AERONAUTICAL INFORMATION CIRCULAR - MOÇAMBIQUE
INSTITUTO DE AVIAÇÃO CIVIL DE MOÇAMBIQUE
DIRECÇÃO DOS SERVIÇOS DE NAVEGAÇÃO AÉREA
AERONAUTICAL INFORMATION SERVICE

Tel: (258) 21-465416
Fax: (258) 21-465415
AFTN: FQHQYSYX
iacm@tvcabo.co.mz
ais@iacm.gov.mz
www.iacm.gov.mz

ALAMEDA DO AEROPORTO
Caixa Postal, 227 - Maputo
IACM

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TECHNICAL CIRCULAR

RELIABILITY PROGRAMMES

1. Authority

This advisory circular is issued by the Executive Chairman of the Institute of Civil Aviation de Mozambique (IACM) in pursuance of powers vested in him under Article 31 of Law 21/2009 of 21 September and Article 12 of Resolution 19/2011 of 30 November.

2. Purpose

This Technical Circular (TC) is issued to provide information and guidance to operators on reliability programmes.

3. References

- MOZCAR Part 121/127/135;
- ICAO Document 9389 - AN/919, Chapter 7, Sections 7.3.4 through 7.3.14.6;
- U.S. FAA Advisory Circular 120-17, Maintenance Control by Reliability Methods, as amended;
- "Airline/Manufacturer Maintenance Programme Planning Document", Maintenance Steering Group (MSG) 3, and Chapter 4, Section "Introduction to General Functions" and.

4. Preamble

A. The word "reliable" is a broad term meaning dependable or stable the term, as used by the aviation industry, applies to the dependability or stability of an aircraft system or part thereof under evaluation. A system or component is considered "reliable" if it follows an expected law of behavior and is regarded "unreliable" if it departs from this expectation. These expectations differ greatly depending upon how the equipment is designed and operated.

B. Reliability programmes should describe the techniques used for measuring the performance and calculating the remaining service life of the component sufficiently in advance in order to take corrective maintenance action prior to failure. Essentially, reliability programmes are used for the control of maintenance by establishing performance levels for each type of unit and/or system individually or as a class. Generally, reliability programmes depend on the collection of data which can be analyzed and compared to previously established programme goals.

C. There are numerous (maintenance reliability programmes) now in operation which uses new and improved maintenance management techniques. Although the design and methods of application vary in some degree, the basic goal are the same to recognize, access, and act upon meaningful symptoms of deterioration before malfunction or failure in order to establish and monitor the maintenance control requirements. However, it must be stressed that reliability programmes are designed to supplement the operator's overall programme for maintaining aircraft in a continuous state of airworthiness.

D. Performance standards (alert values, etc.) are established by actuarial study of service experience using statistical methods coupled with application of technical judgement. These standards are used to identify trends or patterns of malfunction and/or failures experienced during programme operation. Even though reliability programmes vary, they should provide means for measurement, evaluation, and improvement predictions. They should contain the following elements: an organizational structure, a data collection system, a method of data analysis and display, procedures for establishing performance standards or levels, procedures for programme revision, procedures for time control, and a section containing definitions of significant terms used in the programme.

E. It is intended that the specific needs of each operator, in terms of operating philosophy, record keeping practices, etc. be reflected in their reliability programmes. The extent of statistical and data processing required for programme operation is entirely dependent on the character of the particular programme. Programmes may be simple or complex depending on the size of the operator and other factors. The smaller as well as the larger operator may develop maintenance reliability programmes to meet his own specific needs.

F. A good reliability programme should contain means for ensuring that the reliability which is forecast has actually been achieved. A programme which is very general may lack the details necessary to satisfy the reliability requirement. It is not intended to imply that all of the following information should be contained in one programme. It is realized that operating philosophy and programme management practices, etc., for each operator are different; however, the following information could be applied to the specific needs of either a simple or a complex programme.

5. Key Elements

5.1 Organizational Structure

A. The programme should contain an organizational chart which includes:

(1) a diagram of the relationship of key organizational blocks;

(2) a listing of the organizational elements by title responsible for the administration of the programme;

(3) a statement describing lines of authority and responsibility. The programme should identify the organization responsible to management for the overall reliability functions. It should define the authority delegated to these organizations to enforce policy and assure necessary follow-up and corrective actions; and

(4) a procedure for the preparation approval and implementation of revisions to the programme.

5.2 Data Collection System

A. It is important that the data be as factual as possible in order that a high degree of confidence may be placed in any derived conclusion. Data accuracy is particularly important when it is used for predicting reliability because the prediction technique at best gives a broad estimate of the expected reliability. Therefore the more dependable the data the higher the degree of confidence can be placed in the reliability estimate. Data should be obtained from units functioning under different operational conditions. The following are typical sources of information: unscheduled removals, confirmed failures, pilot reports, sampling inspections, functional checks, shop findings, bench checks, Service difficulty Report, and any other source that the operator may consider appropriate.

5.3 Data Analysis And Display

A. Data display and reporting provide a timely and systematic source of information, and even though after-the-fact, this material is a necessary prerequisite for correcting existing deficiencies. Reporting is not an end objective, but rather a necessary link in the chain of events leading to system improvement. The principal reason for gathering reliability data is to use it for making various determinations and predictions. Among these are such items as failure rate of parts and components, serviceability, and maintainability.

B. In general, almost any desired information can be extracted from these data if they are obtained in a planned and organized manner and carefully recorded and collated. However, the methods of analysis must be clearly understood in order to interpret properly the results obtained. Reliability data collected and analyzed with no particular end in view usually results in conclusions that are defective for one reason or another. The programme should provide the information necessary to properly evaluate the graphic presentations submitted in support of the programme. These are used to reveal briefly and simply via graphics those aspects which would normally require a cumbersome analysis of a text or tabular material.

5.4 Performance Standard

A. Each reliability programme should include a performance standard expressed in mathematical terms. This standard becomes the point of measure of maximum tolerable unreliability. Thus, satisfactory reliability trend measurements are those which fall at or preferably below the performance standard. Conversely, a reliability trend measurement exceeding the performance standard is unsatisfactory and calls for some type of follow-up and corrective action.

B. A performance standard may be expressed in terms of system or component failures per 1000 hours of aircraft operation, number of landings, operating cycles, departure delays, or other findings obtained under operational conditions. In some instances, an upper and lower figure may be used. This is known as a reliability band or range and provides the standard by which equipment behavior may be interpreted or explained.

C. When the performance standard is exceeded, the programme should provide for an active investigation which leads to suitable corrective action.

D. A description of the types of action appropriate to the circumstances revealed by the trend and the level of reliability experience should be included in the programme. This is the central core of maintenance control by reliability measurement. It is the element that relates operating experience to maintenance control requirements. Statistical techniques used in arriving at reliability measurements presented in support of maintenance control actions should be described. Appropriate action might be:

   (1) actuarial or engineering studies employed to determine need for maintenance programme changes;

   (2) actual maintenance programme changes involving inspection frequency and content, functional checks, or overhaul limits and times;

   (3) aircraft system or component modification, or repair;

   (4) other actions peculiar to the condition that prevails.

E. The results of corrective action programmes should become evident within a reasonable time from the date of implementation of corrective action. An assessment of the time permitted should be commensurate with the severity or safety impact of the problem. Each corrective action programme should have an identified completion date.

F. Due to the constantly changing state-of-the-art, no performance standard should be considered fixed because it is subject to change as reliability changes. The standard should be responsive and sensitive to the level of reliability experienced. It should be "stable" without being "fixed". If over a period of time the performance of a system/component improves to a point where even abnormal variations would not produce an alert, then the performance standard has lost its value and should be adjusted downward. Conversely, should it become evident that the standard is consistently exceeded in spite of the best known corrective measures to produce the desired reliability, then the performance standard should be re-evaluated and a more realistic standard established. Each programme should contain procedures to accomplish, when required, such changes to the prescribed, performance standards.

5.5 Establishing Initial Standards

A. In order to establish the initial standards for structural components, powerplants and systems, the past operating experience with same, or in the case of new aircraft, similar equipment should be reviewed in sufficient depth to obtain a cross section of subject systems performance. Normally, a period of six months to one year should be sufficient. For a system common to a large fleet of aircraft, a representative sample may be used while small fleet systems may require 100 per cent review. Operators introducing a new aircraft into service may establish their alert by using this available data. However, after the operator completes about one year's operating experience, the alert value should be adjusted based upon his experience.

B. Due to different operating conditions and system design, it is necessary to use different measuring devices (either singly or combined) to obtain satisfactory performance criteria. As stated before, there are various methods used to evaluate and control performance, i.e., aircraft diversions, mechanical interruptions in flight, delays and flight cancellations, component unscheduled removal rates, etc.

C. The following are typical examples of methods that can be used to establish and maintain alert values. It should be understood that the methods of evaluation given below are only illustrative and that other suitable methods of evaluation could be used:

(1) Pilot reports per 1000 aircraft departures

(a) Several operators have selected pilot reports as related to the number of departures as the primary measure of aircraft systems performance reliability. The reference base for the computation of alert values is a cumulative rate of the previous calendar year's experience. This provides a large statistical base and takes into consideration the extremes in seasonal effects. The base line for each system is initially calculated by compiling the number of pilot reports logged for the previous twelve-month period times I 000 divided by the number of aircraft departures for the same twelve-month period. The purpose of multiplying the pilot reports by 1000 is to arrive at a figure that expresses the rate per 1000 departures since the rate is expressed in events per 1000 departures.

(b) In order for this to be a cumulative rate for the previous twelve months, the rate is calculated monthly; however, the data for the first month is dropped and the data compiled for the last month is added. This process is repeated each month; i.e., if the initial calculation was from March 1998 to February

1999, the next month's calculation would cover the period from April 1998 to March 1999.

(c) When the base line is computed for a particular system, an alert value is established at a point above the base line equal to, say, five pilot reports per 1000 aircraft departures. The alert values assigned to each system represent the maximum rate of pilot-reported malfunctions considered to deviate sufficiently from the base line to require investigation.

(2) Pilot reports per 1000 aircraft hours

(a) For the purpose of measuring reliability, pilot reports per 1000 aircraft flight hours may be selected as the indicator of aircraft systems performance. Performance standards in terms of pilot reports per 1000 hours are established for each of the aircraft systems. Several programmes in current use utilize two performance numbers, an "alert" number and a "target" number. A review and evaluation of a minimum of six to twelve month's history of pilot reports is accomplished to establish the initial alert and target numbers. Established alert and target numbers are valid for a six-month period. At the end of the six-month period, all alert and target numbers are reviewed and adjusted accordingly.

(b) The alert number is defined as the three-month moving (running) average which is considered to indicate unsatisfactory performance.

(c) Historically, alert numbers show seasonal variations. To provide a more realistic alert number, the year is divided into six-month periods. One period encompasses the winter months, the other, the summer months. When reviewing a particular six-month period to ascertain if the alert number is still practical, it is important that the comparison is made between similar periods.

(d) The target number is defined as the operator's goal and predicted level of performance at the end of a six-month period. Target numbers are set to specify the operator's desires and expectations for future system performance. The target number is established in the same manner as the alert number. The difference being that the alert number is the upper limit of the range and, when exceeded, indicates unsatisfactory performance. The target or the lower limit is set as a goal which represents a level that the operator believes is attainable.

(e) Each month a three-month running average for each system is calculated. A three-month running average is obtained by compiling and analyzing data for three consecutive months; i.e., the total pilot reports for three months are divided by the number of aircraft hours flown during the same three-month period. The result of this calculation is the three-month average. To maintain a running average requires that the first month's data be deleted and the data for the current month be added to the sum of the previous two months. This process is repeated monthly to maintain a three-month running average. Any system which either exceeds the alert or which has a trend indicating the target will not be met is considered to be in need of special attention.

5.6 Calculation Used to Establish Alert Values Statistically

A. Many programmes establish alert values by reviewing past performance and then, by using "good judgement", establish the numerical value for the alert. This generally works well, however, the value can become controversial since the "good judgement" of one person may well be different from that of another person. In an effort to avoid the controversial aspect, some operators prefer the statistical or mathematical approach. This .is a broad term that could cover a number of methods of gathering numbers of instances and evaluating the result. In any case to be effective, a sufficient quantity of accurate data must be available for analysis.

B. In order to establish system alert values, an evaluation of the operational performance of each system to be controlled by the programme is made. The yardsticks covering failure performance are clearly defined in the programme. Using these definitions, the failure data for each system are extracted from pilot reported malfunctions for at least a twelve-month period. The "mean" and the "standard deviation" are then computed from those data and each system's alert value is established equal to the mean plus three standard deviations.

C. The current performance level of each system is computed on a monthly basis as a three-month cumulative performance rate. This rate is computed by multiplying the number of in-flight malfunctions for a three-month period by 1000 and dividing by the total aircraft flight hours for the same period. To maintain a cumulative rate requires that the first month's data be deleted and the data for the current month be added to the sum of the previous two months. When a trend of deteriorating system performance is detected, or if a system is over the alert value, an active investigation is conducted. This evaluation is made to assess the causes of the change in system performance and to develop an active corrective programme, if required, to bring the system performance under control.

4.7 Monitoring By Age/Reliability Relationship

A. Several operators use an actuarial analysis technique as a basic requirement for making technical decisions concerning component reliability in their "on-condition" overhaul and monitored maintenance reliability programmes. Components selected for these programmes are those on which a determination of continued airworthiness may be made by visual inspection, measurements, tests, or other means without a tear down inspection or periodic overhaul. Under these programmes, components are allowed to operate in service subject to meeting the established performance standard or the established "on-condition" base line data,

B. Initially, an actuarial analysis of each component is prepared to determine its reliability versus age characteristics. A component is considered acceptable for inclusion in the programme when the analysis shows that reliability does not deteriorate with increased time in service up to a predetermined point established by the operator. Normally, this cut-off point is considered to be the practical limit based on the amount of data collection and analysis required to qualify the component.

C. When the reliability of a component deteriorates to a value above the established performance standard, another actuarial analysis is made to determine the component's reliability versus age characteristics. Normally, this analysis will also include a determination of the reasons for the deterioration and the corrective action required to bring the condition under control. This reliability analysis is a continuing process and reveals whether a component requires a different maintenance programme or is in need of a design change to improve reliability.

D. An actuarial analysis is also made when the observed performance of a component improves to the point where more components are reaching higher operating times without experiencing premature removal failures. With such an improvement in survival characteristics possible, it is desirable to make a reliability analysis to determine its age-to-reliability characteristics.

E. In the past, component performance has been evaluated largely on the basis of gross premature removal rate and the subsequent analysis of the teardown findings in the shop. The introduction of the "on-condition" overhaul concept has made it increasingly important to gain more information about the operating performance of the components and to examine the relationship of this performance to the time in service. This need has fostered the development of actuarial analysis techniques.

F. This method of analysis requires, for a specified calendar period, that the following information be available for each component under study:

(1)the time on each operating component at the beginning of the study;

(2)the time on each component removed and installed during this period;

(3)the reason for removal and disposition of each component; and

(4)the time on each operating component at the end of the study period.

G. An analysis is made of the performance of each component as its life progresses from one overhaul to another as follows:

(1) a time and failure distribution chart is prepared which shows the amount of operating time for each component and the failures experienced in each 100-hour time bracket for the specified study period. In conjunction with this chart, a digest of the causes of failure for each 100-hour time bracket is also prepared;

(2) the next step is to develop failure rate and survival curves versus time since overhaul (TSO). A failure rate curve shows the failure rate/1 000 hours for each component in each 100-hour time bracket. A survival curve shows the number of units remaining at any given TSO. The shape of the survival and failure rate curves are valuable when determining the deterioration of reliability. The operating time which can be realized between consecutive overhauls is determined by the area which is under the survival curve and is bounded by the horizontal and vertical axes;

(3) additional information is available from these data by developing a probability curve. This curve will show the probability of a component

reaching a given TSO and the number of components expected to fail in a given time bracket. The number of components that would probably fail in a given time bracket is obtained by taking the difference of the ordinates at the beginning and end of a given time bracket. This would also be a reflection of the slope of the survival curve at that point. The percentage of components which survive to a given TSO is also the probability of a single component operating to that time without failing. The percentage of components surviving to a given TSO can also be considered to be the number of components which survive to that TSO out of each 100 components which enter service; and

(4) a still better evaluation is possible by developing a conditional probability curve. This curve will show the probability of failure of a component within a given time interval. Data for a conditional probability is obtained by dividing the number (or percentage) of components entering an interval by the number (or percentage) of components removed during an interval. It is considered that this curve best depicts the relationship between reliability and overhaul time.

H. Some advantages of this type of analysis are as follows:

(1) a determination can be made as to whether failures are being prevented by the TSO specification;

(2) an indication is given statistically concerning the current TSO limit and whether or not it has reached an optimum point;

(3) an indication is provided as to what might occur to the overall premature removal rate if the TSO limit is changed;

(4) an indication will be provided of any unusual high rate of premature removals/failures that have occurred immediately after a check and repair or overhaul;

(5) in some cases, an indication may be given that scheduled interim maintenance would result in an improvement of the overall premature rate;

(6) other useful conclusions can be made concerning the relationship of the failure to the time in service, time intervals, engineering change accomplishment, etc; and

(7) also, this technique of in-service component reliability analysis readily lends itself to computer programming.

I. These advantages emphasize the importance of such an analysis as a valuable tool in determining a maintenance programme that is best for the component involved.

(8) Does the programme provide for revision of the Operations Specifications, Maintenance, Part D, whenever a change is made to the current document?

B. It should be ensured that the proposed Time Between Overhaul (TBO) adjustment does not conflict with a corrective action programme established by a previous reliability analysis. A provision should be made for the Directorate of Airworthiness Standards (DAWS) to be advised when increases to time limitations of system/components controlled by the programme occur. Furthermore, operators should be encouraged where possible to include a graphic display of major system/component (engine/airframe) TBO escalation.

4.9 Approval Of Reliability Programmes

A. Maintenance reliability programme approvals are a means of complying with the CAA Regulations and, therefore, become part of the AOC holder's Maintenance Operations Specifications which are discussed in detail later in this chapter. The programmes are to be administered and controlled by the AOC holders and monitored by the Airworthiness Inspector. An operator's application for approval should be accompanied by a document describing programme operation. The document should contain the essentials of systems operation and any other instructions required because of the particular programme or character of maintenance organization involved.

B. The AOC holder should submit the maintenance reliability programme and standard for determining time limitations to be included in the Maintenance Operations Specifications, Part D. It is not necessary to enter the entire document in the OpsSpecs, Part D. Due to the differences encountered in the programmes submitted for approval, the OpsSpecs will vary somewhat from operator to operator.

C. An attempt should be made to list all the important elements that should be considered regardless of the programme being evaluated. It is recognized that all of the elements may not apply to a particular programme; however, the Airworthiness Inspector should use those that are appropriate to the programme he is approving. Emphasis should be given to the elements entered in the OpsSpecs.

D. The procedures for implementing revisions to the programme should be described in sufficient detail to identify the isolated areas which require DAWS approval. The AOC holder should also identify the segment of his organization which has the overall responsibility for the approval of amendments to the programme. The areas involving programme revision which require DAWS approvals include:

(1) reliability measurement;

(2) changes involving performance standards, including instructions relating to the development of these standards;

(3) data collection analysis;

(4) data analysis methods and application to maintenance programme;

(5) procedures for adding or deleting systems/components; and

(6) procedures for transferring systems/components to other programmes.

E. When evaluating programme revision procedures consideration should also be given to the following:

(1) Does the programme provide for periodic review to determine if the established performance standard is still realistic or in need of recalculation?

(2) What distribution is given to approved revisions?

(3) Are the overhaul and inspection periods, work content, and rescheduled maintenance activities controlled by reliability methods reflected in the appropriate maintenance manuals?

5. **Reliability Programme Authorization**

A. The pages are used to authorize and control reliability programmes which generally fall into one of two categories:

(1) those which control the inspection, check and overhaul times for the entire airframe or power-plant; or

(2) those which control the inspection, check and overhaul time for complete systems or for individually specified items within the system.

B. In the case listed in A. above, the authorization listed on the page may serve as the sole control as far as the SOPs are concerned. When the entire airframe or power plant is governed by a reliability programme, there is no need to list individual items on the aircraft maintenance pages. However, the airframe or powerplant controlled by an approved programme must be adequately identified on the authorization page. (See Appendix A to this Circular for a sample Reliability Programme Authorization page.) In the case listed in b) above, where complete systems or selected individual items are controlled by a reliability programme, reference to the control programme must be made on the authorization page, specifically identifying the controlling document. Individual items must be further identified on the aircraft maintenance page on which they appear by an asterisk, control programme name or acronym, or other symbol. The identification marks and symbols used must be identified on an authorization page.

APPENDIX A

SPECIFIC OPERATING PROVISIONS PART D
XYZ AIRLINES
AUTHORIZATION PAGE
Reliability Programme Authorization
Douglas DC-XXX

XYZ Airlines is authorized to utilize the provisions of a maintenance reliability programme which contains the standards for determining maintenance intervals and processes.

The programme for these systems are described in and the standards are established in XYZ document (enters -name, number, and date).

The time limitations for the overhaul, inspection and checks of the aircraft and/or systems/components controlled by the programme are contained in XYZ Airlines DC-XXX Maintenance Manual.

1. The service time limits will be listed in the 5-2-0 section of the Maintenance Manual.
2. The component overhaul time limits and life limits will be listed in the 5-2-1 section of the Maintenance Manual.
3. The service item checks and scheduled maintenance tasks to be performed at routine service periods will be listed in the 5-2-2 section of the maintenance Manual.
4. The inspection and maintenance of aircraft structures will be listed in the 5-2-3 section of the Maintenance Manual.
5. The parts and sub-components not listed in the 5-2-1 section of the Maintenance Manual will be checked, inspected and/or overhauled at the same time limit specified for the components or assembly to which such components are related.

In the event the programme document referenced above is cancelled, the maintenance programme covered by said document will be completely re-evaluated and maintenance and overhaul time limits established by the CAA.

INSTITUTE OF CIVIL AVIATION OF MOZAMBIQUE

THE CHAIRMAN OF THE BOARD AND CEO

Capt. João Martins de Abreu