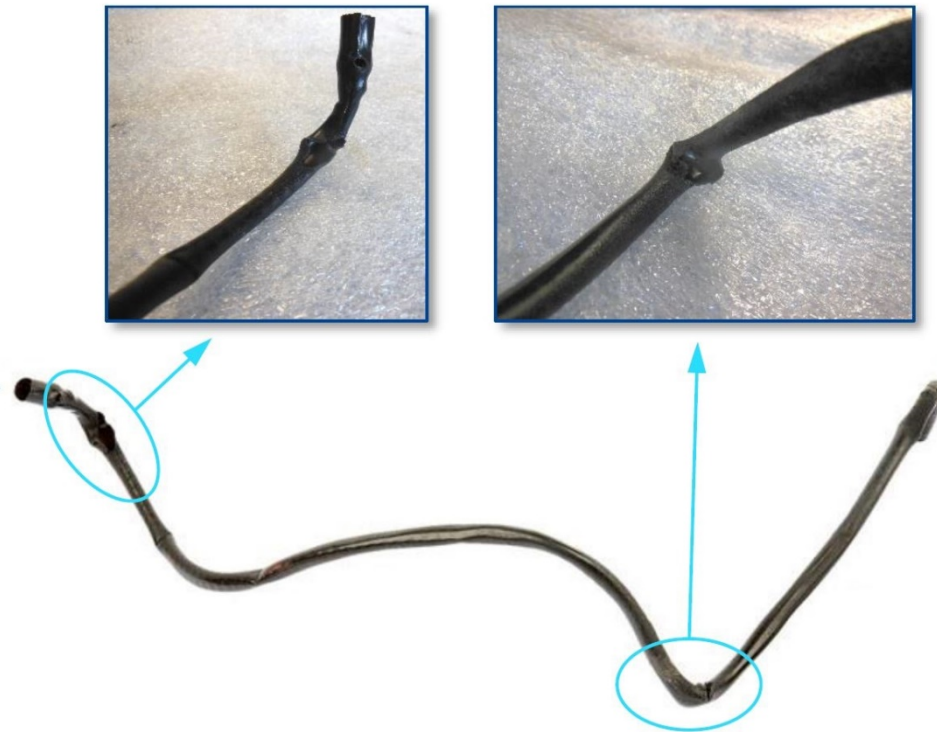


Figure 22 – No. 2 engine flexible vent line with heat damage and elongation

No. 1 ENGINE EXAMINATION DETAILS

The No. 1 engine was utilized by the pilot during the OEI emergency procedures to return to the airport. The No. 1 Engine was not damaged during the incident but it was decided to examine the engine to look for any commonalities from the No. 2 engine examination. The examination of the No. 1 engine's rear bearing assembly showed it contained significant coking. The bearing was found covered with coke but otherwise in good condition and moved smoothly. The 3-way union was partially blocked with coke.



Figure 23 – No. 1 engine rear bearing

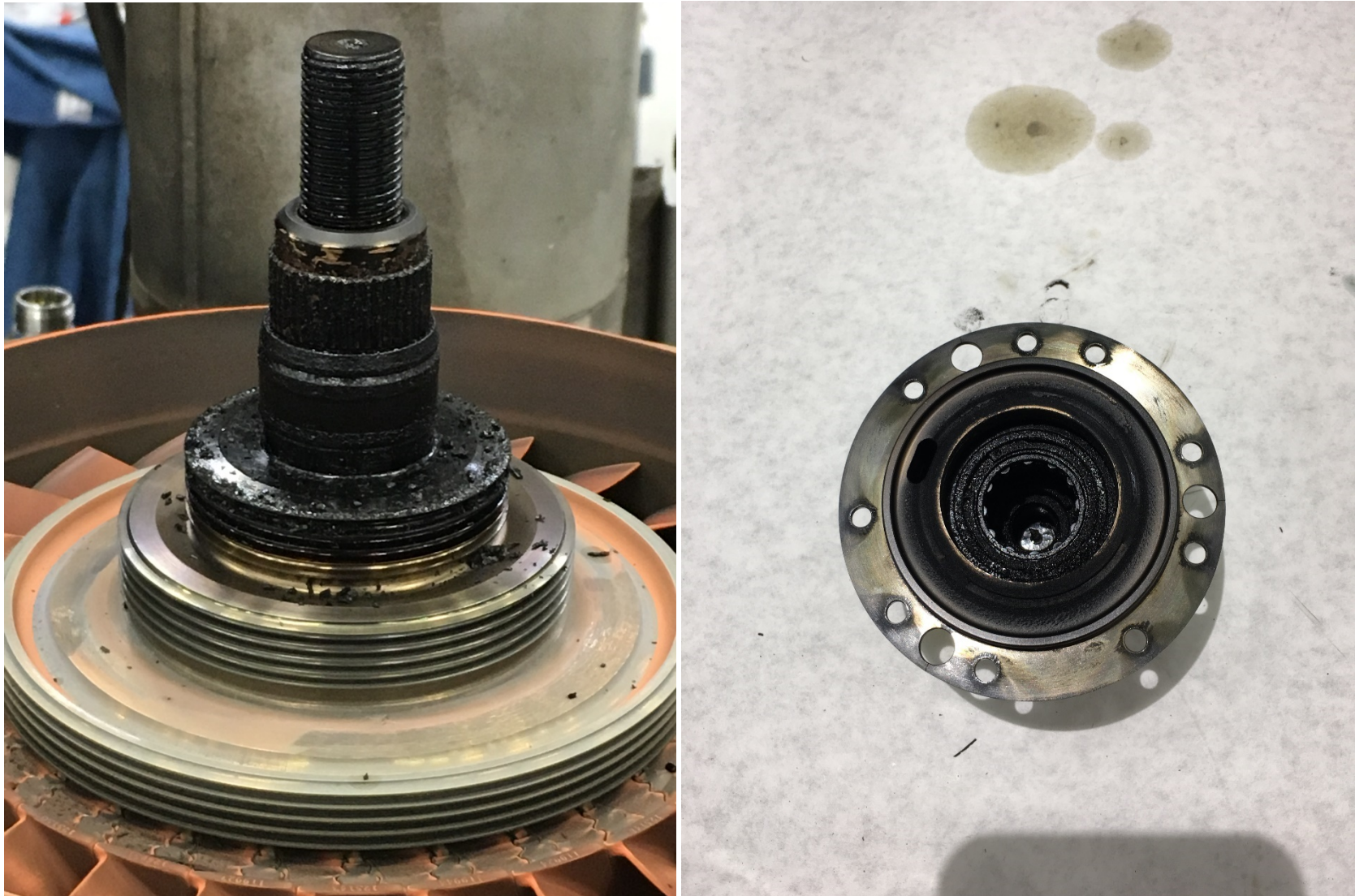


Figure 24/25 – No. 1 shaft with coking (L) and rear bearing in casing (R)

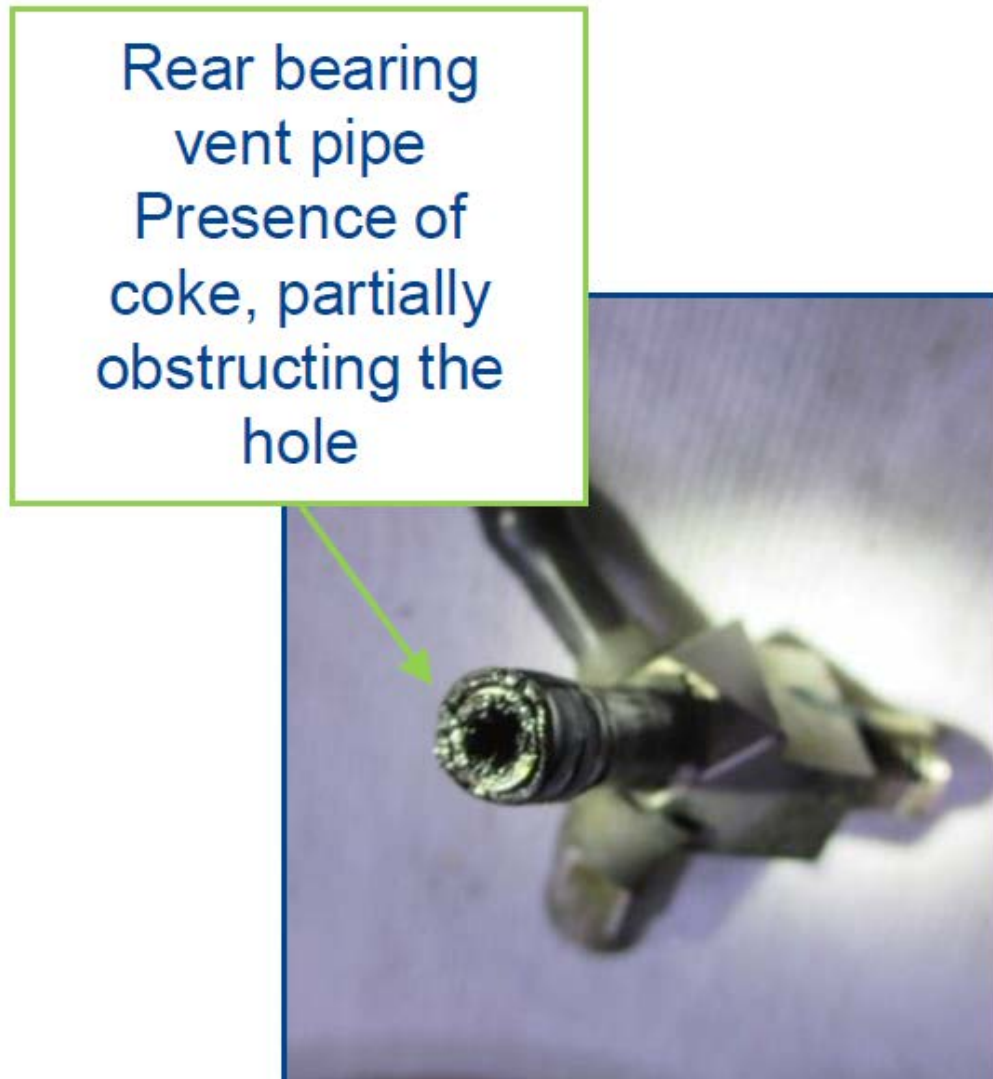


Figure 26 – No. 1 engine deck fitting / 3-way union, vent line orifice partially obstructed with coking

CORRECTIVE ACTIONS

1. As a result of the investigation, Avera McKennan made the following changes to their maintenance practices and operations. Checked their fleet for deck fitting restrictions and coking. Changed from Mobil Jet II oil to more high-temperature oil (2197). Cleaned rear bearings on rest of fleet. They're following the oil flow check and trend analysis in the maintenance manual. Will now manually note the results in engine logbook Section E, but no electronic tracking. Lowered oil change interval from 300 hours to 200 hours.
2. On November 16, 2017, the FAA issued SAIB SW-18-04 Subject ENGINE OIL DRAINAGE SYSTEM alerting Airbus Helicopter MBB-BK 117 C-2 helicopters owners, operators, maintainers, and repair facilities of possible blockage of the engine oil drain system based on preliminary findings from two recent NTSB investigations involving this particular helicopter model. The first NTSB investigation was this event involving N911MK (CEN17IA094). The other NTSB investigation was ERA17MA316 on September 8, 2017, where the examination of the No. 1 engine gas generator rear bearing area exhibited a build-up of coke and the left airframe 3-way union deck drain fitting and vent line were obstructed; the No. 2 engine gas generator rear bearing area did not exhibit a build-up of coke and the right airframe 3-way union deck drain fitting and vent line were free of obstruction. The SAIB recommended a repeat inspection of the 3-way union deck drain fitting and the gas generator rear bearing vent lines for obstructions, which may include carbon or coke deposits, every 100 hours of service operation. At the time that the SAIB was issued there were no inspection or cleaning instructions for the 3-way union deck drain fitting. As part of the inspection, the FAA requested that the results of the inspection be forwarded to the Rotorcraft Standards Branch. The SAIB contains non-regulatory information and guidance that does not meet the criteria for an AD; thus, the recommended actions are not mandatory. Not all operators chose to participate in the voluntary reporting of findings; therefore, the information gathered thus far was incomplete and the number reported inspection was too low to assess if a systemic gas generator rear bearing coking or blockage problem existed. Of the data gathered, there were reports of completely blocked or partially blocked oil drain and vent lines.
3. Prior to this incident and the aforementioned accident ERA17MA316, there was no inspection of the 3-way union deck fitting or the oil vent line drain that attached to it. On January 29, 2018, Airbus Helicopters issued Information Notice (IN) No. 3213-I-71 informing MBB-BK 117, C-1, C-2, and C-2e operators that inspection and cleaning procedures will be introduced into the next versions of the applicable master servicing manual and aircraft maintenance manual (AMM). The IN No. 3213-I-71 stated that the cleaning would be required every 400 flight hours and cleaning of the 3-way union deck fitting using an ultrasonic bath. The information notice included AMM TASK 71-71-00, 6-1 for inspecting the oil line drains and the 3-way union deck fitting (the task instructions call the 3-way union deck fitting the drain collector) and TASK 71-71-00, 7-1 for 3-way union deck fitting (drain collector).
4. On February 16, 2018, Turbomeca issued SL No. 1642 (1642/96/ARRIEL/25), 3rd issue, titled ARRIEL 1 – ALL VARIANTS OIL COKING IN THE GAS GENERATOR REAR BEARING HOUSING, to remind operators of the maintenance actions and operating procedures which are recommended in order to prevent excessive coke formation in the gas generator rear bearing and the consequences of excessive coke formation. SL No. 1642 (1642/96/ARRIEL/25) issues 1 and 2 primarily focused on inspection for gas generator rear bearing coking and

ways to mitigate its formation, as does issue 3, but issue 3 also included guidance and recommendations relating to the overhaul health of the oil system. Similar to SL No. 1642 issue 2, SL No. 1642 issue 3 reiterated the need to perform a 30 second stabilization time at ground idle as required in the flight manual, recommends the use of HTS oils to reduce the risk of coking occurrence in the gas generator rear bearing and reminds operators of the performance of the permeability test (TASK 72-43-10-280-801-A01). Issue 3 goes on to remind the operator the importance of conducting the applicable gas rear bearing (strainer and electrical magnetic plug) inspection and cleaning, compliance with the oil drain frequency, the user to the RULER™ test to determine the health of the oil and that the oil permeability check “..should be considered as monitoring of the trend of the quantity of oil collected during successive checks.”; none of these were covered in previous issues of the SL.

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