European Aviation Safety Agency

Notice of Proposed Amendment 2017-07

Rotorcraft gearbox loss of lubrication

RMT.0608

EXECUTIVE SUMMARY

The objective of this NPA is to address a safety issue related to the ability of Category A rotorcraft to continue safe flight for an extended duration after suffering a loss of oil from a gearbox that is reliant on a pressurised lubrication system to provide lubrication and cooling of rotating components.

The specific objective is to reduce the level of risk associated with loss of lubrication of rotorcraft gearboxes and to implement recommendations arising from the Joint Certification Team (JCT) review of rotorcraft gearbox certification specifications (CSs). This aims to both reduce the potential for lubrication system failures from occurring and to mitigate the consequences of any failure.

The objective shall be achieved by improving the safety assessment of pressurised lubrication systems, and by improving the certification and development testing specifications for the 'loss of lubrication' condition in order to substantiate a maximum period of continued operation which can be included in the rotorcraft flight manual (RFM) emergency procedures. More specifically, this NPA proposes to amend CS 29.917(a) to include rotor drive system gearbox lubrication systems in the definition of the rotor drive system. This means that these lubrication systems will be considered to be within the scope of the design assessment of 29.917(b). As the design assessment CS currently addresses the risk of single hazardous and catastrophic failures, additional material has been added to complement the Federal Aviation Administration (FAA) Advisory Circular (AC) 29-2C, supporting 29.917(b), specifically in the domain of lubrication systems. CS 29.927(c) on 'loss of lubrication' has been completely revised and replaced by a more objective-based CS that requires substantiation of the gearbox ability to continue safe operation (for at least 30 minutes) after a loss of lubrication to be followed by a safe landing. This is supported by substantial changes to the associated acceptable means of compliance (AMC). Finally, CS 29.1521 has also been amended to include an additional power plant limitation that describes how the RFM emergency procedures should reflect the test evidence relating to a loss of lubrication.

The proposed changes are expected to provide an increase in the safety level of rotorcraft operations.

Action area:	Rotorcraft operations		
Affected rules:	ED Decision 2003/15/RM (CS-27)) ED Decision 2003/16/RM (CS-29		
Affected stakeholders:	Rotorcraft design organisations and operators		
Driver:	Safety	**Rulemaking group:**	Yes
Impact assessment:	Full	**Rulemaking Procedure:**	Standard

Table of contents

1. About this NPA

1.1. How this NPA was developed

The European Aviation Safety Agency (EASA) developed this NPA in line with Regulation (EC) No 216/2008[1] (hereinafter referred to as the 'Basic Regulation') and the Rulemaking Procedure[2]. This rulemaking activity is included in the EASA 5-year Rulemaking Programme[3] under rulemaking task RMT.0608. The text of this NPA has been developed by EASA based on the input of the rulemaking group (RMG) RMT.0608. It is hereby submitted to all interested parties[4] for consultation.

1.2. How to comment on this NPA

Please submit your comments using the automated **Comment-Response Tool (CRT)** available at **http://hub.easa.europa.eu/crt/**[5].

The deadline for submission of comments is **31 July 2017.**

1.3. The next steps

Following the closing of the public commenting period, EASA will review all comments.

Based on the comments received, EASA will develop a decision amending the certification specifications (CSs) and acceptable means of compliance (AMC) to CS-27 and CS-29.

The comments received and the EASA responses will be reflected in a comment-response document (CRD). The CRD will be annexed to the decision.

[1] Regulation (EC) No 216/2008 of the European Parliament and of the Council of 20 February 2008 on common rules in the field of civil aviation and establishing a European Aviation Safety Agency, and repealing Council Directive 91/670/EEC, Regulation (EC) No 1592/2002 and Directive 2004/36/EC (OJ L 79, 19.3.2008, p. 1) (http://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1467719701894&uri=CELEX:32008R0216).

[2] EASA is bound to follow a structured rulemaking process as required by Article 52(1) of Regulation (EC) No 216/2008. Such a process has been adopted by the EASA Management Board (MB) and is referred to as the 'Rulemaking Procedure'. See MB Decision No 18-2015 of 15 December 2015 replacing Decision 01/2012 concerning the procedure to be applied by EASA for the issuing of opinions, certification specifications and guidance material (http://www.easa.europa.eu/the-agency/management-board/decisions/easa-mb-decision-18-2015-rulemaking-procedure).

[3] http://easa.europa.eu/rulemaking/annual-programme-and-planning.php

[4] In accordance with Article 52 of Regulation (EC) No 216/2008 and Articles 6(3) and 7) of the Rulemaking Procedure.

[5] In case of technical problems, please contact the CRT webmaster (crt@easa.europa.eu).

2. In summary — why and what

2.1. Why we need to change the rules — issue/rationale

CS 29.927(c) currently requires a test to be perfomed to demonstrate that any failure that can result in a loss of lubricant will not impair the capability of the rotorcraft to operate under autorotative conditions for 15 minutes (Category B) or to continue safe flight for at least 30 minutes (Category A) unless such failures have a probability which is considered to be 'extremely remote'.

Service experience has highlighted a number of concerns with regard to the existing approach, including:

— Use of the term 'extremely remote': the complexity of lubrication system failure modes can result in the potential for unforeseen variables which can make prediction of their associated criticality and frequency of occurrence very challenging. Accordingly, it may not be possible to apply the 'extremely remote' concept to some lubrication system failures as the confidence level of any associated assumptions may not be adequate.

— Substantiation of gearbox loss of oil endurance: when complying with CS 29.927(c), completion of a 30-minute test simulating a 'loss of lubrication' condition will typically result in an associated RFM emergency procedure requiring that the rotorcraft be landed in a considerably shorter period of time. Taking into account the challenging environmental conditions associated with certain types of Category A rotorcraft operations, a substantiated capability for continued operation of at least 30 minutes after loss of lubrication, to be stated in the associated RFM emergency procedures, would improve the likelihood of a positive outcome of such an event.

— Safety analysis: gearbox lubrication systems are currently not defined as part of the rotor drive system and are, therefore, not automatically subject to CS 29.917(b), which requires a design assessment of the rotor drive system. Consideration of lubrication system safety via other approaches may not be fully representative as lubrication systems are typically an integral part of the rotor drive system.

Furthermore, a number of issues were highlighted by an accident which occurred on 12 March 2009, involving a Canadian-registered Sikorsky S-92A rotorcraft (registration C-GZCH), which experienced an in-flight loss of lubrication of its main gearbox (MGB). The MGB eventually failed, contributing to a loss of control and subsequent crash. The investigation revealed that the loss of MGB lubrication was due to failure of the titanium studs that retain the MGB oil filter housing. The designated safety investigation authority the Canadian Transport Safety Board (TSB), in its safety investigation report (Aviation Investigation Report A09A0016) of February 2011, made the following two recommendations for changes to the airworthiness design standard:

— A11-01:

The Federal Aviation Administration, Transport Canada and the European Aviation Safety Agency remove the 'extremely remote' provision from the rule requiring 30 minutes of safe operation following the loss of main gearbox lubricant for all newly constructed Category A transport helicopters and, after a phase-in period, for all existing ones; and

— A11-02:

The Federal Aviation Administration assess the adequacy of the 30 minute main gearbox run dry requirement for Category A transport helicopters.

In response to this accident and the corresponding TSB safety recommendations, the Transport Canada Civil Aviation (TCCA), the FAA and EASA created the Joint Cooperation Team (JCT). The objective of this team was to conduct a review of the current design CSs and AMC relating to the certification of rotorcraft gearboxes, specifically with respect to loss of lubrication. The JCT completed this review and made recommendations regarding the adequacy of the current CSs, including the use of the 'extremely remote' criterion. These recommendations propose a harmonised action to address gaps identified in the existing CSs, clarify their intent, and redefine test CSs to allow substantiation of a greater endurance capability in the event of a loss of lubrication.

2.2. What we want to achieve — objectives

The overall objectives of the EASA system are defined in Article 2 of the Basic Regulation. This proposal will contribute to the achievement of the overall objectives by addressing the issues outlined in Chapter 2.1.

The specific objective of this proposal is to minimise the risk of hazardous and catastrophic failures related to loss of lubrication from rotorcraft gearboxes using pressurised lubrication systems. In determining the scope of this rulemaking task, RMG RMT.0608 considered and reviewed the JCT recommendations. The amendments to the CSs and their associated AMC proposed in this NPA aim to both minimise the likelihood of hazardous and catastrophic lubrication system failures as well as mitigate the likely consequences of any failure. This will be achieved by improving the safety assessment of pressurised lubrication systems, as well as the certification test specifications to demonstrate the behaviour of gearboxes experiencing loss of lubrication in order to substantiate a maximum period of continued operation which can be included in the RFM emergency procedures.

The scope of this NPA is to address this safety issue with respect to CS-29 and CS-27 Category A helicopters. Accordingly, the amendments proposed in this NPA are limited to CS-29 and the associated AMC. For CS-27 Category A rotorcraft, the safety implications of gearbox loss of lubrication are less significant due to both design and operational differences. Notwithstanding this amendments will be proposed to both CS 29.917(b) and CS 29.927(c), which will result in the changes becoming applicable to CS-27 Category A rotorcraft, as these CSs are listed within CS-27 Appendix C which contains the additional provisions for CS-27 Category A rotorcraft. Furthermore, as each of the CS-29 amendments proposed by this NPA are interrelated, it is proposed that each of the amended provisions should also be referenced in CS-27 Appendix C. The impact on CS-27 Category A rotorcraft is addressed in Chapter 4 of this NPA.

2.3. How we want to achieve it — overview of the proposals

This NPA proposes to amend CS 29.917(a) to include rotor drive system gearbox lubrication systems in the definition of the rotor drive system. This will result in these lubrication systems being considered within the scope of the design assessment of CS 29.917(b). As the scope of this design assessment is currently limited to single hazardous and catastrophic failures, additional AMC are needed to supplement FAA AC 29-2C, supporting CS 29.917(b), specifically with regard to lubrication systems.

CS 29.927(c), addressing loss of lubrication for Category A rotorcraft, has been significantly changed. This is now a more objective-based CS and requires substantiation of the ability of the gearbox to continue safe operation for at least 30 minutes after indication of low oil pressure, followed by a safe landing. Demonstration includes a minimum of one test within the certification programme, simulating the most severe failure mode of the normal-use lubrication system. The most severe failure mode of the normal-use lubrication system is determined by the design assessment previously mentioned. The test begins by establishing the necessary entry operating conditions and, upon indication that a lubrication failure has occurred, the rotorcraft continues to operate for one minute at maximum continuous power. This is followed by a period of operation proposed by the applicant (of no less than 36 minutes) at the minimum power setting for continued flight. The test concludes with a 45-second period at a power setting that simulates landing. The results allow substantiation of an acceptable safety margin against the 30-minute requirement by means of extended duration at minimum power for continuous flight, multiple tests, or any other acceptable approach proposed by the applicant. Substantiation of a continued flight capability exceeding 30 minutes may be possible using an extended test duration provided that an appropriate safety margin has been substantiated. The new test definition will be supported by substantial amendments to the supporting AMC.

Finally, CS 29.1521 has been modified, by adding an additional powerplant limitation stating the need for the RFM emergency procedures to reflect the test evidence relating to the loss of gearbox lubrication.

Note: TSB ASR A11-01 recommends taking action to address all newly constructed Category A transport helicopters and, after a phase-in period, all existing ones. A review of helicopter types certified in accordance with the current CS 29.927(c) has shown that most types complied without using the ‘extremely remote’ rationale to exclude particular lubrication system failure modes. For helicopter types where potential lubrication system failure modes were excluded from the ‘loss of lubrication’ test on the basis of extremely remote likelihood of occurence, additional actions have been taken to ensure that an acceptable level of safety is maintained.

CS-27 Appendix C, which identifies additional provsions for Category A rotorcraft, is amended to include each of the CS-29 amendments proposed by this NPA.

2.4. What are the expected benefits and drawbacks of the proposals

Compliance with a ‘loss of lubrication’ test by all CS-29 Category A new rotorcraft types will ensure that continued level flight at maximum take-off gross weight can be maintained for a defined duration after loss of lubrication. This duration will be specified in the emergency procedures for loss of lubrication in the RFM. This provision will provide increased opportunity for the flight crew to optimise circumstances affecting the safety of the eventual landing.

The only significant drawbacks of this proposal are economic. This results from the increased cost of certification testing, and potential for increased weight of the gearbox and lubrication system, dependant upon the design solution chosen by the applicant. But the impact to CS-29 helicopter manufacturers is considered to be negligible.

For the full impact assessment of alternative options, please refer to Chapter 4.

3. Proposed amendments and rationale in detail

The text of the amendment is arranged to show deleted text, new or amended text as shown below:

— deleted text is ~~struck through~~;

— new or amended text is highlighted in grey;

— an ellipsis '[…]' indicates that the rest of the text is unchanged.

3.1. Draft certification specifications (Draft EASA decision)

3.1.1. Draft resulting text: CS-27 – Book 1

APPENDICES

1. Amend CS-27 Appendix C as follows:

Appendix C

Criteria for Category A

C27.1 General: A small multi-engine rotorcraft may not be type certificated for Category A operation unless it meets the design installation and performance ~~requirements~~ provisions contained in this appendix in addition to the ~~requirements~~ provisions of this CS-27.

C27.2 *Applicable CS-29 paragraphs*. The following paragraphs of CS-29 must be met in addition to the ~~requirements~~ provisions of this ~~code~~CS:

(…)

29.908(a)	—	Cooling fans.
29.917(a), (b) and (c)(1)	—	Rotor drive system: Design. (29.917(a) replaces 27.917(d))
29.927(c)(1) and (c)(2)	—	Additional tests.
(...)		
29.1351(d)(2)	—	Additional requirements for Category A rotorcraft (Operation with the normal electrical power generating system inoperative.)
29.1521(k)	—	Powerplant limitations.

(…)

3.1.2. Draft resulting text: CS-29 – Book 1

BOOK 1

SUBPART E — POWERPLANT

2. Amend CS 29.917 as follows:

CS 29.917 Design

(a) *General.* The rotor drive system includes any part necessary to transmit power from the engines to the rotor hubs. This includes gearboxes, shafting, universal joints, couplings, rotor brake assemblies, clutches, supporting bearings for shafting, any attendant accessory pads or drives, lubricating systems for drive system gearboxes, oil coolers and any cooling fans that are part of, attached to, or mounted on the rotor drive system.

(…)

3. Amend CS 29.927 as follows:

CS 29.927 Additional tests

(a) Any additional dynamic, endurance, and operational tests, and vibratory investigations necessary to determine that the rotor drive mechanism is safe, must be performed.

(…)

(c) *Lubrication system failure.* For lubrication systems required for proper operation of rotor drive systems, the following apply:

(1) *Category A.* ~~Unless such failures are extremely remote, it must be shown by test that any failure which results in loss of lubricant in any normal use lubrication system will not prevent continued safe operation, although not necessarily without damage, at a torque and rotational speed prescribed by the applicant for continued flight, for at least 30 minutes after perception by the flight crew of the lubrication system failure or loss of lubricant.~~ Confidence shall be established that the rotor drive system has an in-flight operational endurance capability of at least 30 minutes following lubrication system failure.

(2) ~~*Category B.* The requirements of Category A apply except that the rotor drive system need only be capable of operating under autorotative conditions for at least 15 minutes.~~ Demonstration must include a test of at least 36 minutes, dependent upon the number of tests and component condition after test, following simulation of the *most severe failure mode* of the *normal-use lubrication system* as determined by the failure analysis of CS 29.917(b). The test shall be conducted such that it begins upon the indication to the flight crew that a lubrication failure has occurred and its loading is consistent with one minute at maximum continuous power followed by the minimum power needed for continued flight at rotorcraft maximum gross weight. The test shall end with a 45-second

out of ground effect (OGE) hover to simulate a landing phase. Test results must substantiate an acceptable positive margin against the 30-minute requirement by means of an extended test duration, multiple test specimens, or other approach prescribed by the applicant and accepted by EASA, and must support the procedures published in the rotorcraft flight manual (RFM). Flight duration longer than 30 minutes may be demonstrated by means of a correspondingly longer test with appropriate margin and substantiation.

(3) *Category B*. Confidence shall be established that the rotor drive system has an in-flight operational endurance capability to complete an autorotation descent and landing following a lubrication system failure.

(4) Demonstration must include a test of at least 15 minutes and 30 seconds following the *most severe failure mode* of the *normal-use lubrication system* as determined by the failure analysis of CS 29.917(b). The test shall be conducted such that it begins upon the indication to the flight crew that a lubrication failure has occurred and its loading is consistent with 15 seconds at maximum continuous power after which input torque should be reduced to simulate autorotation for 15 minutes. The test shall be completed by application of an input torque to simulate minimum power landing for approximately 15 seconds.

(…)

4. Amend CS 29.1521 as follows:

CS 29.1521 Powerplant limitations

(a) *General.* The powerplant limitations prescribed in this paragraph must be established so that they do not exceed the corresponding limits for which the engines are type certificated.

(…)

(k) *Continued operation after rotor drive system gearbox loss of lubrication.* For gearboxes which utilise a pressurised lubrication system, the maximum duration of operation after a failure resulting in loss of lubrication and 'red oil pressure' warning must not exceed the maximum period demonstrated during certification, as prescribed by CS 29.927(c).

3.2. Draft acceptable means of compliance and guidance material (Draft EASA decision)

3.2.1. Draft resulting text: CS-29 – Book 2 (Acceptable Means of Compliance and Guidance Material)

5. Amend AMC 29.917 (amendment of AC 29.917) as follows:

AMC 29.917

Rotor drive system design

Vibration Health Monitoring: Where Vibration Health Monitoring is used as a compensating provision to meet CS 29.917(b), the design and performance of the vibration health monitoring system should be approved by requesting compliance with CS 29.1465(a).

Lubrication Systems: A dedicated safety assessment should be performed addressing all rotor drive gearbox lubrication systems and, in particular, the following:

(a) Identification of any single failures, malfunction, or foreseeable combination of failures that may result in loss of oil supply to dynamic components. This normally takes the form of a failure mode and effects analysis. Compensating provisions should be identified to minimise the likelihood of occurrence of these failures.

(b) Identification of the *most severe failure mode* that results in the shortest duration of time in which the gearbox should be able to operate following indication to the flight crew of a *normal-use lubrication system* failure. This should be used for simulating lubrication failure during the CS 29.927(c) loss of lubrication test.

(c) Where compliance with CS 29.927(c) is reliant upon operation of an *auxiliary lubrication system*, sufficient independence between the *normal-use* and *auxiliary lubrication systems* should be substantiated. Common-cause failure analysis, including common-mode, particular-risk, and zonal safety analyses, should be performed. It should be established that no single failure or identified common-cause failure will prevent operation of both *normal-use* and *auxiliary lubrication systems*, apart from failures determined to be *extremely remote lubrication failures*.

6. Create a new AMC 29.927 (amendment of AC 29.927) as follows:

AMC 29.927

Additional tests

This AMC replaces FAA AC 29.927 (Amendment 29-26)

(a) Explanation

(1) AMC 29.927 revises the rotor drive systems loss of lubrication test provisions for Category A rotorcraft, as defined in CS 29.927(c). This changes the related requirement to show a capability through testing of at least 36 minutes' duration. Additionally, minimum periods and load conditions are now defined directly in theprovision. The failure condition to be simulated is the most severe loss of lubrication failure mode of the *normal-use lubrication system*, which is defined below. In addition, the term 'unless such failures are extremely remote' has been removed from the requirement. Assessment of the lubrication system reliability is now addressed under 29.917(b).

(2) The provision is intended to apply to pressurised lubrication systems and should not be applied to splash-lubricated gearboxes since historically, their design has not been as critical or complex when compared to pressurised systems. The likelikood of loss of lubrication is significantly greater for gearboxes that use pressurised lubrication and external cooling. This is due to the increased complexity of the lubrication system, the external components that circulate oil outside of the gearbox, and the resultant rapid leakages that may occur with a pressurised system. A pressurised lubrication system is more commonly used in the rotorcraft's main gearbox but may also be used in other rotor drive system gearboxes. Dedicated loss of lubrication testing is not required for gearboxes using non-pressurised splash lubrication systems. However, any assumptions regarding this failure condition should be stated in the functional hazard analysis (FHA) along with adequate justification.

(3) This provision is applicable to any pressurised lubrication gearbox that is essential for continued safe flight and safe landing. Accordingly, this provision is not applicable to gearboxes which are not essential for continued safe flight and safe landing and which have a lubrication system which is *independent* of other essential gearboxes.

(4) The lubricating system has two primary functions. The first is to provide lubricating oil to contacting or rubbing surfaces to reduce heat energy generated by friction. The second is to dissipate heat energy generated by friction of meshing gears and bearings, thus maintaining surface and component temperature. Accordingly, a loss of lubrication leads to increased friction between components and increased component surface temperatures. With increased component surface temperatures, surface hardness may be lost resulting in the inability of the component to carry or transmit loads appropriately. Thermal expansion in gearbox components may eventlually lead to the mechanical failure of bearings, journals, gears, shafts, and clutches that are subjected to high loads and rotational speeds. A loss of lubrication may result from internal and external failures. Failures include, but are not limited to: oil lines, fittings, seal plugs, sealing gaskets, valves, pumps, oil filters, oil coolers, accessory pads, etc.

(5) The intent of the rule change for Category A rotorcraft is to provide confidence in the continued flight capability of the rotorcraft, which should be of at least 30 minutes' duration after the loss of lubricant pressure in any single rotorcraft drive system gearbox, aiming to optimise eventual landing opportunities. In order to enable the crew to determine the safest action in the event of loss of gearbox oil, the emergency procedures of the rotorcraft flight manual (RFM) should include instructions defining the maximum time period within which the rotorcraft should have landed. This AMC provides guidance for completion of the loss of lubrication test and on how to demonstrate confidence in the margin of safety associated with the *maximum period of operation following loss of lubrication*, as defined in the RFM emergency procedures. This margin of safety is intended to substantiate a period of operation that has been evaluated as likely to be safer than making a forced landing over hostile terrain.

(b) Procedures

(1) CS 29.927(c) prescribes a test which is intended to demonstrate that no hazardous failure or malfunction will occur within a defined period, and in a specified reduced-power

condition, in the event of a significant failure of the rotor drive lubrication system. The failure of the lubrication system should not impair the ability of the crew to continue safe operation of Category A rotorcraft for the defined period after indication of the failure has been provided to the flight crew. For Category B rotorcraft, safe operation under autorotative conditions should be possible for a period of at least 15 minutes. Some damage to rotor drive system components is acceptable after completion of the lubrication system testing. However, the condition of the components will influence the margin of confidence established for the *maximum period of operation following loss of lubrication*.

(2) Since this is a test of the capability of the gearbox to operate with *residual oil* or oil supplied from an *auxiliary lubrication system*, the method for draining the oil and the operating conditions are also defined in the provision . The entry condition for the test should also be representative and is defined in this AMC. For Category B rotorcraft, it is necessary to simulate an autorotation for a period of 15 minutes followed by a minimum-power landing.

(c) Definitions

For the purposes of this test and assessment of continued operation after loss of lubrication, the following definitions apply:

(1) *Maximum period of operation following loss of lubrication*: this is the period stated in the RFM emergency procedures. This is only intended to be used in conjunction with the instruction to 'Land as soon as possible'. Accordingly, this does not constitute a safe period of operation, but a period that has been evaluated as likely to be safer than making a forced landing over hostile terrain.

(2) *Most severe failure mode*: it is defined as the failure mode that results in the shortest duration of time in which the gearbox is expected to operate following indication of a *normal-use lubrication system* failure to the flight crew.

(3) *Residual oil*: the oil present in the gearbox after experiencing the *most severe failure mode*. (Note: when the lubrication system incorporates an *auxiliary lubrication system*, this will supplement the *residual oil* in the event of failure of the *normal-use lubrication system*).

(4) *Normal-use lubrication system*: the lubrication system relied upon during normal operation.

(5) *Auxiliary lubrication system*: any lubrication system that is *independent* of the *normal-use lubrication system*.

(6) *Independent*: an *auxiliary lubrication system* should be able to function after failure of the *normal-use lubrication system*. Failure modes which may result in the subsequent failure of both *auxiliary and normal-use lubrication systems* should be shown to be *extremely remote lubrication failures*.

(7) *Extremely remote lubrication failure*: lubrication failures where confidence is provided that the likelihood of occurrence of the failure mode has been minimised, either by structural analysis in accordance with CS 29.571, laboratory testing, service experience or other

means indicating a level of reliability better than one failure per 10 million hours. Typically, failure modes involving external pipes or hoses should not be considered as *extremely remote lubrication failures*.

(d) Certification test configuration

Each gearbox lubricated by a pressurised system that is essential for continued safe flight and safe landing should be tested. Deviations from the gearbox configuration being certified may be allowed where necessary for installation of test instrumentation or equipment to facilitate simulation of the *most severe failure mode*.

(e) Loss of lubrication test

(1) Category A rotorcraft

(i) Test entry condition: the test starting condition should be 100 % of the torque associated with all engines operative (AEO) maximum continuous power (MCP) and at the nominal speed for use with MCP. In addition, the torque necessary for the anti-torque function should be simulated for straight and level flight at the same flight conditions. The oil temperature should be stabilised at the maximum oil temperature limit for normal operation.

(ii) Draining of oil: once the oil temperature has stabilised at the maximum declared oil temperature limit for normal operation, the oil should be drained simulating the *most severe failure mode* of the *normal-use lubrication system*. the *most severe failure mode* should be determined by the failure analysis of CS 29.917(b). The location and rate of oil drainage should be representative of the mode being simulated.

(iii) Depleted-oil run: upon illumination of the 'low oil pressure' warning or other indication, as required by CS 29.1305, continue to operate at AEO MCP and the nominal speed for use in this condition for 1 minute. Then, reduce the torque values to be equal to or greater than those necessary to sustain flight at the maximum gross weight and the most efficient flight conditions under standard atmospheric conditions (Vy). This condition should be maintained for at least 36 minutes. When determining the torque values to sustain flight at the maximum gross weight and the most efficient flight conditions (Vy), it should be assumed that the condition starts at 100 % maximum take-off weight (MTOW), and, thereafter, consideration for fuel burn during the test is allowed.

(iv) Simulated landing: to complete the test, power should be applied to the gearbox for at least 45 seconds to simulate an out of ground effect (OGE) hover.

(v) Test conditions: for (i) to (iv) above, the input and output shaft torques should be reacted, as appropriate, at the input and output quills, and the corresponding input and output shaft loads should be applied. The main gearbox's vertical load should be applied at the mast, and should be equal to the maximum gross weight of the rotorcraft at 1 g.

(vi) This test may be conducted on a representative bench test rig. The test should be performed with all the accessory loads represented by a load associated with normal cruise conditions.

(vii) For successful demonstration, the gearbox should continue to transmit the necessary torque to the rotors throughout the duration of the test. The loss of drive to accessories which are essential for continued flight should constitute a test failure.

(2) Category B rotorcraft

(i) The provisionsfor Category A apply except that the rotor drive system need only perform a depleted-oil run for 15 minutes operating at a torque and speed to simulate autorotative conditions.

(ii) A successful demonstration may involve limited damage to the rotor drive system provided that it is established that the autorotative capabilities of the rotorcraft were not significantly impaired. If compliance with Category A provisons is demonstrated, Category B provisionswill be considered to have been met.

(3) The test parameters described in (e)(1) above have been chosen to represent an occurrence of loss of oil in flight, namely a reaction/transition period for the crew to be able to reduce power followed by an extended period at reduced power for continued flight at Vy. When determining the torque necessary for the reduced-power segment of this test, an international standard atmosphere (ISA) sea level condition is considered to be acceptable.

(4) Should the applicant wish to establish a positive safety margin for a Category A rotorcraft for a *maximum period of operation following loss of lubrication* longer than 30 minutes, it will be necessary to extend the test duration representing flight at Vy, described in (e)(1)(iii) above.

(f) Determination of the *Most Severe Failure Mode*

(1) The objective of the loss of lubrication test is to demonstrate operation following the *most severe failure mode* of the *normal-use lubrication system*. The determination of the *most severe failure mode* may not be immediately obvious, as leakage rates vary, and system performance following leaks from different areas varies as well. Thus, a careful analysis of the potential failure modes should be conducted.

(2) The starting point for determination of the *most severe failure mode* should be an assessment of all potential lubrication system failure modes. This should be accomplished as part of the CS 29.917(b) design assessment, and include leaks from any connections between components assembled together, such as threaded connections, hydraulic inserts, gaskets, seals, and packings (O-rings). Failure modes, such as failure of externals lines, component retention hardware and wall-through cracks that have not been substantiated for CS 29.307, CS 29.571 and CS 29.923(m) should also be considered. The determination that a failure is an *extremely remote lubrication failure*, when used to eliminate a potential failure mode from being considered as a candidate *most severe failure mode*, should be substantiated. Where leakage rates or the effect of failure modes

cannot be easily determined, then a laboratory test should be conducted. Once the *most severe failure mode* has been determined, this should form the basis of the conditions for the start of the test.

(g) Use of an *auxiliary lubrication system*

Use of an *auxiliary lubrication system* may be an acceptable means of providing extended operating time after loss of lubrication. The *auxiliary lubrication system* should be designed to provide sufficient independence from the *normal-use lubrication system*. Since the *auxiliary lubrication system* is by definition integral to the same gearbox as the *normal-use lubrication system*, it may be impractical for it to be completely independent. Therefore, designs should be conceived such that shared components or interfaces between the *normal-use* and *auxiliary lubrication systems* are minimised and comply with the design assessment provisions of CS 29.917(b). Failure of any common feature shared by both the *normal-use* and *auxiliary lubrication systems* which could result in the failure of both systems should be shown to be an *extremely remote lubrication failure*. If compliance with CS 29.927(c) is reliant on the functioning of an *auxiliary lubrication system*, then:

(1) in the unlikely event of a combined failure of both the *normal-use lubrication system* and the *auxiliary lubrication system*, the RFM emergency procedures should instruct the flight crew to 'Land immediately' unless testing representing this failure mode has been performed in order to substantiate that an increased duration is justified; and

(2) a means of verifying that the *auxiliary lubrication system* is functioning properly should be provided during normal operation of the *normal-use lubrication system*. However, if there are no such means, the flight crew should be alerted in the event of a detection of a malfunction of the *auxiliary lubrication system*.

(h) Independence of the *auxiliary lubrication system*.

(1) In order to ensure that the *auxiliary lubrication system* is sufficiently independent:

(i) failure of the pressurised portion of the *normal-use lubrication system* should not result in a subsequent failure of the *auxiliary lubrication system*;

(ii) common failure modes shown to defeat both the *normal-use* and the *auxiliary lubrication systems* should be shown to be *extremely remote lubrication failures*; and

(iii) control systems, logic and health-reporting systems should not be shared; consideration should be given to the design process to ensure appropriate segregation of control and warning systems in the system architecture.

(2) Methods which should be used to demonstrate that failure modes of common areas are *extremely remote* include:

(i) field experience of the exact design with an exact application;

(ii) field experience with a similar design/application with supporting test data to allow comparison;

(iii) demonstration by test of extremely low leakage rates;

(iv) redundancy of design;

(v) structural substantiation with a high safety margin for elements of the lubrication systems assessed against CS 29.571; and

(vi) assessement of potential dormant failure modes of the *auxiliary lubrication system* and in order to minimise this risk, determination of the health of the *auxiliary lubrication system* prior to each flight.

(i) Determination of the *maximum period of operation following loss of lubrication*

In order to enable the flight crew to determine the safest action in the event of loss of gearbox oil, the RFM emergency procedures should include instructions defining the maximum period of time within which the rotorcraft should land. Accordingly, it is necessary to demonstrate reasonable confidence in the ability of the gearbox to continue safe operation after experiencing loss of oil or a lubrication failure. (i)(1) to (i)(5) below describe acceptable means of compliance (AMC) to demonstrate a level of confidence in the ability of the gearbox to continue safe operation, after experiencing loss of oil or lubrication failure, for a specified period at given operating conditions. This AMC explains how the test duration, the number of tests, the condition of the gearbox components upon completion of the tests, and the gearbox behaviour during these tests may be combined to establish a positive safety margin when determining the *maximum period of operation following loss of lubrication*. However, any other data, in particular that identified in (i)(6) to (i)(11) below, should also be considered as supporting evidence regarding the understanding of the gearbox behaviour after loss of lubrication.

(1) Certification test duration

The duration of the loss of lubrication certification test, as defined in (e) above, should be used as the starting point for determination of the *maximum period of operation following loss of lubrication*.

(2) Reduction factor based on supporting data

In order to substantiate the *maximum period of operation following loss of lubrication*, a suitable safety factor should be applied to correlate the test duration with the *maximum period of operation following loss of lubrication*. Suitable reduction factors are as follows:

(i) ≤ 0.6 should be used where no supporting data is available to provide understanding of the gearbox behaviour and confidence in the repeatability of the certification test data.

(ii) ≤ 0.8 should be used where the certification test duration is corroborated by one or more development tests. The development test results should show consistency of the temperature history, and demonstrate good correlation with the certification test.

(iii) ≤ 0.9 should be applied if a high level of understanding of the limiting design characteristics is established and supported by repeatable test data.

(iv) When determining the appropriate reduction factor, consideration should also be given to any factors which may reflect the health or stability of gearbox components during the test(s). These factors are addressed below and include: temperature history, maximum temperatures achieved with respect to physical limitations of the material, simulation results, and the time difference between the demonstrated duration up to test failure and the duration of the certification test.

(3) Reduction factor based on the condition of components at the end of the certification test

This should be applied in accordance with the definitions of (4) below. This fixed-period reduction should be 2 minutes for CLASS 1 ('Good' condition), 5 minutes for CLASS 2 ('Fair' condition), and 10 minutes for CLASS 3 ('Imminent failure' condition).

(4) Post-test condition of gearbox components

During loss of lubrication tests, components may suffer a progressive state of damage/deterioration, particularly when when relying on a limited quantity of *residual oil*, which may further reduce in quantity and increase in temperature. The classification of component condition is described below:

CLASS 0 — Intact/serviceable

Parts in new condition. It is impractical to expect components to be in this condition after the test, but this classification is stated for reference only.

CLASS 1 — Good

— Parts are still well oil-wetted with little or no discolouration (light yellow to light/local blue).

— Local moderate scuffing of gear teeth and/or local moderate scorings on bearing-active surfaces is present.

— Hardened surfaces (gear teeth and bearing-active surfaces) may show slight/local reduction in hardness (maximum 2 points on the Rockwell C Hardness (HRC) scale).

— Normally, operation in these conditions should not significantly alter the vibration and noise signatures of the gearbox during test.

— The efficiency of the gearbox should be unchanged or reduced by no more than 2 %.

— Gearbox still transmits the required torque and rotates smoothly.

CLASS 2 — Fair

— Parts are almost completely dry, little *residual oil* in localised areas.

— Dark blue to brown discolouration is present, showing signs of uniform wear.

— Coatings such as silver plating are still visible but may be worn out locally or discoloured.

— Heavy localised scuffing on gear teeth as well wear on active surface of gear teeth are visible.

— Surface hardness may have been reduced more significantly (up to a maximum of 4 points on the HRC scale).

— Normally, operation in these conditions could cause moderate changes to the vibration and noise signatures of the gearbox during test.

— Efficiency of the gearbox may be reduced by up to 4 %.

— Gearbox still transmits the required torque.

CLASS 3 — Imminent failure

— Parts show evidence of plastic deformation or melting in local areas due to high temperatures.

— Macroscopic wear of some of the rolling elements of bearings and gear teeth, with appreciable alteration of dimensions and associated increase in clearances and plays.

— Bearing cages are worn or with incipient breakage.

— Normally, operation in these conditions causes significant and audible changes to the vibration and noise signatures of the gearbox during test.

— Efficiency of the gearbox may be reduced by up to 10 %.

— Gearbox still transmits the required torque and is still capable of rotating immediately after test (after it has cooled down, it may be more difficult to rotate).

CLASS 4 — Failed

In this case, there is a complete and gross plastic deformation of parts, and bearing balls and rollers are melted. Parts in this conditions mean that the test specimen has failed, hence, this classification is also provided for reference only.

(5) Calculation of the *maximum period of operation following loss of lubrication*

Application of the factors described in (2) and (3) above can be represented by the following formula:

$$T_d = (K_r \times T_c) - T_p$$

where:

— T_d is the Maximum Period of Operation Following Loss of Lubrication, for which confidence has been established and which is to be referenced in the RFM emergency procedures;

— K_r is the confidence/reliability reduction factor defined in (2) above;

— T_c is the duration of the certification test (from low-pressure indication to end of test); and

— T_p is a fixed-time reduction factor to account for condition at the end of the test, as defined in (3) above.

(6) Multiple tests

Further to a full-scale certification test with a test configuration as described in (d) above, additional full-scale or modular development tests may be performed to increase confidence when determining the *maximum period of operation following loss of lubrication*.

(i) When two or more tests are submitted to show compliance with thisprovision, the test of shortest duration will be considered to be the certification test and should be used as the basis for demonstrating the *maximum period of operation following loss of lubrication*. If excessive variation is experienced between tests, it should be investigated and explained.

(ii) Note: Where the above text refers to multiple tests this does not necessarily mean completely different gearboxes. The intent of using data from multiple tests is that the parts replaced between tests are those potentially limiting the performance of the gearbox when operating under *residual oil* or oil supplied from an *auxiliary lubrication system*. Where particular design characteristics are known to be critical to *residual oil* performance, parts should be selected at the most severe end of the tolerance range of the dimensions/specifications impacting these characteristics.

(7) Development tests

The applicant is encouraged to perform development tests in order to explore the behaviour of the gearbox closer to the point of failure. The first objective of this additional testing is to evaluate the consistency between tests (using different gearbox components), and the second objective is to evaluate the time difference between the point at which the certification test was concluded and the likely time of gearbox failure (if the test had continued). Of equal importance is the identification of the gearbox design features which are most likely to initiate gearbox failure in the event of continued operation after loss of lubrication. When using development test results to corroborate the certification test duration and, thus, support the determination of the *maximum period of operation following loss of lubrication*, the criteria for the reconciliation between the development test data and an official valid test should include:

(i) for full scale loss of lubrication tests:

(A) the test conditions, i.e. loads, entry point and test profile, should be duplicated on the development test as for the official test, and any deviations should be substantiated;

(B) the representativeness of parts should be demonstrated and documented;

(C) the test equipment and instrumentation should be qualified and calibrated; and

(D) the correlation between development and official test should be demonstrated by absolute temperatures and temperature rates of change; and

(ii) for modular tests:

(A) the lubrication conditions, loads, entry point and test profile should be duplicated on the development test compared to the official test;

(B) in particular, the lubrication conditions should be conservatively simulated to avoid that the isolated module benefits from secondary lubrication from the boundaries of the module, which may not be representative of the module conditions in a full test;

(C) the representativeness of parts should be demonstrated and documented;

(D) the test equipment and instrumentation should be qualified and calibrated; and

(E) the correlation between development and official test should be demonstrated by correlation of temperatures.

(8) Maximum temperature reached during test

(i) Similarly to the rate of temperature change, general experience from 'total loss of lubrication' tests performed has shown that successful tests do not exceed certain values of temperature measured at critical locations of the gearbox. The applicant should record temperature measurements from critical points of the gearbox or at related locations in order to compare with previous experience. This data should be used to validate analysis models and to support the application of a high K_r value when determining the *maximum period of operation following loss of lubrication*.

(ii) Note: Monitoring devices (i.e. contact temperature probes) in critical locations may provide additional data to the flight crew to prevent reaching the critical failure conditions. The degree of reliability and redundancy of such devices should be considered in the failure analysis.

(9) Temperature rate of change during test

Gearboxes operating after loss of lubrication sometimes exhibit portions of the test where a stable (approaching to zero temperature rate of change) or meta-stable ('small' temperature rate of change) thermal response is maintained. It is considered that confidence in the behaviour of the gearbox may be greater for a maximum absolute temperature measured under these conditions in the context of the certification test or an official test. Portions of the test that exhibit a larger temperature rate of change should be investigated and substantiated.

(10) Models/simulations

Numerical simulation of loss of lubrication conditions is not considered sufficient to demonstrate confidence in absolute temperature values achieved during the certification test, when applied to the prediction of the *maximum period of operation following loss of lubrication*. However, it may be possible to apply numerical simulation (0-3 dimensional) to extrapolate test results to other boundary or entry conditions.

(11) Secondary indication

Another possible means to increase confidence in the ability to continue to operate safely after suffering loss of lubrication is to provide a secondary indication, which may indicate when the most critical mode of degradation has progressed to a level where gearbox functional failure may be imminent. If such a design feature is selected, the following considerations are necessary:

(i) evidence should be available, preferably from multiple tests, to provide confidence that the failure mode being monitored is always the most critical failure mode after loss of lubrication, and that the rate of degradation up to the point of failure is understood;

(ii) inhibition of the warning to the flight crew in the event that oil pressure is normal may be considered to reduce likelihood of a false warning resulting in an instruction to 'land immediately'; and

(iii) availability/reliability of the warning should be justified; it should be possible to test the correct functioning of the sensor or warning during pre-flight/start-up checks or during routine maintenance.

4. Impact assessment (IA)

4.1. What is the issue

As described in Chapter 2 of this NPA, the JCT was set up to conduct a review of the current design requirements and associated guidance material relating to gearbox loss of lubrication. The final report of the JCT dated 28 September 2012 includes findings regarding the adequacy of the current requirements as well as recommendations for amending FAR 29/CS-29 and the associated guidance material. These recommendations address the following aspects of gearbox and lubrication system design, aiming both at reducing the risk of occurrence and mitigating the effects of gearbox loss of lubrication:

— safety assessment of pressurised lubrication systems;

— testing requierements to demonstrate the behaviour of gearboxes experiencing loss of lubrication; and

— substantiation of a maximum period of continued operation which can be stated in the RFM emergency procedures.

These recommendations, as stated below, were agreed and further developed by the RMG RMT.0608:

(a) all new CS-29 Category A rotorcraft types should comply with at least one 'loss of lubrication' test to meet CS 29.927(c) and the term 'extremely remote' should be removed from the requirement.

(b) a new CS 29.927(c) should define a test which can justify confidence that 30 minutes of continued flight post loss of lubrication would be probable.

(c) AMC to CS 29.927(c) should be changed to define the method for draining the oil; and

(d) the lubrication systems should be subjected to the rotor drive system design assessment of CS 29.917(b).

4.1.1. Safety risk assessment

A typical rotorcraft rotor drive system main gearbox consists of many highly loaded dynamic components that are essential for safe flight and landing. Due to the single-load-path architecture of rotor drive system designs and the dependence of safety upon the continued integrity of these 'critical parts', it is accepted in the certification process that rotor drive systems are likely to be subject to a greater risk of failure than other rotorcraft and fixed-wing aircraft systems. The function of a rotor drive system gearbox is to transmit power from the engines to the rotors, whilst at the same time reducing rotational speed and increasing torque. Lubrication, usually provided by oil, is an essential feature of these gearboxes, reducing friction and providing cooling at points of moving contact between critical gears, shafts and bearings. Consequently, depletion of lubrication supply eventually results in increased friction, increased temperature and eventually in loss of drive or loss of control of the rotorcraft.

The capability of early rotorcraft gearbox designs to continue operation after loss of lubrication was quite limited. Some designs showed that mechanical failure was likely within just a few minutes of continued operation under power after loss of lubrication. By the 1980s, civilian helicopter passenger transport was becoming increasingly more established, and the use of helicopters in support of offshore industries was also increasing. Consequently, rotorcraft designs were developed to improve lubrication system reliability and gearbox capability in the event of loss of lubrication in order to reduce the risk of lubrication failures leading to ditching or crashing into water. In 1988, FAR 29.927(c) (at Amendment 26) was amended to require gearboxes with pressurised lubrication systems to demonstrate a capability to continue operation for a minimum of 30 minutes after loss of lubrication by completing a bench test. This amendment significantly improved the above-mentioned Regulation. However, a single 30-minute bench test might only provide confidence for an associated RFM emergency procedure for a much shorter duration of continued flight following lubrication system failure. Considering the current number of helicopters used for offshore work and the growing need for transport to locations further offshore, the risk of an accident following lubrication system failure has increased. Accordingly, to maintain or reduce this risk, there is a need to amend and improve CS-29.

Considering this growing risk to civilian CS-29 helicopters and mindful of lessons learned following recent accidents, EASA is of the opinion that the current CS-29 provisions addressing rotor drive system gearbox loss of lubrication need to be amended in order to achieve an acceptable level of safety. Furthermore, knowledge of and tools for rotorcraft drive system design have improved significantly since the last amendment of FAR 29.927(c) such that better ‘loss of lubrication’ capabilities can now realistically be achieved. Based on the hazard severity of this failure mode and the experienced frequency of events, the level of risk is considered to be high.

4.1.2. Who is affected

This NPA will affect designers and operators of large rotorcraft as well as certifying authorities.

The four largest helicopter manufacturers affected by the changes proposed in this NPA are Airbus Helicopters, Bell Helicopter, Leonardo Helicopters, and Sikorsky Aircraft Corporation.

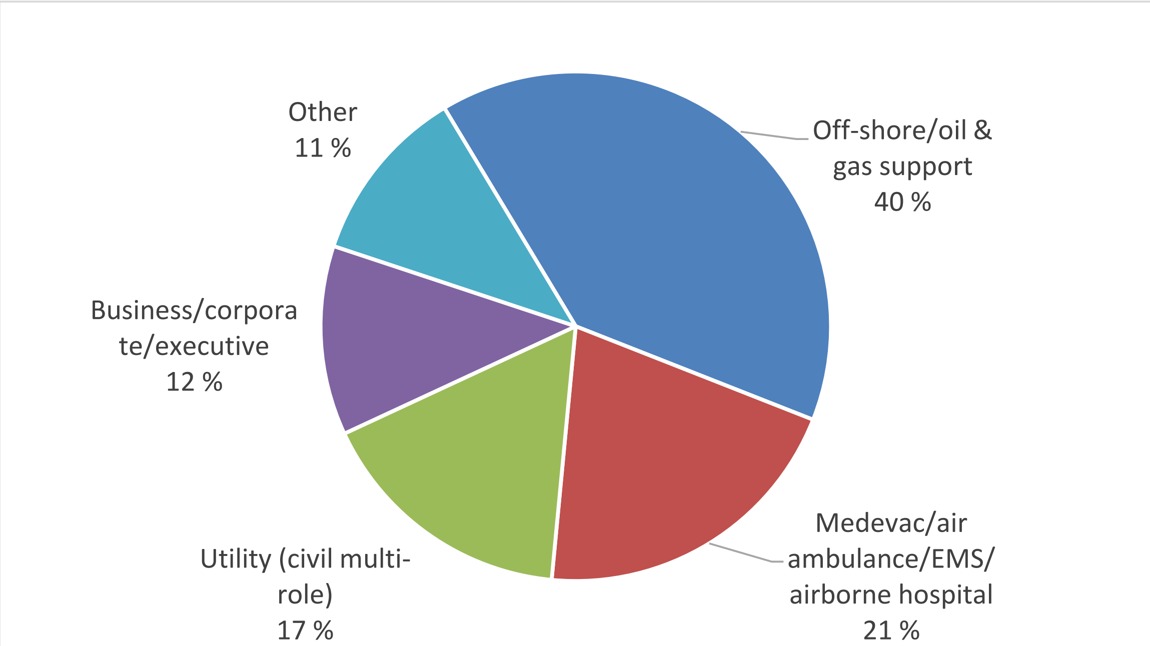
In February 2016, there were 682 large helicopters operated in EASA Member States (MSs) (see Table 1 below). Approximately 4 out of 10 helicopters are operated in offshore oil and gas support, every fifth helicopter in medical services, and 4 out of 10 in various other usage categories. Typically, the usage and the number of passengers carried are higher for offshore oil and gas support operations, thus increasing exposure to airworthiness risks.

Table 1 — Large helicopters by manufacturer

Manufacturer	Fleet
Airbus Helicopters	317
Sikorsky	113
AgustaWestland	93
Bell Helicopter Textron	76
WSK-PZL Swidnik	35
Mil Moscow Helicopter Plant	26
Agusta-Bell	16
Indonesian Aerospace	4
Kamov	2
Total	682

[1] In-service and temporarily stored helicopters operated by EASA MSs civil operators on 10 February 2016

Figure 1 — Large helicopter fleet by usage



4.1.3. How could the issue/problem evolve

The increased number of helicopters currently in service for offshore work, coupled with the growing need for transport to locations further offshore, potentially increases the risk of an accident following a lubrication system failure. This is due to the fact that for offshore helicopter operations the capability to continue flying and subeqeuntly land safely after a rotor drive system gearbox 'loss of lubrication' event is more critical for this type of operation.

EASA was part of the JCT that recommended improvements to the current 'loss of lubrication' requirements and associated guidance material for Category A rotorcraft, intended to be implemented in the United States, Canada, and Europe. Therefore, for future harmonisation purposes, it would be advantageous for EASA to implement these proposed amendments to CS-29 and associated AMC.

4.2. What we want to achieve — objectives

The specific objective of this proposal is to reduce the risks associated with loss of lubrication of rotor drive system gearboxes and to implement recommendations arising from the JCT's review of rotorcraft gearbox certification requirements. This aims to both reduce the potential for lubrication system failures from occurring and to mitigate the likely consequences of any failure.

4.3. How it could be achieved — options

In order to achieve the above objectives, the options below were identified.

Table 2 — Selected policy options

Option No	_Short title_	**Description**
0	Do nothing	Baseline option — no change in rules; risks remain as outlined in the issue analysis.
1	Amend CS-29 and CS-27	Rulemaking to provide enhanced CSs and AMC that reflect certification best practice.

Option 1 should provide enhanced CSs and AMC in line with the JCT's recommendations, including the following:

All CS-29 Category A new rotorcraft types (i.e. not applicable to variants unless there is an amendment to 21.A.101) should comply with a 'loss of lubrication' test.

Propose an amendment to CS 29.927(c) 'Additional tests' to stipulate that a loss of lubrication test is required. The term 'extremely remote' should be removed and the rule should be rewritten to become a prescriptive 'loss of lubrication' durability test of the rotor drive system gearboxes used on Category A rotorcraft. Essential test parameters should be prescribed, including the torque value(s) and rotational speed(s), that should be applied to the rotor drive system to ensure that continued level flight at maximum take-off gross weight (subject to a possible reduction due to fuel burn) can be maintained for a duration after loss of lubrication.

The duration of the 'loss of lubrication' test should consider the operational need, particularly with regard to offshore operations in support of oil and gas resources. Upon completion of the test, the test results and the duration of the test should be taken into consideration when developing the appropriate emergency procedures for loss of lubrication in the RFM.

Lubrication system design should be subject to the drive system design assessment of CS 29.917(b). The lubrication system is an integral part of the rotor drive system and is necessary for maintaining continued safe operation of the rotor drive system.

4.4. Methodology and data

4.4.1. Methodology applied

The methodology applied for this IA is the multi-criteria analysis (MCA), which allows comparing all options by scoring them against a set of criteria.

MCA covers a wide range of techniques that aim at combining a range of positive and negative impacts into a single framework to allow easier comparison of scenarios. Essentially, it applies a cost-benefit assessment to cases where there is a need to present multiple impacts representing a mixture of qualitative, quantitative, and monetary data, and where there are varying degrees of certainty. The MCA key steps generally include:

— establishing the criteria to be used to compare the options (these criteria must be measurable, at least in qualitative terms); and

— scoring how well each option meets the criteria; the scoring needs to be relative to the baseline scenario.

The criteria (safety, economic, environmental, and social) used to compare the options were derived from the Basic Regulation and the guidelines for the IA were developed by the European Commission.

The scoring of the impacts uses a scale of –5 to +5 to indicate the negative and positive impacts of each option (i.e. from 'very low' to 'very high' negative/positive impacts). Intermediate levels of benefit are termed 'low, 'medium', and 'high' to provide for a total of five levels in each one of the positive and negative directions, with also a 'no impact' score possible.

4.4.2. Data collection

The number of helicopters operated by EASA MSs is based on data from Ascend Fleets. It includes helicopters in service and those out of service and temporarily stored on 10 February 2016.

The financial information used to assess the economic impact is based on the publicly available annual reports of the largest affected aircraft manufacturers as well as on the development cost estimates provided by the RMG.

The safety occurrence database of EASA identifies accidents and incidents over the last 10 years. This database contains accidents and serious incidents within the scope of EASA (i.e. ocurrences involving European products operating worldwide plus other occurences involving an EASA MS, either as state of occurrence, state of operator, or state of registry). In addition, the database includes all accidents with large commercial aeroplanes and rotorcraft worldwide.

4.5. What are the impacts

4.5.1. Safety impact

The analysis relating to CS-29 Category A (or equivalent) rotorcraft occurences and accidents showed that over the last 10 years there were:

— 1 fatal accident,

— 2 non-fatal accidents,

— 2 serious incidents, and

— 4 incidents.

Examination of the information available for these 9 events shows that 7 of them involved loss of oil, and 2 involved loss of oil pressure. Of the 9 events, 8 were determined to result in the need for an imminent forced landing, and 1 for a landing which might be necessary before reaching a safe landing site.

Data is not available to estimate how many operating hours were operated by these types of rotorcraft over the last 10 years, thus, it is not possible to provide a reliable occurence rate relating to these events. Accordingly, a qualitative assessment has been made.

Note: Over the same 10-year period, there were 2 recorded incidents involving CS-27 Category A rotorcraft. As discussed in Chapter 2 of this NPA, the safety risk applicable to CS-27 Category A rotorcraft is considered to be much less significant.

It is qualitatively assessed that approximately 50 % of these incidents could be avoided if the proposed amended provisions are included in CS-27 and CS-29. This failure condition is currently considered to be one of the significant airworthiness safety risks for CS-29 rotorcraft, and the proposed risk mitigation measures would reduce the risk of an incident resulting from a loss of lubrication. This is particularly pivotal for helicopters that are operated in an offshore environment where it might not be possible to land immediately in the event of a loss of lubrication. The risk of a accident following a loss of lubrication could be reduced by subsequently maximising the duration of continued flight time for the helicopter after the failure has occurred. This would increase the probability of the pilot being able to find a suitable landing site within the remaining continued flight time.

The following scale was used to assess the safety impact from the proposed amendment to CS-27 and CS-29:

Reduction in number of events (%)	Safety Impact Score
81-100 %	+5
61-80 %	+4
41-60%	+3
21-40%	+2
1-20%	+1
0	0

Option 0: No impact on safety is envisaged.

Option 1: It is anticipated that there will be an increase in the level of safety due to the estimated 50 % reduction in the number of loss of gearbox lubrication events. The qualitative assessment of the safety benefit gives a score of 3 (medium safety benefit) based upon the 50 % estimated reduction in the number of events (see safety impact table above).

Assessment	**Option 0** Do nothing	**Option 1** Amend CS-29 and CS-27
Safety impact	0	+3

4.5.2. Environmental impact

There have been no environmental impacts identified.

4.5.3. Social impact

There are no relevant social impacts for either option.

4.5.4. Economic impact

In order to assess the significance of each identified increase in development costs per new type, these amounts need to be compared to a financial indicator that accurately represents the affected manufacturers.

The thresholds expressed in percentages and the corresponding MCA scores are shown in Table 3 and Table 4 below:

Table 3 — Economic-impact scores

Impact	Score	Share of annual turnover	
		More than	No more than
Very high	5	1 %	
High	4	0.6 %	1 %
Medium	3	0.2 %	0.6 %
Low	2	0.05 %	0.2 %
Very low	1	0.01 %	0.05 %
Insignificant	0	–	0.01 %

Table 4 — Economic impact of development costs

Average revenue per manufacturer (2014, in million)	EUR 4 920
Annual development cost (in million)[1]	EUR 0.100
Development cost as share of annual revenue	0.0020%
Impact score	Insignificant

Notes:

[1] A manufacturer is assumed to deliver a new CS-29 type every 5 years, therefore the EUR500 000 development cost per type equals EUR100 000 annual cost.

The development cost of EUR 100 000 per year is no more than 0.01 % of the annual revenue of an average affected manufacturer, which, in accordance with Table 4, equates to an insignificant economic impact.

Table 5 — Economic-impact scores

Assessment	**Option 0** Do nothing	**Option 1** Enhanced standards
Economic impact	0	0

Option 0 would mean no harmonised certification specifications over the long term, therefore, a low negative impact is expected.

The intention of Option 1 is that the amended CS-29 and associated AMC will maintain harmonised certification specifications on this subject over the long term.

4.5.5. General Aviation and proportionality issues

Manufacturers of large rotocraft do not include small and medium-sized enterprises or operators in General Aviation (GA).

4.6. Conclusion

4.6.1. Comparison of options

Assessment	**Option 0** Do nothing	**Option 1** Enhanced standards
Safety impact	0	3
Environmental impact	N/a	N/a
Social impact	N/a	N/a
Economic impact	0	0
GA and proportionality issues	N/a	N/a
Total score	**0**	**3**

The conclusion of this IA is as follows.

Option 0 'Do nothing' would result in no improvement to safety. This is considered to be the e undesireable option on the basis of the need to address the safety issues described in Chapter 2 above.

Option 1 'Enhanced standards' has the highest score (higher score than Option 0), is considered to address the safety issues described in Chapter 2, and is assessed to have an only insignificant economic impact.

Accordingly, Option 1 is recommended.

Note: With only 2 recorded 'loss of lubrication' incidents involving CS-27 Category A rotorcraft over the same 10-year period as the one used for this assessment, the safety risk applicable to CS-27 Category A rotorcraft is considered to be less significant. Based on the tangible safety improvement through the enhanced CSs of Option 1, it is proposed that the amended provisions in CS-29 remain equally applicable to CS-27 Category A rotorcraft by referencing them in CS-27 Appendix C.

4.7. Monitoring and evaluation

Events involving loss of gearbox oil which are hazardous and catastrophic will be monitored in Europe and the USA through the regulator's safety data monitoring and analysis functions. Due to the low frequency of events involving loss of gearbox oil, it may be difficult to monitor any trend data of occurrences. In addition, due to the fact that the amended certification specifications will be only applicable to new designs, it will be important to differentiate between occurrences involving pre- and post-CS-amendment designs. The safety risk portfolios for rotorcraft operations will be closely monitored for any increased number of occurrences relating to loss of gearbox lubrication.

5. References

5.1. Related regulations

N/a

5.2. Affected decisions

— Decision No. 2003/16/RM of the Executive Director of the Agency of 14 November 2003 on certification specifications for large rotorcraft (‘CS-29’); and

— Decision No. 2003/15/RM of the Executive Director of the Agency of 14 November 2003 on certification specifications for small rotorcraft (‘CS-27’)

5.3. Other reference documents

— Aviation Investigation Report A09A0016 – Main Gearbox Malfunction / Collision with Water. Cougar Helicopter Inc. Sikorsky S-92A, C-GZCH. ST John’s, Newfoundland and Labrador, 35 NME – 12 March 2009