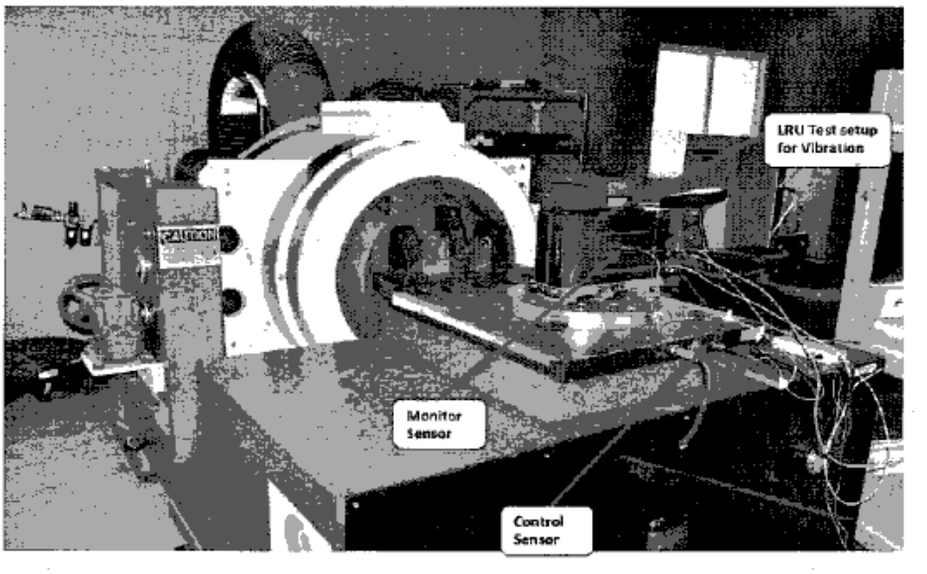
AQA DIRECTIVE ON ENVIRONMENTAL STRESS SCREENING (ESS)

Resonance test on Avionics LRU:



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PREFACE

Manufacturing of Modern Electronic hardware involves number of individual operations and processes that may results in ***inadvertent*** defects. Some patent defects can be detected through conventional Quality Assurance Processes (Visual & Functional Checks) whereas the latent defects (specially the ones that get introduced during the manufacturing processes) are detectable through Environmental Stress Screening (ESS). Inability to find the latent defects by obvious means is the consequence of the increased complexity and density of packing of the modern electronic products.

2. The latent defects need to be discovered and corrected before the product leaves the factory otherwise they will show up as product failure during service exploitation with possible serious consequences and always with undesirable cost impact.

3. The Quality Directive on ESS was initially issued in 2015. This present document Revision is with updation and additionally covers, Delta ESS to ensure proper Workmanship during repair/ rework and also provide certain extent of severity while testing LRUs for 'Defect Not Confirmed' (DNC) cases. This is essential to ensure reliability of electronic product during its entire service life.

Date: 18 *Dec 2023*

(S Chawla)

AMENDMENT SHEET

Sl. No.	Amendment No.	Date of Amendment	Amendment Page Nos	Remarks (Details of Amendment)	Signature of Competent Authority
01	01	05 Dec 23	-	Quality Directive 04-03/2015	

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1.0 INTRODUCTION

(A) ESS:- The requirement of Environmental Stress Screening (ESS) has been envisaged in various Military Standards and Guidelines, ***including DDPMAS, JSS and JSGs*** Technical Standing Order (TSO) of HQ DGAQA and Unit Standing Orders (USOs) of the Field Establishments (FEs).

ESS is a vehicle by which the latent defects are accelerated to early failures in the factory, resulting in precipitation of infant failures of bath-tub curve.

The ESS can be viewed as a production tool & extension of QC inspection & testing processes during manufacturing and required to be applied on each of the production equipment to precipitate the latent defects.

The ESS is not a pass fail criteria and the failure during ESS shall be welcomed to introduce the remedial action so that the equipment is free from premature failures during the use by Services.

(B) DELTA ESS:- ***Delta ESS is a sub set of ESS which is applicable for the products/ units only which has undergone for ESS while its production. It can be applied during service life cycle of products in following conditions:-***

> ***(i) During service life of products/ LRUs/ Components received on DI / IDI / PWR / Rectification on reported snag/ fault but while testing on ground with Rig/ Jigs/ Tester the snag is not confirmed. In that case a severity is applied while testing the components so as any intermittent kind of fault can resurface while testing.***
>
> ***(ii) The unit for which repair/ rework/Modification has been carried out involving change in components, in that case to ensure correct standard of workmanship the severity in the form of Delta ESS is applied while testing the components post repairing.***

The Delta ESS simulates the actual airborne conditions of Aircraft including Temperature cycling and Vibrations which increases the chances of finding Failures/ Faults.

Although the various field establishments dealing with Electrical / Electronic LRUs have already implemented the ***ESS and Delta ESS, there is a need to incorporate a uniform ESS & Delta ESS procedure across Field Establishments.***

2.0 SCOPE/ APPLICABILITY

The procedures specified in this document are applicable on :-

(i) Indigenous Sub-assemblies & LRUs of airborne & Ground Equipment including Test Rigs for Electronic equipments.

(ii) TOT projects for which ESS procedures were not shared by OEM.

Note: This Directive is not applicable for mechanical components.

3.0 OBJECTIVE

To implement an uniform ESS & Delta ESS, procedure to be followed by all DGAQA Field Establishments (FEs) so that the product delivered to the Services are free from infant failures ***and Defects which are not Confirmed while testing at Ground Conditions should re-surface / re-appear during repair/ re-work.***

4.0 BACKGROUND

Process of ESS ***and Delta ESS*** has been standardized as application of Thermal Cycling (TC) and Random Vibration (RV). There have been the following two approaches of ESS as per Military Standards. ***The following table brings out the assembly defect types precipitated by thermal and vibration screens:-***

DEFECT TYPE	*THERMAL SCREEN*	*VIBRATION SCREEN*	*THERMAL & VIBRATION SCREEN*
Defective part, broken part & solder connection	*x*	*x*	*x*
Improperly installed parts, PCB etc, shorts & opens/loose contacts & loose wire terminations	*x*	*x*	--
Wire insulation, contamination, component or parameter drift, hermetic seal failure, PWB opens/ shorts, components incorrectly installed, wrong components, chemical contaminations and defective wire termination	*x*	--	--
Improper crimping or mating,	--	*x*	--

debris, chafed/ pinched wires ,adjacent boards rubbing/ parts shorts, poorly bounded components , mechanical flaw, inadequate secured high mass components and particle contamination.			
Loose hardware	--	x	x
Fasteners and etching defects	--	--	x

(a) <u>Basic Approach:</u>

There are two basic approaches to the application of stress screening. In one approach, the Government explicitly specifies the screens, screening parameters to be used and failure free periods. Another approach is to have the contractor propose a screening program and is subjected to the approval of the Government. The first one is established approach since long through CEMILAC/RCMA & DGAQA and a uniform implementation of this approach is required as per MIL-HDBK2164A,MIL-STD-202G, CEMILAC Joint Airworthiness Standard (01/2007), CEMILAC Directive 14/2015, JSG 0613 of MoD, applicable as on date. This approach specifies the minimum Thermal Cycling of 33 and half Hrs, including 10 cycles of which last three Cycles are Defect Free. The minimum duration of one cycle is 3 Hrs 20 minutes with the temperature extremes as per operational temperature specification of the equipment being screened.

(b) <u>Quantitative Approach:</u>

The Detailed mathematical calculations is required from various input database such as packing density, defect density, precipitation efficiency (PE), thermal analysis, component level specs of huge no. of components for this approach. The data needed for a systematic quantitative approach of ESS application is not fully developed. It requires the temperature extremes of component specifications which are very much higher than the operating temperature of the equipment. In this approach, PE above 95% (should be case for Defence Equipment) can only be achieved through the higher temperature extremes with higher rate of change of temperature and more no. of cycles. However, if we increase the temperature extremes and rate of change of temperature further, the no. of temperature cycles can be reduced. It may be noted that testing any LRU beyond its spec limits does not stand to any logic unless it is proved.

It has also been noticed that in some cases an approach which is mix of both basic approach & quantitative approach is being followed. The less duration and less no. of cycles (applicable for low extremes of components specs of quantitative approach) have been adopted whereas for high extremes of LRU specs (applicable for basic approach) which are always lower than the component level specs. This mix approach is not acceptable as it may not serve the very purpose of ESS. Hence either Basic or Quantitative approach may be followed in true spirit for the PE of more than 95%. The scenario is appended below.

Sl. No.	Difference of Temp extremes (ΔT) - °C	Temp rate of Change °C/Min	Number of Cycles	Precipitation Efficiency (PE)	Remarks
1	100	5	6	74.96%	Dwell time corresponds to stabilization of the temp of components to max safe value as per component specification
2	100	5	10	90.05%	
3	100	10	10	98.83%	
4	100	5	12	93.73%	
5	100	5	14	96.05%	
6	*120	5	10	92.37%	
7	*120	10	10	99.30%	
8	*140	5	10	94.05%	
9	*140	10	10	99.56%	

* Generally applicable for Industrial Components

Normally it is observed that 80% of defects are susceptible to detection during thermal screening & remaining 20% during Random Vibration (RV). More importance is to be given to thermal screening over Random Vibration.

The major differences between both the above approaches are as follows:

Sl. No.	Parameter	Basic Approach	Quantitative Approach
1.	Applicable Standards	MIL HDBK 2164A/JSG 0613/ CEMILAC JAS 01/2007 and CEMILAC	MIL HDBK 344
2.	Temp extremes	Lower (Equipment Specs)	Much Higher (Component Specs)
3.	No. of Cycles	Fixed (10)	Variables from 2 to 30 as per desired PE
4.	Dwell Time	Variable, minimum 3 Hrs 20 minutes for one cycle (90 minutes at each extreme)	Variable, is a function of the difference in the thermal masses of the items being
5.	Rate of change	5 °C/min or 10°C/min	5 °C/min to 40 °C/min as per desired PE
6.	Total duration	40 Hrs/33 1/2 Hrs	Variable as per above
7.	Vibration	0.04g2/Hz (6.06 grms) for a selected band of frequencies for 15 minutes (5 mins/ axis) as per Fig 'A'	Variable, 0.5 to 10 grms for 5 to 60 minutes on susceptible axis

5.0 THE *DIRECTIVE FOR ESS*

The following test procedure shall be performed in the given sequence:

(a) Functional Check: Carry out the Functional Check of the equipment as per the ATP/ PAT ***prior to commencement of Random Vibration-1 and record the result.***

(b) Initial Vibration:

(i) Calibration of Test setup: The test setup applicable for vibration consists of vibration table/ platform, sensors and fixture. The following to be ensured before starting the vibration test on UUT.

- *Preventive maintenance record of vibration table/ platform.*
- *Calibration record of sensors.*
- *For ensuring Calibration of Vibration Test Set up, the recommended Vibration profile i.e. Sinusoidal vibration to be run by mounted Fixture along with sensor to establish resonance and transmissibility factors as shown in Fig. 'A'. The outcome of this Vibration profile shall be used as reference, Fig. 'B'.*

Note:- The fixture used should be same which was used during qualification of UUT. (Fixture may be approved by RCMA concerned in case of airborne UUT and for ground based UUT the fixture to be approved by OEM/ designer as part of Technical Specification).

Resonance test on Vibration Fixture:

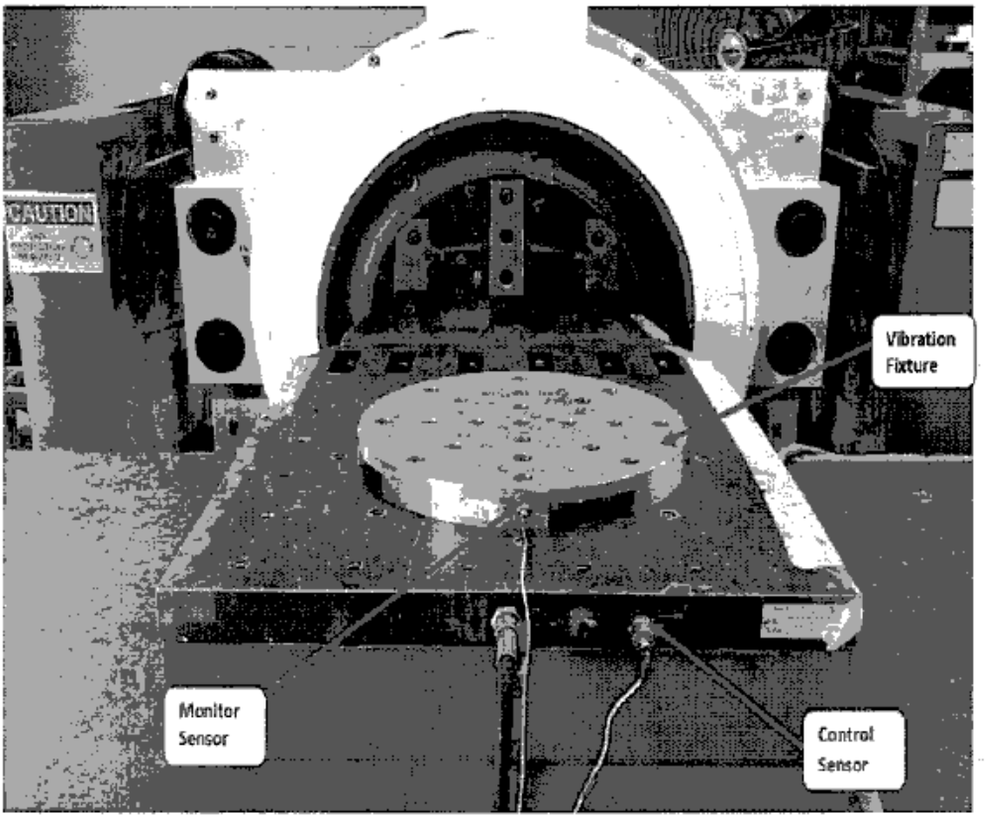


Figure A

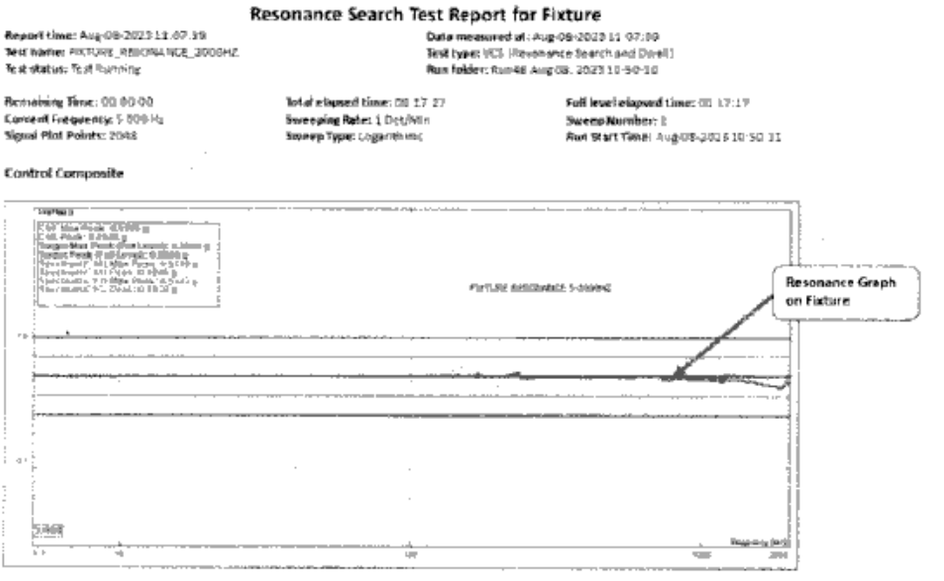


Figure B

(ii) Test Procedure: Now the UUT shall be mounted on calibrated fixture and sensor as shown in figure C and the UUT to be subjected to applicable vibration i.e. Random Vibration profile as per Fig 'D' on all the three axes. The duration of Random Vibration shall be 5 minutes per axis. The equipment should be switched ON during each axis of vibration and key performance parameters of the equipment are to be monitored .The failures, if any, shall be recorded and analyzed for the corrective action.

Resonance test on Avionics LRU:

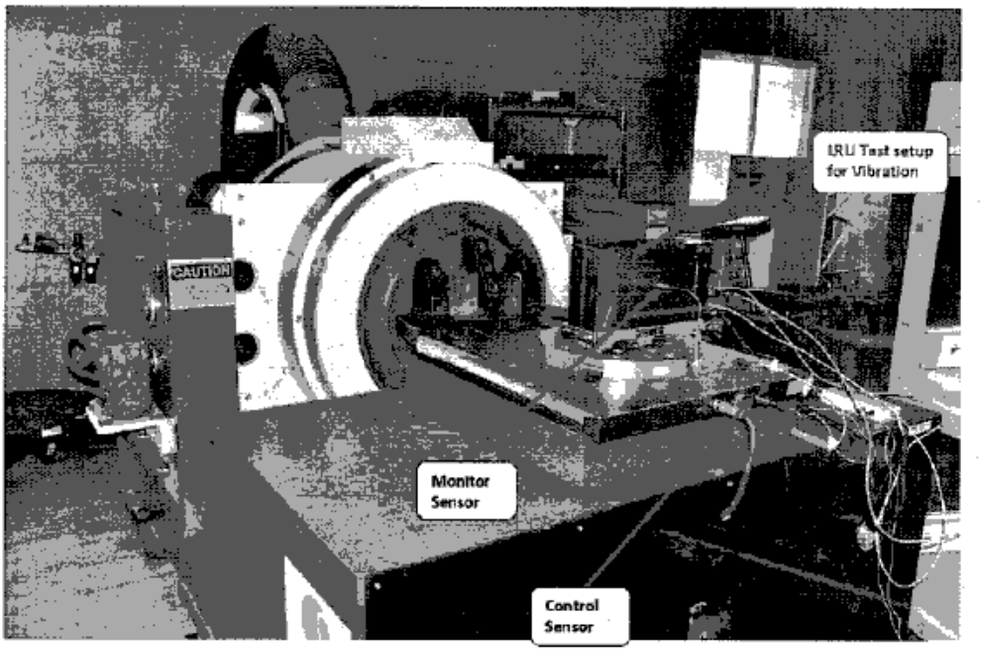


Figure C

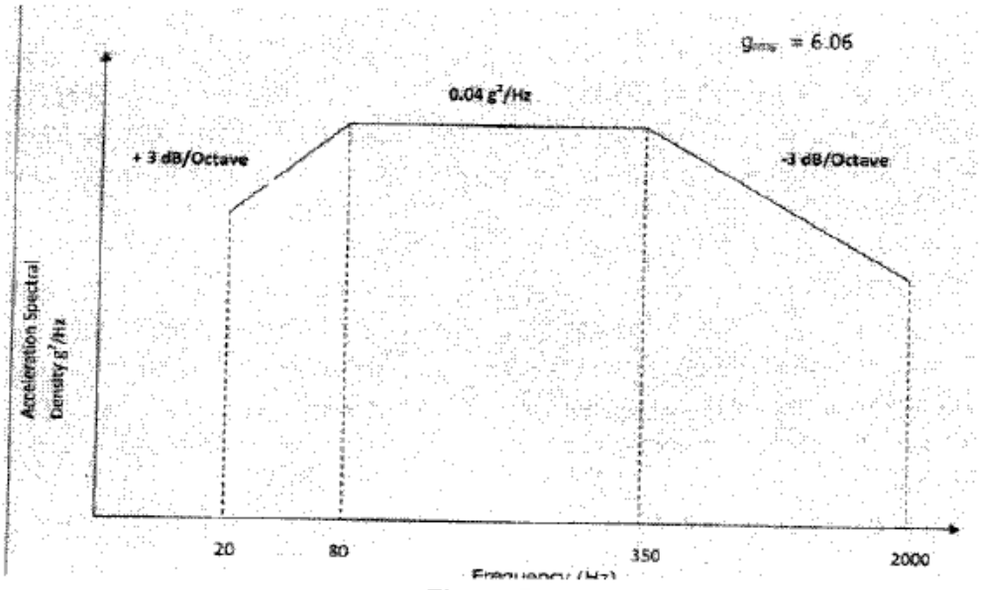

g_{rms} = 6.06
0.04 g^2/Hz
+ 3 dB/Octave
-3 dB/Octave
Acceleration Spectral Density g^2/Hz
20
80
350
2000

Figure D

(c) **Thermal Cycling:** After Random Vibration, the equipment shall be subjected to the minimum 10 Nos. of thermal cycling for Ambient Cooled equipment as per ***Figure E*** and minimum 12 Nos. of thermal cycling for Supplementary Cooled equipment as per **Figure F.** The approximate duration of one cycle shall be 3 Hrs 20 minutes. ***The rate of temperature change shall be ≥10°C/minute***. The equipment shall be switched ON & OFF as depicted in the figures. The key performance parameters of the equipment are to be monitored during full switch ON period of the equipment. The failures, if any, shall be recorded and analyzed for the corrective action. The Environmental Chamber generated graphical record of the thermal cycling shall be available. Last three thermal cycles should be fault free. The extremes of the temperatures will be governed by the specification of the equipment.

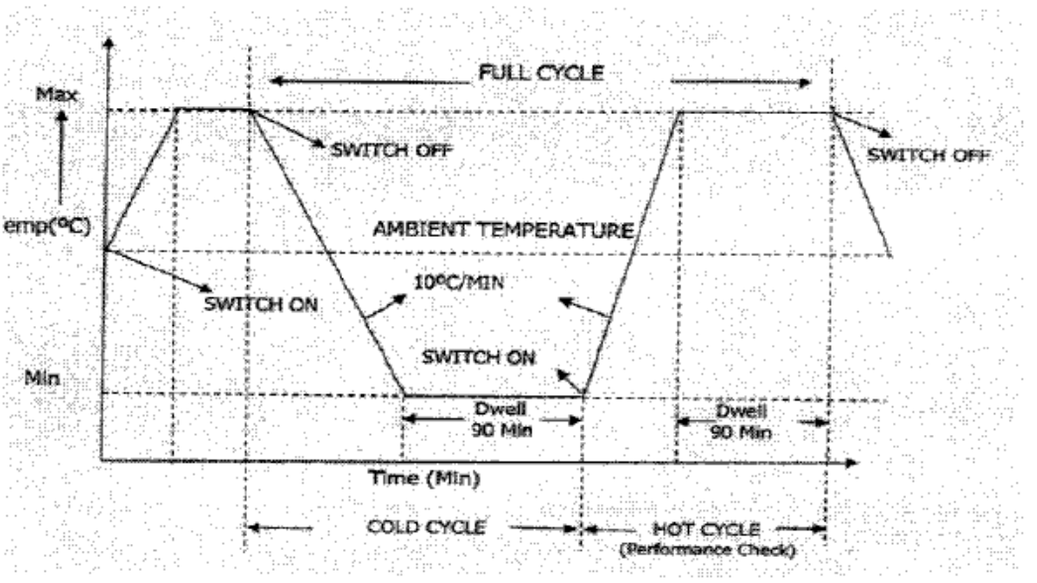


Figure E

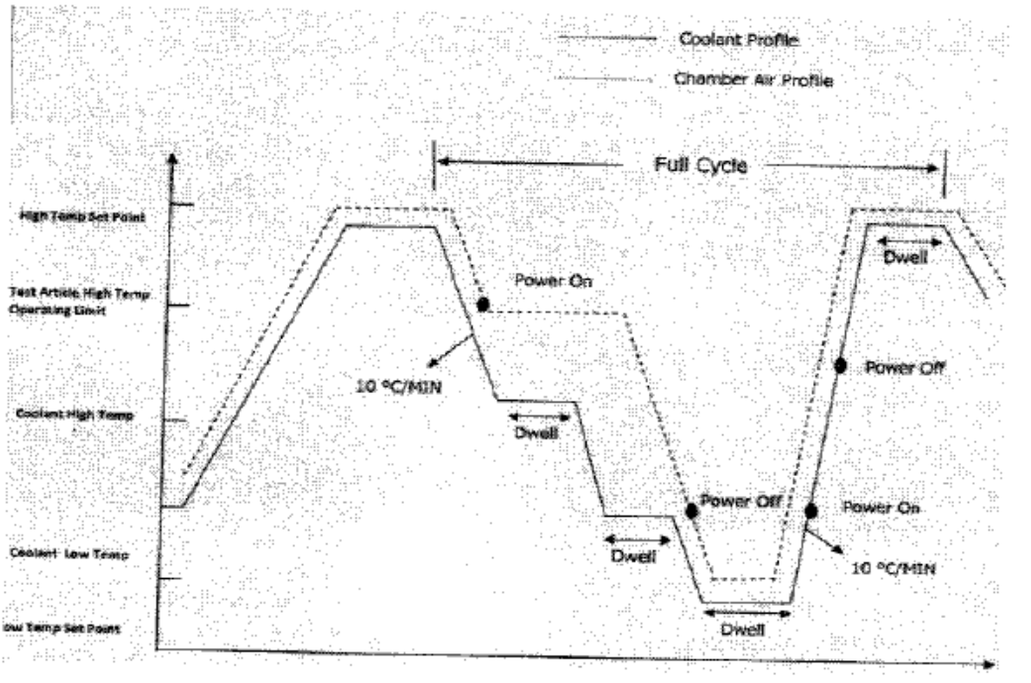


Figure F

The higher rate of temperature change and more no. of thermal cycles have been found more effective (to have PE greater than 95%) in precipitating the latent defects. Based on the thermal survey of the equipment, the thermal cycling profile can be tailored decrease in the dwell time and increase in the no. of cycles or vice-versa, keeping the total duration of thermal cycling to 33 Hrs(minimum) for the Ambient cooled equipment and 38 Hrs(Minimum) for the Supplementary cooled equipment.

(d) **Final Vibration** The equipment shall be subjected to Random Vibration profile as per ***Figure D*** above on all the three axes. The duration of Random Vibration shall be 5 minutes per axis. The equipment should be switched ON during vibration and key performance parameters of the equipment are to be monitored. The failures, if any, shall be recorded and analyzed for the corrective action.

(e) ***POST ESS*** **Functional Check** :- Carry out the Functional Check of the equipment as per the ATP/PAT& Results are to be recorded.

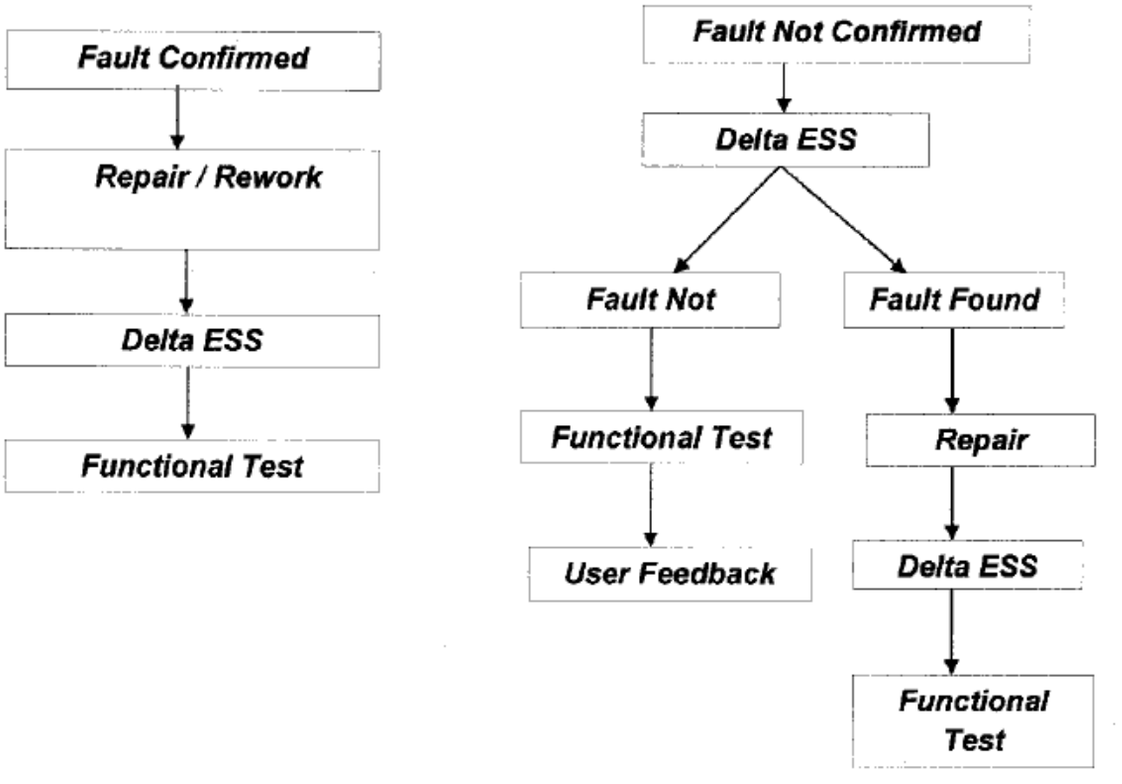
6.0 DIRECTIVE FOR DELTA ESS:

6.1 JUSTIFICATION: In case of usage of MIL grade components the de- rating values of Temperatures/ vibrations were quite high & rugged to sustain and extremes of climatic variations. But with the increasing usage of COTS, Industrial grade and LCSO electronic components the intermittent failures/ faults are being reported more on application of extremes/ variable climatic conditions. It is also observed that the

trends of faults reported at different bases are also different due to geographical conditions faced at that base. i.e. the types/ causes of faults at Leh are different than the Jaisalmer/ North East bases.

In view of above it is recommended to consider the climatic/ geographical conditions of the base from where the components has been loaded and accordingly the severity of delta ESS can be customized while testing the components. However, the generic directive on the Delta ESS as follows:

6.2 Flow chart for Delta ESS



The following test procedure shall be performed in the given sequence for Delta ESS:

(a) Functional Check :

Carry out the Functional Check of the equipment as per the ATP/PAT. Results are to be recorded. Further sequence to be followed as per flow chart mentioned in Para 6.2

(b) Initial Vibration:

The equipment shall be subjected to Random Vibration profile as per Fig 'D' only on critical axis. The duration of Random Vibration shall be 5 minutes. The equipment should be switched ON during vibration and key performance parameters of the equipment are to be monitored. The failures, if any, shall be recorded and analyzed for the corrective action.

Note: grms as applicable for Airborne/ Ground Equipment

(c) Thermal Cycling:

The equipment shall be subjected to the minimum 03 Nos. of thermal cycling for Ambient Cooled equipment as per Fig 'E' & for Supplementary cooled equipment as per Fig 'F'. The duration of one cycle shall be 3 Hrs 20 minutes. The rate of temperature change shall be 10°C/minute. The equipment shall be switched ON & OFF as depicted in the figures. The key performance parameters of the equipment are to be recorded.

(d) Final -Vibration:

The equipment shall be subjected to Random Vibration profile as per Fig 'D' only on critical axis. The duration of Random Vibration shall be 5 minutes. The equipment should be switched ON during vibration and key performance parameters of the equipment are to be monitored. The failures, if any, shall be recorded and analyzed for the corrective action.

(e) Post Delta ESS Functional Check:

Carry out the Functional Check of the equipment as per the ATP/PAT. Results are to be recorded.

(f) User feedback: - User feedback to be obtained in case of Defect Not Confirmed (DNC) cases even after carrying out Delta ESS.

7. Conclusion: It is pertinent to mention that a well-planned and tailored ESS program brings out the latent defects at manufacturing stage itself. As a result, early field failures are

eliminated which in turns enhances the operational reliability during its useful life. Even though ESS is a manufacturing process, now days it is being widely used as part of acceptance tests. A closed loop ESS program will certainly have the following benefits:

- ***(a) Better operational reliability due to elimination of early failure.***
- ***(b) Few warranty period failure.***
- ***(c) Helps in planning for spare parts.***
- ***(d) Better economy through fault detection and correction during the product development.***
- ***(e) Improved overall quality of the process and product.***
- ***(f) Helps in streamlining the process to weed out infant mortality failures.***
- ***(g) Improved productivity.***
- ***(h) Lower repair cost.***
- ***(i) Better image with customers.***

A sincere effort of field Establishment of DGAQA is required to ensure that the above procedures of the Directive are incorporated in all the ATPs/PATs being followed during production of all electronics LRUs of airborne and Ground applications. Under the provisions of DDPMAS 2002, suggestions shall also be given to CEMILAC/ RCMA to incorporate these procedures in the QTP & ATP for airborne equipment during Design & Development.

8.0 Way Ahead: ***By adopting HALT (Highly Accelerated Life Testing) during qualification and HAAS (Highly Accelerated Stress Screening) for ATP/ PAT will definitely reduce the testing time and improve the reliability of deliverables. However, the testing labs and industries are required to be equipped with testing facilities which is a constraint at present.***