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**Title:** CPCP for Safe Life Items

**Submitter:** EASA, MRB Section

**Issue:** A Corrosion Prevention and Control Programme (CPCP) is required for all primary aircraft structure and currently developed during the MRB process. Recently there have been some issues with CPCP tasks for non damage-tolerant (i.e. safe life) items, indicating that the current MSG-3 wording may require improvement.

**Problem:** The following bullets do summarize the Problem:

- Corroded metallic items will fail earlier due to fatigue than uncorroded items.
- Fail-Safe Items are usually tested and certified for a service life of the uncorroded item or a certain limited level of corrosion.
- Documented in-service experience shows that fatigue failure of Safe Life Items, caused by premature crack initiation due to corrosion, is still an issue
- This is partly an economic issue, but mostly a safety issue
- Unless the design of the aircraft does reliably prevent corrosion, maintenance has to limit corrosion to a level which does not interfere with the certified life of the part.
- EASA regulation does require to control corrosion also for safe-life parts which are likely to be affected by corrosion
- As the current regulation and older maintenance related documents do mention: only the **combination of inspections and discard** will allow to apply the safe-life philosophy :
  The life limit takes care of discarding an item before it develops FD
  Inspections for AD/ED/CPCP take care that the condition of the item is in line with the assumptions used when determining the life limit
- Normally the MSG-3 Structures Analysis Procedure (Chapter 2-4) should cover all this.

However, there are still current MRBR existing where this has not been fully taken into account, there are safe life items with a documented history of corrosion issues and/or premature failure which are not adequately analyzed and not adequately covered by ED/CPCP tasks.

This illustrates the need for improvement.

**Details:** **Basic Material Properties**

The crack initiation of metals due to repetative, cyclic loading (also called fatigue) is highly influenced by the surface condition of the loaded part. Especially corrosion pits can cause local stress peaks and initiate cracks. The fatigue life of metalic items is significantly reduced, if they corrode.

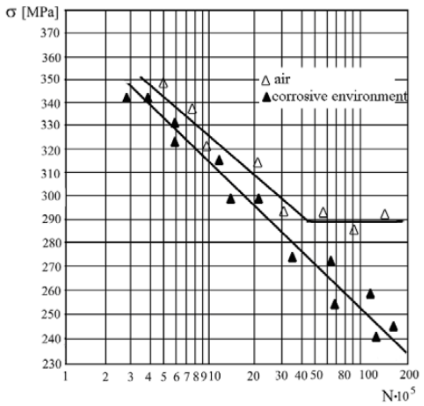



Fig. 2. Fatigue curves in laboratory atmosphere and corrosive environment.

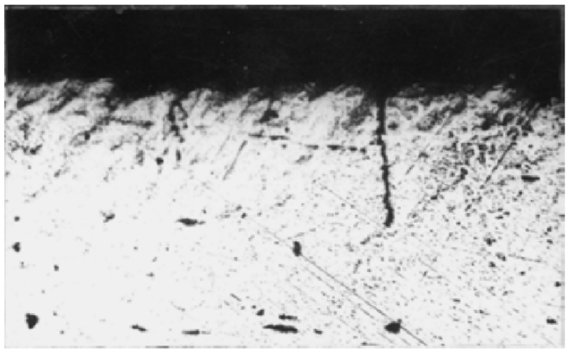


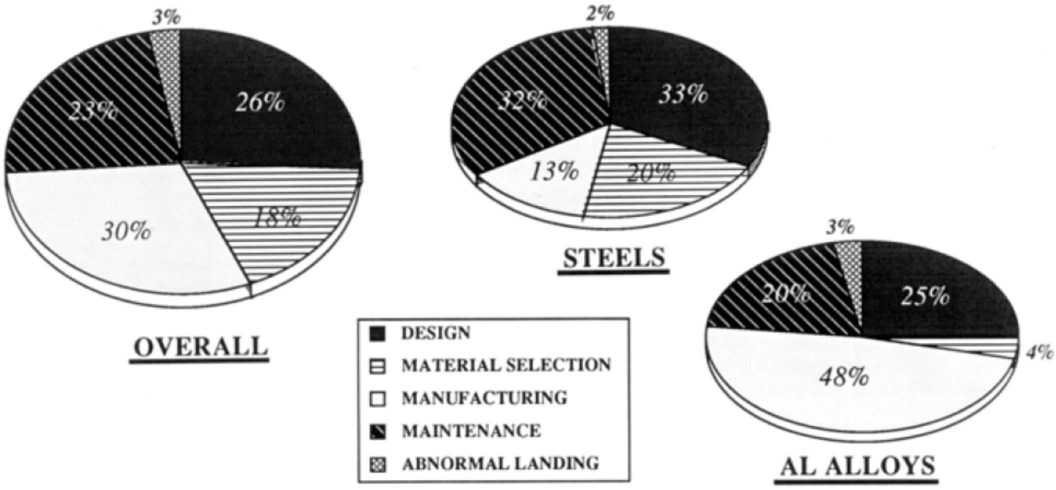
Fig. 3. Corrosion pits and starting cracks in the specimens section.

**Service Experience**

Documented issues with premature failure of Safe Life structural items due to corrosion do exist in large numbers, Scientific Studies, Accident/Incident Reports, Service Bulletins and Airworthiness Directives do demonstrate that corrosion control for safe life items is an important issue.

Appendix 10: Corrosion pit (tilted) Photos (2): IfW

This picture from an accident investigation shows a cracked Landing Gear Bogey (Safe Life Item), the crack originated from uncontrolled corrosion on the inner diameter.
(upper surface is crack, lower is cut to obtain the specimen)




Distribution of landing gear failures in the Canadian Air Force during 20 years (from: First International Conference on Failure Analysis, ASM International, 1992)
Practically all Maintenance related failures of steel parts (which are typically Safe Life design and make 32% of the failures) are due to lack of corrosion control and subsequent premature fatigue failure.

An example from a recent EASA Airworthiness directive is worded "*In some instances, **corrosion pits caused the cracking** of the forward lug (sometimes through its complete thickness). If not detected, the **cracking may lead to the complete failure** of the fitting and thus could affect the structural integrity*", illustrating that not controlling corrosion on safe life items could lead to an unsafe condition.

Another EASA Airworthiness directive is even more detailed on the same issue :

> *(7) If, during any inspection as required by paragraph (5) or (6) of this AD, as applicable, the chromium plating on the outer diameter of any pin is found cracked, or the base material is exposed, or **any corrosion is found on the chromium plating on the outer diameter** of any pin, before next flight, replace the pin with a serviceable pin in accordance with the instructions of paragraph [...]*
>
> *(8) Replacement of a pin, as required by paragraph (7) of this AD, does not constitute terminating action for the **repetitive inspections required** by paragraph (6) of this AD.*

This additionally illustrates that replacing a part with a new one, does not mean that it will perform better than the old one, it still requires to be inspected for condition during its service life to timely detect damage (e.g. corrosion, wear, accidental damage) which would reduce the fatigue life of the item.

**Current Regulation / Guidance**

The latest Revision 12 of EASA CS-25 does state:

> *FATIGUE (SAFE-LIFE) EVALUATION, General:*
>
> *The evaluation of structure under the following fatigue (safe-life) strength evaluation methods is intended to ensure that catastrophic fatigue failure, as a result of the repeated loads of variable magnitude expected in service, will be avoided throughout the structure's operational life. Under these methods the fatigue life of the structure should be determined. The evaluation should include [...] evaluating the **possibility of fatigue initiation from sources such as corrosion, stress corrosion**, disbonding, accidental damage and manufacturing defects based on a **review of the design**, quality control and **past service experience**; and Providing necessary **maintenance programmes and replacement times** to the operators.*

EASA general acceptable means of compliance for airworthiness of products, parts and appliances clearly states:

> *Note: The certification philosophy for safe-life items under CS 25.571 neccessitates no further investigation under ageing aircraft programmes that would provide damage tolerance based inspections. However, **this does not exclude safe-life items such as landing gear from the CPCP** and SB Review or from re-assessment of their safe-life if the aircraft usage or structural loading is known to have changed.*

Appendix 4 to EASA AMC 20-20 does detail some definitions with respect to CPCP, especially:

> ***Level 1 corrosion** is:*
> *(1) Corrosion, occurring between successive corrosion inspection tasks that is local and **can be reworked or blended out within the allowable limit**; or*
> *(2) Corrosion damage that is local and exceeds the allowable limit, but can be attributed to an event not typical of operator's usage of other aircraft in the same fleet (e.g. mercury spill);*

and in contrast

> ***Level 2 corrosion** is that corrosion occurring between any two successive corrosion inspections task that requires a single rework or blend out which exceeds the allowable limit.*
> *[...]*
> *A finding of Level 2 corrosion **requires repair**, reinforcement, or **complete or partial replacement** of the applicable structure.*

AMC 20-20 does as well state that the CPCP "*addresses all corrosion likely to affect Primary Structure*", which in turn means that items which are not likely to be affected by corrosion (i.e. their resistance to the environment is high enough and/or the protection from the environment is good enough to prevent corrosion) do not need to be covered by the CPCP.
So if *review of the design and past service experience* do show, that corrosion will not likely affect certain items, no CPCP is required.
This again applies independent of the damage tolerant or safe-life concept.

According to EASA 21.A.435(a) and GM 21.A.435(a), a repair to a life limited (=Safe Life) part always is a major repair, the same applies to any repair which "*requires a permanent additional inspection to the approved maintenance programme, necessary to ensure the continued airworthiness of the product.*".
So unless a manufacturer can provide allowable corrosion limits for safe life items, any corrosion will be level 2 corrosion. For many safe life items there are currently no allowable limits defined, so the CPCP has to be basically a corrosion prevention program.

**Maintenance Development Guidance**

Already the basic document for Reliability-centered Maintenance clearly identified in 1978 how Safe-Life Items need to be maintained.
Although today we do no longer apply the systems logic to develop structures tasks, and the numbers stated might no longer be applicable today due to significant improvement of the corrosion properties of modern alloys and protection systems, the basic facts are still valid today:

> ***There should be 20 to 30 inspections before the expected appearance of a fatigue crack*** *on the most significant items. [although there may be as few as five for those of least significance.] Such inspections not only protect the structure from the effects of incipient corrosion and accidental damage, but also make it possible to confirm that the design fatigue life has in fact been achieved.*
>
> ***Safe-life items must also be inspected to find and correct any deterioration that could prevent attainment of the safe-life limit.*** *The ratings for corrosion and susceptibility to accidental damage will provide rankings for the relative intensity of such inspections,*

Task development according to the RCM report:

4. *Is an on-condition task to detect potential failures both applicable and effective?*

*For safe-life items the answer to question 4 is no. Although the initiation of a fatigue crack can still be defined as potential failure, unless its propagation characteristics meet damage-tolerant load requirements, we cannot rely on on-condition inspections to prevent fatigue failures.*
***Such inspections are applicable to detect corrosion and accidental damage, which can greatly shorten fatigue life, but since they will not prevent all functional failures, we must look for other tasks***

5. *Is a discard task to avoid failures or reduce the failure rate both applicable and effective?*

*A safe-life limit is based on the fatigue life of the item, as established during developmental testing. However,* ***since corrosion and damage can affect that life, these factors may prevent a structural element from reaching the safe-life age*** *established on the basis of testing in a less hostile environment.* ***Consequently we cannot conclude that a safe-life discard task alone will satisfy the criterion for effectiveness in preventing critical failures****, and the answer to this question is no.*

6. *Is a combination of preventive tasks both applicable and effective?*

*Both on-condition and discard tasks are applicable, and* ***a combination of the two meets the effectiveness requirements. The*** *[on-condition]* ***inspections ensure that the item will reach its safe-life limit, and the discard task ensures that it will be removed from service before a fatigue failure occurs.***

Some more remarks for Safe-Life structures:

*Note that an analysis of any one of the functions listed in Section 9.1 would follow the same path and lead to the same outcomes: on-condition inspections for damage-tolerant items and on-condition* ***inspections plus discard at the safe-life limit for safe-life items.***

***The safe-life limits are effective only if nothing prevents the item from reaching them, and in the case of structural items there are two factors that introduce this possibility: corrosion and accidental damage. Both factors reduce the expected fatigue life from that for an undamaged part.***

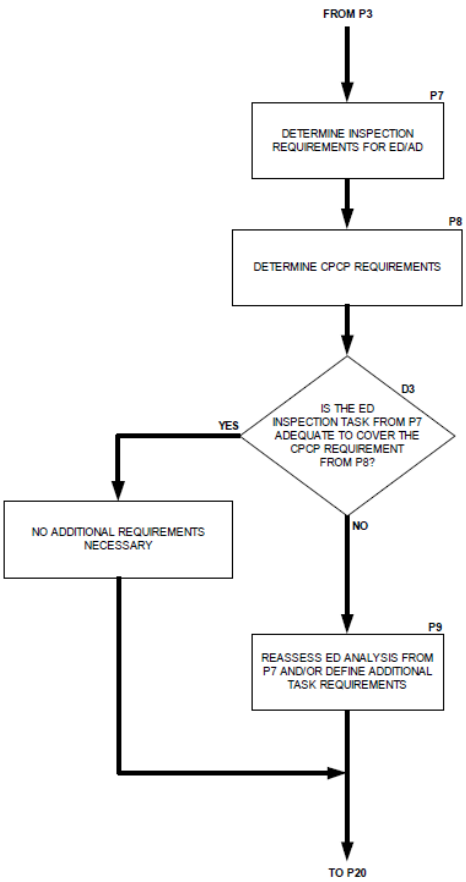
All these statements do still fully apply.

**MSG-3**

The MSG-3 ED/AD/CPCP analysis should normally include "*evaluating the possibility of fatigue initiation from sources such as corrosion, stress corrosion, disbonding, accidental damage and manufacturing defects based on a review of the design, [...] and past service experience; and providing necessary maintenance programmes*", so it will meet the 25.571 requirement.

- The *sensitivity to relative size of damage* rating does allow to take into account the size of damage which will give a *possibility of fatigue initiation.*
- The *Susceptibility to corrosion* rating does allow to take into account "*manufacturer and operator experience with similar aircraft structure*" and "*relevant design features e.g. choice of material, assembly process, corrosion protection systems, galley and toilet design etc.*"
- The ED ratings will be selected according to the design of the aircraft ("*review of the design*",P7), the CPCP requirement will be taking into account the *past service experience.* (P8)

Figure 2-4-4.3. Accidental Damage and Environmental Deterioration (Metallic) Logic Diagram



Step P8, related to procedure step h, taking into account the CPCP information of paragraph 2-4-2.5 and related detinitions in the glossary should normally clearly describe what a *CPCP requirement* should do.
The wording "*The program is expected to allow control of the corrosion on the aircraft to Corrosion Level 1 or better*." should make clear that any level of corrosion which interferes with the safe life limit, and therefore requires a major repair or a replacement of the item, is Level 2 corrosion and indicates that the CPCP is not controlling corrosion to the desired level.
So the CPCP requirement determined under P8 should allow to control corrosion to a level which does correspond to the assumptions made during the Safe-Life evaluation and does not reduce the service life of the item.

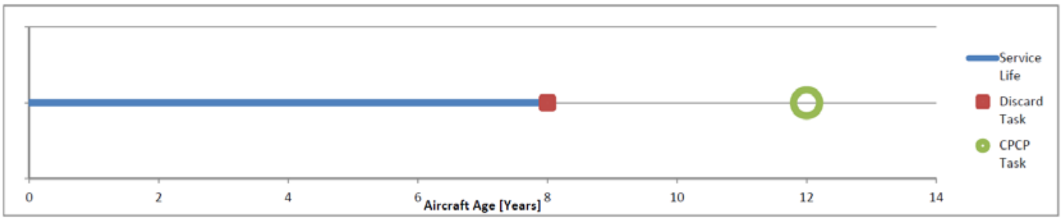
Decision box D3 should normally be quite clear, a task scheduled after the life of an item can hardly be found to "*adequately cover the CPCP requirement*", however this box has frequently answered "Yes" even for ED tasks which will never be performed.
So even if the ED analysis following the rating system should result in a *ED inspection task* at an interval higher than the safe life, this still needs to be reviewed against the *CPCP requirement*, hence additional requirements and/or a reassessment of the ED task might be required.

For items from corrosion resistant material or with a protection system which will most likely prevent corrosion to start before the life limit of the item (based on past in-service experience), no CPCP task is required as corrosion is not "*likely to affect*" the item.
*To verify the aircraft's resistance to corrosion deterioration* an age exploration program may be required to confirm that corrosion is indeed not "*likely to affect*" the Safe Life of the item.

**Illustration of Discard/CPCP task combinations**

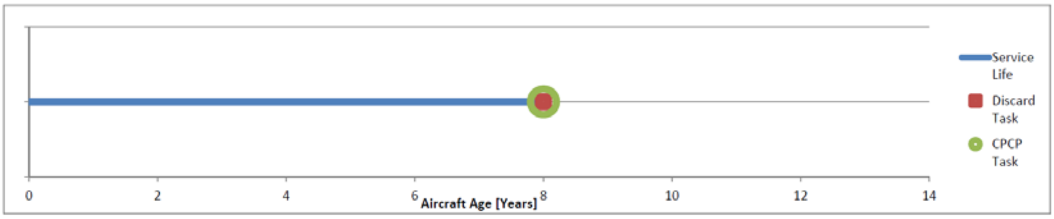
The following charts should illustrate how certain combinations of discard tasks (to prevent FD for Safe-Life items) and CPCP tasks (e.g. inspections, CIC application etc.) will be effectively performen

Case 1: CPCP task initial Interval is **higher** than Life-Limit




It is quite obvious that a CPCP task with an initial interval higher than the discard limit, will only be listed in the MRBR and never be performed on the aircraft, hence it will not be effective to control corrosion to level 1 and therefore not be adequate to cover the CPCP requirement.
Nevertheless such CPCP tasks do exist today illustrating the need for more guidance in MSG-3.

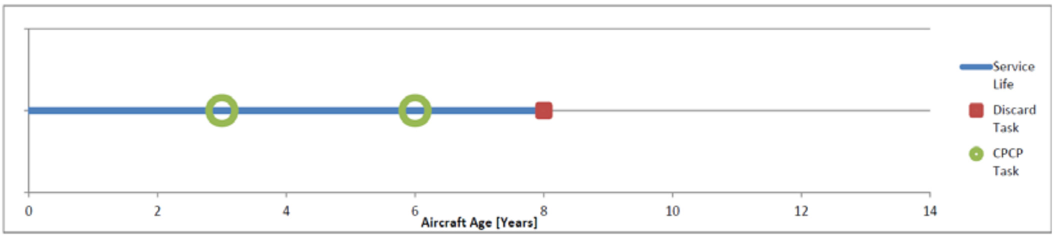
Case 2: CPCP task initial Interval is **the same** as the Life-Limit




Performing a CPCP task at discard (which can then only be an inspection, as it would for example make no sense to apply a corrosion preventing compond or a water repeeling fluid at discard) can be compared with tasks like an Operational Check of an emergency slide:
This task will not have any effect on the actual item, the reliability or safety of that specific item will not be improved, hence formally such task can never be "effective" according to the MSG-3 logic.
However, by learning about the condition of the item at the end of its life allows to react and to maintain the new item or other items in the fleet in a different way to improve its life.

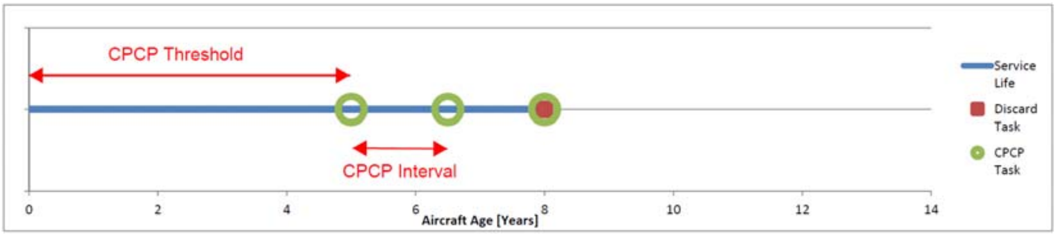
So although an CPCP inspection during discard will not be effective to control corrosion on the inspected item, it will allow to control corrosion in the operators fleet as the condition of the item found will help to react for the other aircraft of the fleet.
If for example an horizontal stabilizer pivot bolt is found corroded at discard, the new one might be installed with an corrosion preventing compound to improve its resistance which has proven inadequate before, or a lower interval for the greasing task of that joint may be introduced to reduce corrosion in the future.

Case 3: CPCP task Interval is **lower** than the Life-Limit



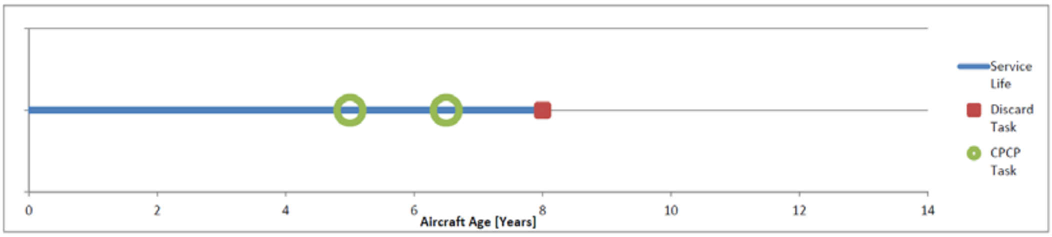

The normal way of controlling corrosion on a safe life item during its service life should be the same as for damage tolerant items: to perform several CPCP tasks throughout the service life of the part, which in this case means to perform several CPCP tasks before the discard of the item.
Each operator will adapt the interval according to his findings, and may eventually even delete the task if it has been proven that it is not required.

Case 4: CPCP task Interval (initial and repeat) are **lower** than the Life-Limit



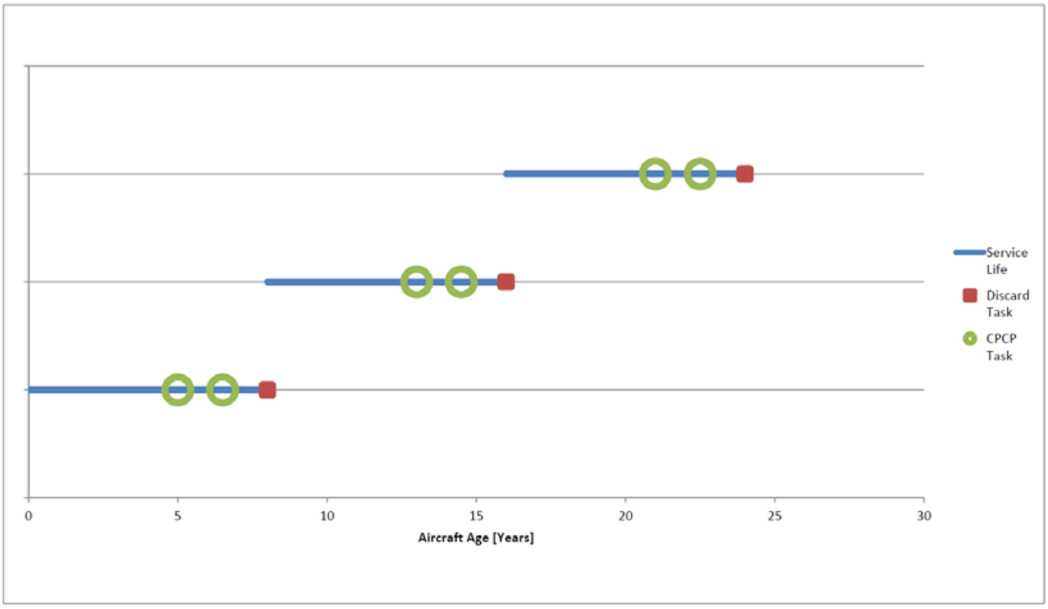

As already stated in the MSG-3 glossary, CPCP is *a program of maintenance tasks* ***implemented at a threshold*** *designed to control an aircraft structure to Corrosion Level 1 or better,* hence a CPCP threshold can be applied to Safe Life items as well with the threshold counted from the start of the service life of that item.

Case 4a: CPCP task Interval **lower** than the Life-Limit




If one CPCP task is due at the same time as the discard, it may be understood as being superseded by the discard task, if previous CPCP tasks did already demonstrate that corrosion is under control.
This may be supported by an age exploration program inspecting a limited number of items at discard.

On Aircraft Level




As the discard task replaces the according item by a new one with a new protection system, the CPCP threshold becomes applicable for the new items installed after each discard.

If the ED analysis and in-service experience with items of similar design, material, protection, operational environment and utilization does support a CPCP threshold beyond the Safe Life discard limit, no CPCP may be required.
However, "*An age exploration program may be desirable to verify the aircraft's resistance to corrosion deterioration before the Corrosion Prevention and Control Program Task Thresholds"* as mentioned in MSG-3. For Safe Life items this might be performed through sampling inspections at discard of such items.

**Recommendation (including Implementation):**

Basically the MSG-3 wording does address the issue, so no major change is required.

However, experience with existing MRBR shows that a little more guidance might be required to clarify

- That the CPCP has to cover all metallic SSI, damage tolerant and safe-life
- That even if no MRB task is required for safe-life items to detect FD, ED/AD/CPCP tasks might be required to prevent FD prior to the certified safe-life limit.
  (prevent premature crack initiation not covered by the certification tests)
- That a CPCP threshold beyond the safe life does not allow to control corrosion, because the task will never be performed.
  However if justified by an according ED analysis supported by in-service experience, such thresholds may be acceptable, meaning corrosion is prevented by timely discard before the protection system has broken down, but should be supported by an age-exploration (sampling) program.

EASA proposes to add 4 sentences / remarks to the MSG-3 Structures Chapter.

Note: The wording proposed for paragraph 2-4-2.6 "*prevents the items to reach their safe-life age*" and paragraph 2-4-4.1 bullet q. "*ensure that the item will reach its safe-life limit*" are taken from the RCM Nowlan-Heap Report.

# 4. Fatigue Related Sampling Inspections

Transport aircraft with the highest number of flight cycles are most susceptible to initial fatigue cracking in the fleet. This means that adequate inspections on such aircraft will provide the greatest benefits for timely detection of fatigue damage. Such sampling inspections are developed on the basis of appropriate statistical variables, including:

a. The number of aircraft inspected.

b. The inspection methods and repeat intervals.

c. The number of flight cycles completed.

A list of SSIs that are suitable for a fatigue related sampling inspections will be established by the Structures Working Group and submitted to the Industry Steering Committee for approval and inclusion in the MRB report proposal. Full details of the fatigue related sampling inspections will be established by a joint operator/ manufacturer task force, based on the manufacturer's technical evaluations, prior to aircraft exceeding the fatigue damage threshold(s).

# 5. Corrosion Prevention and Control Programs (CPCP)

A Corrosion Prevention and Control Program should be established to maintain the aircraft's resistance to corrosion as a result of systematic (e.g. age related) deterioration through chemical and/or environmental interaction. This Program applies to damage tolerant and safe-life structures.

The program is expected to allow control of the corrosion on the aircraft to **Corrosion Level 1** or better. The CPCP should be based on the ED analysis, assuming an aircraft operated in a typical environment. If corrosion is found to exceed Level 1 at any inspection time, the corrosion control program for the affected area must be reviewed by the operator with the objective to ensure Corrosion Level 1 or better.

# 6. Age Exploration Program

An age exploration program may be desirable to verify the aircraft's resistance to corrosion deterioration before the Corrosion Prevention and Control Program Task Thresholds.
For Safe-Life items with a life limit below the CPCP Threshold, an age exploration program may be necessary to verify that no premature crack initiation due to corrosion prevents the items to reach their safe-life age.

To improve on the specific task intervals for non-metallic significant structure, an age exploration program may be desirable to verify the rate of structural deterioration.

Guidelines for age exploration should be established by the Structures Working Group and submitted to the Industry Steering Committee for approval and inclusion in the scheduled structural maintenance tasks and intervals.

# 7. Zonal Inspections

Some parts of the inspection requirements for SSIs and most of the items categorized as Other Structure can be provided by the zonal inspections (Ref. [Section 2-5]).

Tasks and intervals included in the zonal inspections should be based on operator and manufacturer experience with similar structure. For structure containing new materials and/or construction concepts, tasks and intervals may be established based on assessment of the manufacturer's recommendations.

# 1. Procedure

The procedure for developing structural maintenance tasks is shown in the logic diagram (Ref. [Figure 2-4-4.1]) and described by a series of process steps (P1, P2, P3, etc.) and decision steps (D1, D2, D3, etc.) as follows:

a. The structural maintenance analysis is to be applied to all aircraft structure which is divided into zones or areas (P1) and structural items (P2) by the manufacturer.

b. The manufacturer categorizes each item as structurally significant (SSI) or Other Structure, on the basis of the consequences to aircraft safety of item failure or malfunction (D1).

c. The same procedure is repeated until all structural items have been categorized.

d. Items categorized as Structural Significant Item (SSI) (P3) are listed as SSI's. They are to be categorized as safe-life or damage-tolerant (D5), and are additionally subjected to AD/ED/CPCP analysis (either as metallic or non-metallic structure).

e. Items categorized as Other Structure (P4) are compared to similar items on existing aircraft (D2). Maintenance recommendations are developed by the Structures Working Group (SWG) for items which are similar and by the manufacturer for those which are not, e. g., new materials or design concepts (P5). All tasks selected by the SWG (P6) are included in the scheduled structural maintenance (P20).

f. The manufacturer must consider two types of AD/ED analysis; for metallic structure (P7-P9) and for non-metallic structure (P10-P14). Each SSI may consist of one or the other, or both.

g. Inspection requirements for timely detection of Accidental Damage (AD) and Environmental Deterioration (ED) are determined for all metallic SSIs (P7). These can be determined for individual SSIs or groups of SSIs which are suitable for comparative assessments on the basis of their location, boundaries, inspection access, analysis breakdown, etc. The manufacturer's rating systems (Ref. [Subject 2-4-5]) are used to determine these requirements. The manufacturer may propose a validated S-SHM application(s) as long as it satisfies the detection requirement(s).

h. For each SSI containing metallic structure (damage tolerant or safe-life), the maintenance requirements are determined (P8) such that the expectations of the CPCP (Ref. [Heading 2-4-2.5]) are fulfilled.

i. The inspection requirement of the ED analysis is compared with the requirement of the CPCP (D3). If they are similar or identical, the ED task will cover the CPCP requirement. If the CPCP task requirement is not met, the ED task has to be reviewed and/or additional and separate CPCP tasks have to be determined (P9).

j. The process (P7, P8, P9) is repeated until all metallic SSIs are examined.

k. Each SSI containing non-metallic structure is assessed as to its sensitivity to Accidental Damage (AD) or not (D4), on the basis of SSI location, frequency of exposure to the damage source, and location of damage site.

l. SSIs containing non-metallic structure classified as sensitive to Accidental Damage (AD), are assessed for frequency of exposure to each likely damage source and the likelihood of multiple occurrence (P10), and its impact on the Environmental Deterioration (ED) analysis (P11).

m. When applicable, AD impact on the ED analysis is considered when the SSI is assessed for sensitivity to structural composition (P12) and sensitivity to the environment (P13), considering the material type.

n. Inspection requirements for timely detection of damage (e.g., delamination and disbonding) are determined for all SSIs containing non-metallic structure (P14). The manufacturer's rating systems (Ref.[Subject 2-4-5]) are used to determine these requirements. The manufacturer may propose a validated S-SHM application(s) as long as it satisfies the detection requirement(s).

o. All tasks resulting from AD/ED analysis ([Figure 2-4-4.3] and/or [Figure 2-4-4.4]), selected by the SWG, are included in the structural maintenance (P20).

p. The manufacturer categorizes each SSI as damage tolerant or safe-life (D5).

q. For each item categorized as safe-life, the manufacturer determines the safe-life limit (P15) which is included in the aircraft Airworthiness Limitations (P19). No fatigue related inspection is required to assure continuing airworthiness. However, AD/ED/CPCP tasks selected (P20) might be required to ensure that the item will reach its safe-life limit.

r. All remaining SSIs are damage tolerant and the manufacturer determines if timely detection of fatigue damage is dependent on scheduled inspections (P16). Scheduled fatigue related inspection may not be required for SSIs designed to carry the required load with damage that will be readily detectable during routine operation of the aircraft (D6).

*International Maintenance Review Board Policy Board (IMRBPB)*
*Issue Paper (IP)*

***Initial Date (DD/MMM/YYYY): 10/01/2013***
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| **IMRBPB Position:** |
| --- |
| **Date:**<br>**Position:** |

**Status of Issue Paper (when closed state the closure date):**

**Recommendation for implementation:**

**Important Note:** The IMRBPB positions are not policy. Positions become policy only when the policy is issued formally by the appropriate National Aviation Authority.