CHAPTER 12

R&M DESIGN CRITERIA

1. INTRODUCTION

This section is currently under development. However extracts have been reproduced here from DEF STAN 00-41/3 covering R&M Reliability and Maintainability Design Criteria.

1.1 Reliability Design Criteria

For additional guidance refer also to: Def Stan 00-40 (Part 1)(R&MP-1) Appendix A, Chapter 3.

1.2 Introduction to Reliability Design Criteria

The reliability of an item is determined by its design and the associated design, development and manufacturing processes. It is therefore important, during the early design phases of a project, that specific attention is paid to reliability and the effects of design decisions on reliability. This can be achieved by defining and implementing specific design criteria and guidelines.

2. Scope of Reliability Design Criteria

This section contains the following sub-sections:

(a) definition of design criteria;
(b) description of design criteria;
(c) implementation of design criteria.

3. Definition of Design Criteria

3.1 The contract or specification should include requirements which directly or indirectly define design criteria which may affect reliability. These documents should be reviewed and the relevant material extracted. In cases of ambiguity, the agreement of the purchaser should be sought and recorded.

3.2 Direct. Design guidelines, which define best practices derived from the experience gained in the development of items with proven reliability and performance are often specified. Similarly, the contract may require specified items to be used in the design, for example purchaser supplied equipment (PSE), and DEF CON 17 for electronic component selection may be specified.

3.3 Indirect. The specified reliability requirement may include factors which constrain the design solution, for example very high availability targets may necessitate the use of redundancy; if space permits. Similarly, operational and environmental conditions and parameters in which the equipment is expected to achieve its stated reliability may necessitate specific protection measures to be adopted, for example, the exclusion of moisture, tolerance to vibration and

excessive temperature. The design staff can only cater for all of these conditions and parameters if they have an intimate knowledge of the purchaser's requirement and the way the equipment will be used, both in war and peace.

4. Description of Design Criteria

4.1 There are various factors which should be considered when generating design criteria and guidelines. Some of the more common factors are identified and outlined below.

4.1.1 Modular construction. Many items can be designed using a limited number of basic design b locks or modules. These individual modules may also be used in other items with completely different overall functions; these are often known as common modules. This has the advantage that design effort to maximise the reliability of these modules is compounded across all of the uses of these modules either within a specific item or a number of different items. Common modules should be designed to perform in the worst case environment.

4.1.2 Parts selection and control. Reliability characteristics may vary between different parts, and the quality control procedures used in their manufacture and selection can determine their ultimate reliability. Design criteria can therefore be used to restrict, where practicably possible, the use of parts known to be unreliable and impose minimum acceptable quality standards in order to achieve the required reliability.

4.1.3 Off-the-shelf items. Items of proven reliability and compatible with the design and performance requirements need to be used wherever possible. This reduces the risk associated with an item and increases the assurance of meeting the reliability target. Alternatively, design features or parts with a known reliability problem should not be used, or if they are, account of this should be taken when setting reliability targets and planning development activities. (Refer to Def Stan 00-40 (Part 8) (R&MP-8)).

4.1.4 Stress derating. It is generally accepted that the reliability of electronic components is inversely related to the ratio of the applied stress to the rated stress. Therefore, the lower the ratio of the applied stress to the rated stress the higher the expected reliability. The relationship between the derating ratio and the reliability is not linear, and threshold values exist which if exceeded reduce reliability. Within practical limits all components should be used at stress levels below their rated values. (Ref to Part C, Chapter 7)

4.1.5 Design simplification. Item reliability is generally accepted to be inversely related to the number of constituent parts, interfaces and fixings in the design, ie its complexity. Wherever possible, the number of discreet components should be as low as possible, consistent with the achievement of the required performance and other characteristics. This philosophy is applicable to all types of items; mechanical, electromechanical, electrical, electronic and software.

4.1.6 Sensitivity analysis. All designs should be subjected to a sensitivity analysis covering the extreme range of tolerances, transient loading effects and other environmental factors, to ensure that the design is robust and can tolerate all of these likely variations. The stage at which a sensitivity analysis is applied to an item's design depends on its size, complexity and function, but generally all functions and sub-systems in the whole item should be subjected to this type of assessment.

4.1.7 Environmental control. Extremes of internal and external environmental factors such as moisture, vibration, shock, etc are known to degrade the reliability of an item. It is therefore necessary, in some cases, to design in mechanisms to specifically control and/or protect the item

from these extremes. Typical examples include anti-vibration mounts, cooling systems, air conditioning, sealing, etc.

4.1.8 Failure tolerant techniques. An item should be designed that any single Failure does not cause the complete loss of the item's function. Items should be designed to ensure that, wherever possible, successive single failures cause the gradual degradation of the item's capability and performance.

4.1.9 Redundancy. High levels of availability/reliability can be achieved by the use of redundancy and it may be necessary to apply considered use of redundancy to achieve the required levels of reliability. However, the consequences of redundancy in terms of complexity, weight, space, price etc need to be fully assessed and justified at an early stage in the design of an item.

4.1.10 Factors of Safety. The consideration of the reliability and life of non-electronic items is included in the Factor of Safety used in the design. This concept is not dissimilar to the derating of electronic components to achieve a higher reliability, although the relationship between reliability and the Factor of Safety is not easily defined. Past experience and engineering judgement need to be used to define the appropriate Factor of Safety for the item being designed.

4.1.11 Materials compatibility. Material compatibility should be considered at the design stage to ensure that reliability and maintainability are not adversely affected by the use of incompatible materials. For example, corrosion caused by two dissimilar metals in contact can cause failure and/or hinder maintenance etc. Guidance is available in Defence Standards and from MOD Departments.

5. Implementation of Design Criteria

5.1 Design criteria should be developed, agreed and specified in conjunction with the relevant design team or organisation.

5.2 The implementation of these criteria is the responsibility of the chief designer and his team, supported by the reliability engineers. The reliability engineers will mainly be involved in auditing and assessing the compliance of the design with these criteria using functional diagrams, design reviews etc. In addition, the reliability engineers will be required to evaluate concessions requested by the design team.

5.3 The review and audit process should continue throughout the design and development process including the review and updating of the specified design criteria as necessary.

5.4 The employment of suitably skilled and experienced engineers and design staff in and during the development process, and their relationship with the reliability engineering staff, will assist in the achievement of the reliability targets of the project. The employment of suitably skilled or experienced staff will also assist in the development and use of the design criteria.

5.5 Consideration should also be given to providing the design team with checklists using these design criteria to assist inexperienced design personnel.

5.6 Design checklists. A design checklist is a list of questions which addresses the essential design features of an item. A design checklist can be compiled for a variety of reasons but a reliability design checklist will address particular points which are known to affect reliability. The design checklist will be used by the design and reliability engineering staff in their audits

and assessments of the design against the agreed criteria. Any discrepancies will need to be modified before the design can be accepted. A typical design checklist will consider, but is not limited to, the following items:

(a) requirement;
(b) design specification;
(c) environmental requirements;
(d) engineering practices and procedures;
(e) engineering standards;
(f) operating profile;
(g) handling and deployment;
(h) maintainability and testability;
(i) novel features;
(j) producibility.

5.6.1 Design checklists should be compiled as early as possible in the design phase, and used as often as possible. It should be remembered that like many other reliability engineering activities the use of a design checklist will not change the reliability of an item. The reliability will only be improved if changes to the design are implemented as a result of the design errors found during the use of the checklist.

6. Maintainability Design Criteria

For additional guidance refer also to: Def Stan 00-40 (Part 1)(R&MP-1) Appendix A, Chapter 3.

6.1 Introduction to Maintainability Design Criteria

The promptness and ease with which an item can be returned to a usable condition after failure, together with the minimisation of time taken for preventive maintenance, is an important design characteristic. Ease of maintenance can be achieved by defining and implementing specific design guidelines and criteria.

7. Scope of Maintainability Design Criteria

This section addresses the following:
(a) definition of design criteria;
(b) description of design criteria;
(c) implementation of design criteria.

8. Definition of Design Criteria

8.1 The maintenance philosophy to be adopted should be defined in the specification and agreed with the user. This maintenance philosophy should be, wherever possible, consistent with normal practice for the Service and take into account the operational constraints imposed by the type of mission and support requirements. For example, due to the extreme shortage of space available on a ship, together with the potentially large distances from support facilities, the management of manpower, equipment and spares must be optimised. This is to ensure that few potential faults or failures are unrecoverable using available resources and necessitating a large operational/time penalty whilst a remedy is effected.

8.2 The contract or specification should include requirements which directly or indirectly define design criteria which may affect maintainability.

8.3 Direct. Design guidelines, which define best practices derived from experience gained in the development of items with proven maintainability are often specified.

8.4 Indirect. The specified maintainability requirement may include factors which constrain the design solution; for example, very high availability targets may necessitate the use of redundancy if space permits and this may affect the ability to maintain the item or increase preventive maintenance times. Similarly, operational and environmental conditions in which the equipment is expected to operate may necessitate the adoption of specific protection measures such as the exclusion of moisture or tolerance of vibration and excessive temperature; all of which may have a significant effect on the maintainability of the item.

9. Description of Design Criteria

9.1 There are various factors which should be considered when generating design criteria and guidelines. Some of the more common factors are identified and outlined below.

9.1.1 Accessibility. The ease of access, under in-Service conditions, to the components or sub-systems of an item is essential for fault diagnosis and subsequent replacement, repair and testing prior to returning the item to Service. Access should take account of the special support equipment necessary to diagnose, repair or extract/ replace the parts as necessary.

9.1.2 Interchangeability. Interchangeability assists maintenance and logistic support by ensuring that design attention is concentrated on the maintainability characteristics of all parts/modules; including standard parts. With interchangeability there will be additional benefits of better spares scaling in the logistic support loop.

9.1.3 Special tools. All items should be designed to be maintained using standard in-Service tools and test equipment. These should be defined early in the design phase and agreed with the purchaser. Any additional tools and test equipment should be fully justified and agreed with the relevant purchaser authority.

9.1.4 Proven parts. Items with a known operational capability should be used since their maintainability characteristics are understood and are usually documented and defined, thereby easing the design process. These items may already be in-Service and a support facility may exist for them.

9.1.5 Access panels. Items protected from the environment should have adequate access panels for testing, repair and/or removal purposes. These panels should be easily removable and, where applicable, be attached with quick-release fasteners. In all cases, care should be taken to ensure that the fasteners cannot be lost. Guidance may be found in Defence Standards.

9.1.6 Handling. Replaceable items should be designed with adequate attachments to aid fitting, removal/replacement, handling and transportation. These attachments should be suitable for use at all stages of the manufacture and repair cycle. The packaging of items should also be considered, although this may not be the sole responsibility of the equipment designers.

9.1.7 Locking devices. Where items require the use of positive locking for retention, the use of wire-locking is the least preferred method. Where its use cannot be avoided, it shall be fully justified and authorised prior to inclusion as part of a design. Other positive locking devices, including self-retaining fasteners, are more appropriate and should be used wherever practicable.

9.1.8 Protective clothing. Some items may be used in an environment requiring the use of special protective clothing, such as NBC (nuclear, biological, chemical) or for extreme climatic conditions. Where this is a design requirement, maintenance actions should be capable of being carried out without the need to remove this clothing or to use special tools. The relevant purchaser authority should be included in the formulation of any such design criteria.

9.1.9 Maintenance test interfaces. Maintenance interfaces should be considered for injecting test inputs, state indications, diagnostic facilities independence of items for maintenance from other operating items, standardisation and general compatibility of design with maintenance strategy.

9.1.10 Built-in Test (Equipment) BIT(E). Guidelines on the application of BIT, fault detection and identification are given in “Guidelines for the Design and Assessment of BIT in MOD Projects", a CODERM Interim Position Paper IPP 90/1 - which is planned to be revised and reissued in Defence Standard format.

9.1.11 Maintenance skills. The available maintenance personnel and skill levels are fundamental design parameters. These should be clearly defined and considered at the earliest stages of the design process and drawn to the attention of all design staff. Exceptionally, additional skills or training may be required and these should be fully justified and agreed with the purchaser before being implemented.

10. Testability of replaceable items

10.1 In cases of suspected failure, it will be necessary to diagnose faults found in operational items at lower levels in the maintenance structure. Consideration should therefore be given to the ease of testing these items when removed from the operational item.

10.2 The descriptions of the facilities available for testing and repair at each level of repair should be made available to the design team, and all additional requirements generated by the new equipment should be fully justified.

11. Inherent maintainability characteristics

11.1 The need for items requiring regular preventive maintenance should be minimised. Items requiring a minimum of preventive maintenance should be used in preference where they meet operational and performance requirements. Condition-based maintenance could be an important design criterion, with regard to the maintenance strategy.

11.2 The maintenance of some items may pose a safety hazard. The requirement for such tasks should be avoided and where this is not possible, all associated hazards need to be clearly identified and marked.

11.3 Simplification. To aid maintainability, the design of an item should be kept as simple as practicable. A reduction in the number of parts and fasteners used in a design is likely, in most cases, to enhance the maintainability characteristics of that item.

12. Implementation of design criteria

12.1 Design criteria should be developed, agreed and specified in conjunction with the relevant design team or organisation. At the earliest stage there should be an agreement between the purchaser and contractor about the application and scaling of spare parts and how the logistic

support chain is to be structured for the item under development. Maintainability demonstrations may be used as a contractual requirement (Def Stan 00-43 (Part 2)).

12.2 The implementation of these criteria is the responsibility of the chief designer and his team, supported by the maintainability engineers. The maintainability engineers will mainly be involved in auditing and assessing the compliance of the design with these criteria. In addition, the maintainability engineers will be required to agree concessions requested by the design team.

12.3 The review and audit process should continue throughout the design and development process, including the review and updating of the specified design criteria as necessary. These reviews should also include all manuals, maintenance aids and tools as they become available.

12.4 The employment of suitably skilled and experienced engineers and design staff in the design process, and their relationship with the maintainability activities, will assist in the achievement of the maintainability targets of the project. They also aid the development and use of the design criteria.

12.5 Consideration should also be given to providing the design team with a maintainability checklist using these design criteria to assist inexperienced design personnel. Checklists should also be used by the maintainability engineers to aid their audits and assessments of designs.