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The Progressive Trends in Design, Reliability and Maintainability Aspects of Naval Defense Equipments

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***Abstract*— This paper is formulated after many experiences of the author in design, document, assemble, test and evaluation of the most modern naval defense equipments which are integrated on board many ships of the country. The objective of this paper is to provide the reader the various technologies which are employed in making the Reliability and Maintainability aspects of the defense equipments an easy task of the project. The paper also describes various trends which were used in the past, current scenarios and also aiming the future perspectives in the area of Reliability and Maintainability. The reader would definitely enjoy the many experiences which are shared here and many of them will throw light for the current problems and future designs as well. It is worth to note that the entire application is in the arena of defense applications on naval platforms.**

Keywords— *FEM, Qualification Testing, Environmental stress screening, Reliability, MTTR, MTBF, MTBCF, Maintainability, Quality, Fixture, Failure, Corrective action, vibration, Shock, EMI, EMC.*

I. INTRODUCTION

The reliability and maintainability are the two important key elements in the defense electronics. "Reliability" is the ability of a system or component to perform its required functions under stated conditions for a specified period of time.

The need for R&M in the area of defense products is very crucial as it is considered to be prime importance for the life cycle of the product. The availability of working system on board ship is boon to the confidence of the fleet team. In this regard a comprehensive plan in providing quality design with highly reliable product is the duty of design team. The "Maintainability" is the totality of all functions and features that represents "ease" with which a product can be maintained in order to:

- isolate defects or their cause,
- correct defects or their cause,
- repair or replace faulty or worn-out components without having to replace still-working parts,
- prevent unexpected breakdowns,
- maximize a product's useful life,
- maximize efficiency, reliability, and safety,
- meet new requirements,
- make future maintenance easier, or
- Cope with a changed environment.

The Reliability is built in design phase and the product or the system undergoes many tests to evaluate the quality product sustains the E.S.S and Q.T methodologies as per defense guide lines and standards such as JSSS5555 (Indian MIL STD) and various MIL Standards.

Through this paper, the experience gained in various naval projects has been shared highlighting salient points on the progressive trends in attaining the R&M of naval products and systems.

II. DESCRIPTION OF EXISTING METHOD / TECHNIQUE RELATED TO WORK.

A. Environmental Stress Screening:

E.S.S are the tests carried out to bring out the process and workmanship defects which are present in the component / PCB / Module level subassemblies and assemblies before they are integrated in the assembly line for product / equipment manufacturing. These ESS tests are formulated by DQAN guidelines and are executed as a part of system while manufacturing.

B. Environmental Tests

E.T are the tests carried out to bring out the defects due to design and engineering which are present in the component / PCB / Module level subassemblies and assemblies after they are integrated in the assembly line as a product / equipment. These ET tests are formulated by JSS 55555 guidelines and are executed as a part of Qualification Tests after complete manufacturing and before offering to the customer and inducting on the naval platforms.

C. EMI/EMC tests as per MIL STD 461 D/E

EMI/EMC are the tests carried out to bring out the Electromagnetic Interferences and compatibility issue and defects due to components manufacturing, process and workmanship standards , design and engineering flaws which are present in the component / PCB / Module level subassemblies and assemblies after they are integrated in the assembly line as a product / equipment. These tests are formulated and governed by MIL STDs and DQAN guidelines and are executed as a part of Qualification Tests after complete manufacturing and before offering to the

customer and inducting on the naval platforms. The qualified units / products render interference-free platforms and systems onboard ship.

D. *Critical Failures In Various Projects*

From various naval projects experience the types of failures have been analyzed and solutions are described in section 6 and 7

PARAMETERS	TYPES OF FAILURES
Vibration and shock	*Loosening of screws, nuts* *Weld bead failures* *Failure of joints* *Breakage of weak structures/Cross section* *Resonance of fixture*
High Temperature	*Component failure* *Soldering failure*
Damp heat	*Component failure* *Soldering failure* *PCB*
Low temperature	*Component failure* *Failure of Lubricants* *Soldering failure*
Drip proof and driving rain	*Leakage through door* *Leakage through gaskets* *Leakage through fixing screws*
Mold growth	*Failure of samples*
Corrosion	*Failure of samples*
EMI/EMC	*Many types*

III.PROPOSED TECHNIQUE

A.*Vibration & Shock Test*

1) Structural analysis: The structural analysis for vibration and shock is a must in naval equipments to carry out the simulation and to ascertain the possible failures during vibration and shock. The fixture design holds another important key in clearing these tests. The fixture shall be ruggedized to take the vibration and shock loads without yielding and amplifying the degree of the test. The transmissibility in shock is very important parameter in case of the units with rubber mounts, shock mounts and wire mounts. The analysis is carried out using the latest softwares such as ANSYS, Nastran 7, HyperMesh 10 and 3D modeling using SolidWorks, Pro-E, Ideas, Catia, Unigraphics etc.,

2) Modification to fixture: The structural analysis for vibration and shock give important details on probable failures on the fixtures which need to be taken care in the fixture design. Such finer details help in design and manufacturing to get the right fixture without amplification of the vibration and shock excitations given to the machine bed during the tests.

3) Modification to shock mount : The structural analysis for vibration and shock give indirect important details on the functioning of shock mount / rubber mount / wire mount adopted in the unit design. The transmissibility of vibration / shock can get amplified due to improper selection of shock mounts. The mounts are designed as spring elements with stiffness. Through FEM analysis one can revise the shock mount selection when in advance before the actual tests.

4) Fixing of components and screws : The structural analysis for vibration and shock give important details on probable failures on the fixtures which needs to be taken care in the fixture design. Such finer details help in design and manufacturing to get the right fixture without amplification of the vibration and shoc excitations given ti the machine bed during the test.

5) Proper fixing of components/parts : The structural analysis for vibration and shock give important details on probable failures on the fixing and mounting methods which needs to be taken care in the fixture design. Such finer details help in designer to modify the fixing methods, changing the type of fasteners, increasing welding area and bearing surfaces to withstand shock and vibrations. The cross sections of the parts are also modified in many cases to increase the stiffness and provide more strength.

6) Soldering : The structural analysis for vibration and shock give details on probable areas of failures within the unit. In the electronic systems the soldering of components needs to be given due attention so that the transferred load on the PCB does not create failure in the soldering joint. It is wiser to check there are no soldering defects such as dry solder, improper and inadequate joints in soldering areas.

7) Additional Support : The structural analysis for vibration and shock reveals the need for additional members to add strength and stiffness in the weaker areas and cross section. In such cases the FEM as to be repeated to revalidate that the required improvement is obtained or not.

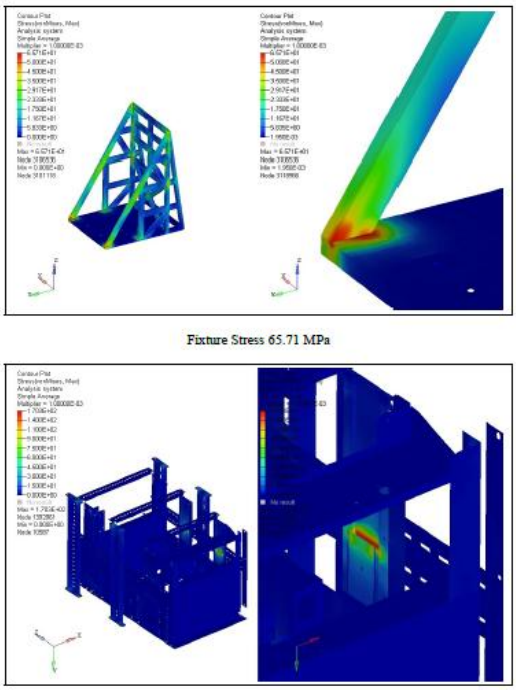

Fig. 1 Snap Shots From Fem Analysis

8) Connectors, PCB's, Cables : The structural analysis for vibration and shock reveals the need for change of connectors , additional members to add strength and stiffness in the PCB's, weaker connector areas , the need of proper anchoring of cables and wire.

9) Mounting of IC's, PMC's : The structural analysis for vibration and shock reveals the need for providing the proper support to IC's and PMC's. Though these components are surface mounted and soldered, the need for additional supports arises if the weights of the components are slightly on the higher side.

B.High, Low Temperature & Damp Heat :

1) Thermal Analysis : The thermal analysis is a must in naval equipments to carry out the thermal heat dissipation simulation and heat flow to ascertain the possible failures due to temperature during thermal test. The boundary conditions, temperatures, conductivity of medium, air flow and heat dissipation techniques are the key factors in achieving the results which are more accurate to close to reality. The analysis is carried out using the latest softwares such as ANSYS, CFD, Solid Works, Pro-E, Ideas, etc.,

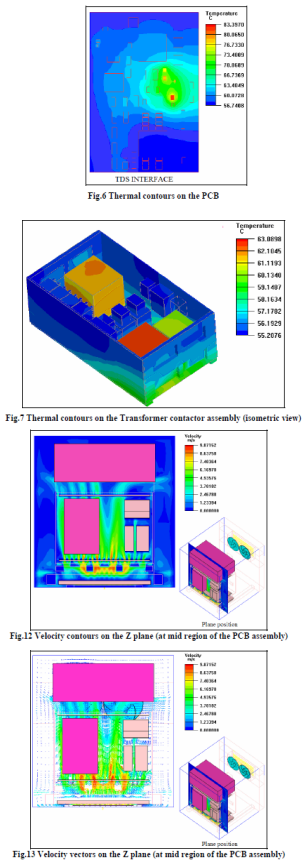

Fig-2 Thermal analysis of typical electronic unit

2) Temperature Range : The temperature range is crucial and this has to be considered correctly in thermal analysis to ascertain the possible failures due to temperature during thermal test.

3) Operating temperature : The operating temperature range of components, special devices, PCB's, COTs items are crucial and this has to be considered correctly in thermal analysis to ascertain the possible failures due to temperature during thermal test. The selection of Industrial and COTs grade components while designing needs to be verified before final design is firmed up. The percentage failures of such devices in both low temperature and high temperature are more in Thermal tests.

4) Humidity Parameters : The humidity parameters of components, special devices, PCB's, COTs items are crucial and this has to be considered correctly in thermal analysis / thermal test. The selection of Industrial and COTs grade components while designing needs to be verified before final design is firmed up. The percentage failures of such devices in 95% RH specs are considerably more.

5) Soldering : The Soldering quality is a main concern in all electronic equipments. Refer III.A.6 for further details.

6) Grounding : The grounding methodology to dissipate the heat by conduction is also important in PCB's and modules. The conduction shall be from components to

PCB layers and continue with grounding / chasis. The design shall be in such a way that these are addressed so as to carry away a considerable amount of heat dissipation through conduction and rest of the thermal aspects through heat convection and radiations.

7) Fans and Blowers for forced convective cooling : The cooling in electronic equipments is the most complicated engineering aspect. The designer shall have all the data regarding thermal requirements of components, special devices, PCB's, COTs items in order to device the most efficient method of cooling. Such data shall be requested from OEM's during the design stages. The fan type , air flow, delivery pressure fans in terms of CFM, cross section of the air path, hindrances, position and placement of fans/ blowers are the key factors which decides the cooling methodology effective and efficient.

8) Dust filters : The dust filters used in the air flow path generally gets clogged faster than expected period if the environment is polluted. A periodic cleaning of the filter is necessary and the same shall be addressed in the maintenance manuals. The percentage blockage shall be properly considered while designing as well as during thermal analysis.

C.Drip Test :

1) Gasket : The Drip test is called in Environmental Tests, in order to verify the system / unit functions in the ship's environment. AC ducts and routings within ship will be carrying either AC medium or chilled water lines and prone to have condensation in their outer surface which finally leads to dripping as water particles. The units shall be designed with proper gaskets which take are off both EMI/EMC and water tightness. Though the drip test is conducted for 15 min, it is advisable to design the better gaskets, gasket grooves with proper fasteners. The gaskets of the chosen polymer shall have the required hardness for adequate compression. The gasket material shall be chosen for the correct medium, temperature, pressure and, environment.

2) Gasket Groove depth : The gasket groove design hand books may be referred for better design of gasket cross section, groove depth, groove width etc. The gasket groove finish and groove machining is critical to clear drip test.

3) Surface Level of the gasket fixing : The gasket groove is generally preferred on the cover for ease of manufacturing. The surface level both on gasket groove side and the housing side shall be in good planarity and level so that the gasket compression after tightening will be uniform and even.

4) Adhesive used to fix the gasket : The gasket groove is generally preferred on the cover for ease of manufacturing. The surface level both on gasket groove side and the housing side shall be in good planarity and level so that the gasket compression after tightening will be uniform and even.

5) Fixing methodology : The pitch of the mounting screws on the cover is important factor for good and even gasket compression. The tapped hole for fixing the screws on the housing side shall be blind and not a through hole. The cover shall be made out of stiffer material and cross section to avoid buckling effect which finally may lead to leakage from the gap between cover and the housing.

6) Design of protection cover or hood : The additional cover or hood helps in proving the drip test by reducing the amount of drip falling on the covered area / visible gasket joints. Such mechanism basically deflects the drips by deflecting inggasket groove is generally preferred on the cover for ease of manufacturing. The surface level both on gasket groove side and the housing side shall be in good planarity and level so that the gasket compression after tightening will be uniform and even.

7) Leakage through screws : The gasket groove is generally preferred on the cover for ease of manufacturing. The surface level both on gasket groove side and the housing side shall be in good planarity and level so that the gasket compression after tightening will be uniform and even.

D. Mold Growth And Corrosion :

1) Material properties : The material properties play a vital role in clearing mold growth and corrosion tests. Mold growth is carried out on painted parts and corrosion test on components and raw materials. Usage of standard proven materials is the simple solution to these tests.

2) Finish : The process qualities of finishing such as primer, paint, varnish, electro-plating etc are verified in this test. Qualified personnel with standard procedures for finishing enhance the finish of the materials.

3) Test report for sub-contracted parts / modules : The requirement of Test Reports shall be one of the mandatory acceptance criteria clearing the various processes. Thus the process verification as per standard norms gets shifted to the vendor's premises.

Fig. 3 Test sample after corrosion test

E. EMI/EMC

The EMI/EMC proving is another critical stage in naval applications as the electromagnetic interferences can cause severe damages on other units which are housed inside the ship's compartment / above deck equipments. The following key factors are to be addressed in proving the reliability of the products is sustaining and clearing EMI / EMC norms.

1) Cable assembly, Sleeving , heat shrink booting : The cable assemblies are crucial from EMI point of view, as the selection of contacts, wires, sleeving, heat shrinking of boots, adhesives used for sealing, grounding of braids on the connector shells, terminations of the wires, quality of solders are the important factors where skills, processes and workmanships plays importance.

2) Grounding : The grounding is another important aspect. A proper grounding needs non ferrous contacts, unpainted with electro-plating for perfect contacts. The grounding shall start from grounding layer of the chosen components to the PCB grounding layer. From PCB the grounding shall extend to the card cage or chassis. All such grounding shall get terminated to an earthing block. The block shall be welded to the housing. The housing / cabinet shall be connected to the floor / ground using proper braid /grounding strip.

3) Honey comb filters, mesh lowers : The RF filters and meshes used in air flow path of modules and units are to be changed chosen properly while designing the units for reliability. The frequency and band width required for filtering depends on the components used inside the module.

4) Blower : The operating frequency and the air flow requirements are to be analyzed while selection of blower during design stage. The noise level in db to be verified before integrating with the system .The usage of capacitances to bring down the spikes /EMI is a better method to avoid or minimize noise levels.

5) Gasket type, material and adhesive : The gasket (EMI) used shall be of the correct bandwidth and right material of adequate silver particles as per standards for EMI requirement. The gasket seating area shall be conductive without any insulation layer. The adhesives used for gasketing shall be conductive type. These adhesive have limited shelf life and hence they are to be used within specified time as per manufacturer's norms for better functioning.

6) Mechanical gaps : In the entire engineering aspect, the gaps existing between parts/ housing pose EMI/EMC issues. If the area is large suitable mesh / cover made out of EMI/EMC material can be designed and integrated.

7) Earthing stud and strap : Earthing stud straps generally made out non-ferrous metals such as brass which are electroplated with tin/silver coating. The contact areas shall be conductive without primer/painting/lacquer coating. The usage ferrous materials lead to issues such as hydrogen embrittlement, and galvanic corrosions. The earthing braids chosen shall be made out of copper and plated with tin/silver. The tightness of fasteners used is also vital otherwise there is a possibility of arcing during leakages.

8) Grounding of components and PCB'S : The details are elaborated under Sec III.E.2.

9) Input power supply and filters : The input power line shall have the desired level of filtering. The RFI filter used shall be closed to the input line to avoid further interferences from the wires in-between. The filters can be integrated at PCB, Module and housing level.

10) Input power supply and filters : The input power line shall have the desired level of filtering. The RFI filter used shall be closed to the input line to avoid further interferences from the wires in-between. The filters can be integrated at PCB, Module and housing level.

11) Requirement of inductors : The usage of inductors for specific noise filtering is a general practice to control / avoid EMI/EMC issues. These inductors shall be secured and mounted properly and junctions to be addressed properly through terminal boards.

12) Painting and masking : The masking of primer and painting is very essential where contacts are necessary for body grounding. The various engineering documents shall clearly bring out the masking areas of the part/Assembly levels. The covers, doors, supports are provided with the EMI/EMC gaskets. The gaskets needs conductive contact areas to suppress EMI /EMC issues.

13) Fixing screws : Generally the loose contacts and loose parts in electronic devices are major concern and can cause noises at different frequencies. Such of those assemblies shall be ensured for proper tightening of screws. Refer section III.E.7 for more details.

14) Grounding of PCB's, card cage, power supply and housing : The power supply modules shall be analyzed properly for grounding methods specified by OEM. The contact mechanism of power supply, its line filters and gaskets are of importance. The power supply shall be very tightly protected for EMI/EMC both inward and outwards thro the lines. The cables shall be properly shielded and booted for better functioning during 'POWER ON' conditions.

15) Operating frequency of critical components : The various components used in electronic systems are of different frequency bandwidth , hence it is wiser to list out the operating frequencies, noise level, spikes etc and address these noise factors by incorporating filters and RF gaskets at different levels.

16) Grounding TB's : Usage of proper grounding blocks is a good process in controlling EMI/EMC issues. The state of the art TB's are available with very good level of insulation and protection which can be identified during design stage proactively to address EMI/EMC issues.

17) Display and monitor specification : Certain displays and monitors have specific noise levels which cannot be filtered completely as the radiation in some bandwidth is more than other frequencies. Usage of special screens for filtering affects the quality of visibility during manufacture of displays. The control can be only through selection of displays and monitors and filtering at input power lines.

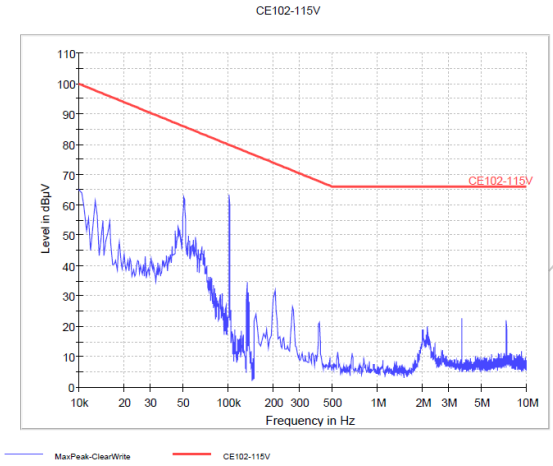

Fig. 4 Test sample after corrosion test

IV. ANALYSIS – KEY RELIABILTY AND MAINTAINABILTY FACTORS

The above chapters cover the design, reliability and maintainability factors. The reliability is to be built into the design by various methodologies. Progressive trends in day to day life of electronic equipment manufacturer are numerous in numbers. Some of the common trends are illustrated below:

A. Access For Maintainability : Access for trouble shooting, FDFL's, repairs and spare part management shall be thought during the initial design itself. 3D visualization through soft -wares provides greater advantages. The maintainability mode can be graphically seen step by step by advanced simulation packages eliminating issues of maintainability.

B.Cable Routing : The cable routing and cable forming has taken new edge making the cable forms outside on a board and incorporating within the main housing. The cable forms helps in maintaining process and workmanship in standardized way than the conventional wiring. The signal and power cable routing separation helps in EMI/EMC and avoids noise being picked up video and signal cables.

C.CBD : The comprehensive configuration base line diagram helps in understanding various issue levels of different projects and different configurations used. CBD table helps maintainer in locating FDFL's and replacement of spares onboard.

D.Connectors – Shock Proof MIL Connectors : The above deck connectors are facing the technology change from aluminium material to brass, brass to steel and steel to titanium. The shock proof MIL connectors are the demand of these days where contact quality is very high. The soldering and crimping quality with least-contact resistance is the prime requirement in cabling of naval equipments.

E. Cooling & fans : Cooling of electronic equipment are discussed with thermal analysis (REFER Sec III.B).

F. CSCI Identifications : Computer software controlled modules are being identified with labels for ease of maintenance during the life cycle of electronic units. These identification provides easy removal of PCB's for software updations as per SUM (Software user manuals).

G.Door Access : Various methods of door accessibility have been invented so far. The most common door has hinges on one side and locking on the other side with suitable EMI/EMC gaskets. The rarely used ones are only bolted or screwed type. The frequently operated doors are being designed with latches for ease of removal.

H.EMI/EMC and filters : The selection of EMI/EMC filters and their importance in illustrated in chapter III.E. The recent trend is simulating the EMI/EMC through software for the entire system and finding the optimal solution for the same.

I.EMI/EMC on power and signal cables : The details have been discussed under chapter III.E. The recent trend is that laying of power and signal cables separately through various branches and shielding the cables is now technology driven.

J.Ergonomics : The Ergonomics (or human engineering) is taken a front seat in design trend wherever human involvement is more. The human engineering is described to a greater extent in human engineering MIL STD hand books. Ergonomics looks at minimum stress level and fatigue to the operators by minimizing the limb movements, providing stress free postures for spine, eye movement, neck movements and limbs. The Ergonomics can be simulated through various 3D animation, visualization and simulation softwares.

K.Fasteners : The quality, variety and method of fastening are taken giant leap in engineering field. Now, we have numerous methods fastening which provides temporary, semi-permanent and permanent type of fastening. A proper selection will enhance the maintainability of a system.

L.Finish : The various finishing process are existing at present and trend is to know the fatigue limit of these finishing processes and predict life of the protection. The finish processes are ROHS compliant and environmental friendly. We have many choices for a particular application and are available as per latest technology and of high standards.

M. Grounding and shielding concepts : The various trends have been discussed in chapter in III.E.

N.Halogen free wires (fire resistant) : The operator's safety is an important element. The naval products which are finally housed in a ship need the halogen free wires as a part the wiring and installation. The halogen free wire does not ignite with fire and does not spread fire. Though they are costlier, the trend is to have there in the ships cabling and internal wiring as they are life saving materials.

O.Handling & lifting : The handling and lifting is an important parameter for transportation and installation. The trend of these days is that the unit is modular so that they can transported in dis-assembled condition and can be assembled together onboard ship. For the purpose of lifting more than 40 Kgs, sufficient lifting hooks or mechanisms shall be provided. Slide rails and guide rails, supports, stowages, lifting tables etc., provide ease of maintenance throughout the life cycle of the product.

P.IP rating : It is suggested that Ingress Protection rating of modules (COTS and Industrial) grade shall be understood while designing. Knowing the rating helps in any modification required on the units to make ruggedized before taking in to assembly line for integration. With certain modifications we can get assurance of clearing environmental/qualification tests.

Q.Labelling : Labels are used for indication, caution, warnings, notice, testing and traceability. The trend is that labeling is being carried out to maximum extent required by the maintainer and operator. The quantity labels are available which have greater life expectancy. These labels also help the testing departments to troubleshoot the functional issues.

R.Maintenance envelope : This is one of the critical requirement from ships, that the maintenance envelope is disseminated well before finalization of ship's routing and construction. The volume of the units helps ship builder/integrator to provide sufficient air flow, maintenance space, cable routing, accessibility to reach LRU's and accessibility of power supply connectors.

S.Modular construction/ hatch/ ship routing : Modular construction helps in taking the module thro the hatch while routing. It helps in transport and carrying of modules in smaller sizes and integrating in the place where required. Hatches are available generally with dimension 32 inch X 32 inch (approximate) cross section which means that the largest cross sectional dimension of the modules shall be limited to 780mm X 780mm.

T.Modules access : Accessibility of modules, LRU's, PCB's, power supplies, monitors, card cages, doors, test points are critical for maintainability point of view and these shall be addressed during design stage.

U.Noise factors : The audible noise for operator shall not exceed 55db and for the silence operation it is required to be around 45db. Generally motors, fans, blowers, pumps create noise to the environment. Suitable sound absorbers may be incorporated to reduce the noise levels along with careful selection of parts /components.

V.Power disrtibution & controls : Power distribution is taken a greater importance in naval defense ships as the requirement of individual control of all units discretely with adequate circuit breakers is envisaged in most of the equipments. The power distribution panel can have fuses, indications, switches and CB's on indication panel. Safety is the main focus in power distribution and console.

W.Power related design : The power requirement shall be studied in detail and the units shall be designed for economic power consumption. Reduction in power consumption for the country's where energy saving schemes are not doing well. The power consumption of all units shall be within economic range so that the ship's input power load can be reduced.

X.ROHS components : Usage of ROHS components shall be the main focus in design. The hazardous substances can create damage to the environment thro air, wind, water, soil etc. The ROHS compliance still not picked up momentum in Indian markets.

Y.Safety & warning : The personal safety is at most importance onboard, hence usage of safety labels, circuit boards, and warning labels shall indicate clearly the high temperature, high current, high voltage and EMI-EMC compliance, handling of materials, power on switches, fuses, selection switches, high radiation, and critical movements of equipments. These labels shall be manufactured as per National and International Standards.

Z.Sea state : The study of sea state helps designer to make the design ruggedized for severe marine conditions such as pitch, roll and yaw. Sea state 4,5 and 6 indicates moderate to high where as Sea state 7,8 and 9 indicates high to phenomenal range.

AA.Slides for card cages/modules : The slides/telescopic rails are adequately used in the withdrawal of card cages and modules. The slides shall have the features such as end

stop, extended withdrawals and locking in facility which facilitates quick , safe and ease of maintenance.

AB. Standardisation : The standardization of units, housings, handles, tools, switches, components etc are required to maintain least varieties and least spare management on board ship.

AC.Switches, test points : The switches and test points shall be used adequately for proper indications. TP's helps in trouble shooting and maintenance activities. Design shall provide TP's for critical and accurate circuits and connections. Also refer section IV.B for more details.

AD.Tools required : The recent trend is that usage of minimum for maintaining operations. During design phase, the fasteners, components, hardwares shall be chosen with an idea of quick and easy removal using common tools. It is evident that such common tools help operator to perform his/her tasks with minimal time. Necessary tools which are required frequently can be hooked/mounted on the equipment itself.

AE.Visual requirements on console : The visual requirements shall follow the guidelines as per the design standards indicated in Annexure. Main focus is that the operators comfort shall be enhanced by minimizing the movements of neck, limbs and eye movements.

V HARDWARE/SOFTWARE DEVELOPMENT

Softwares used for modeling: SolidWorks 2012, ACAD 2010. Softwares used for FEM analysis: ANSYS, Nastran 7, HyperMesh 10.

VI APPLICATION

The application of the guidelines and methodologies expressed in this paper may be to the core of products and systems of Naval platforms which have stringent quality and life cycle requirements. In achieving maintainability and reliability the design phase holds the key.

VII RESULTS AND DISCUSSIONS

The recent trends are throwing a lot of challenges to design, qualify and meet requirements of naval equipments. The whole cycle has to be carried out with QUALITY, TIME & COST in mind.

The designer needs to capture the ideas and conceptualize well before creating preliminary design. The design shall flow through the structured design process. To facilitate the above the design shall take place taking the account of latest technology, obsolescence, life of the product, spare management and materials of class 1 properties. The key factors in deciding the quality of design are detailing, identification of functional blocks, design methodologies adopted, and evaluation of produceabiltiy, testability and reliability of the product/system in terms of design parameters.

The component selection is the core activity and then followed by module design. The module and LRU designs must go through ESS and the entire system shall go through the Q.T checks. The maintainability shall be built in the design. The reliability factor is conglomeration of all the above factors. Prototyping and simulation techniques can help the designer to a greater extent.

VIII CONCLUSION

The Design phase is the first step towards building everlasting quality in a product or a service throughout its useful life. The quality of Design phase can be stated as "Meeting the stated and Implied Customer requirements aptly in terms of Functionality, Cost and Time during all design activities of the product or service". The analysis presented in this paper discusses the various stages of Design phase and identifies the factors affecting/effecting the design in all these stages and elaborates the key factors deciding the design Quality, Maintainability and Reliability.

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Bharat Electronics, Bangalore-560013, India

REFERENCES

[1] E.S.S – DQAN GUIDE LINES.
[2] JSS 55555.
[3] MIL STD 461-E.
[4] MIL HDBK 338b – ELECTRONIC RELIABILITY DESIGN HAND BOOK
[5] MIL 1472 F – HUMAN ENGINEERING
[6] VIBRATION RESISTANCE – B-0
[7] SHOCK PROOF – B-0
[8] Professional Project Management Education: August 2010
[9] PROJECT DESIGN in the context of PROJECT CYCLE MANAGEMENT SOURCEBOOK by Meg Gawler February 2005
[10] GROWTH BY DESIGN: HOW GOOD DESIGN DRIVES COMPANY by Maneesh Mehta
[11] The Engineering Design Process. 2nd ed. New York, N.Y., John Wiley & Sons, Inc
[12] Engineering: Fundamentals and Problem Solving. New York City: McGraw-Hill Companies Inc., 2002
[13] Design for six sigma by C.M Creveling.

DEFINITIONS AND ABBREVATIONS

- **Quality**: The methodology of assuring conformance to specification. The non-inferiority or superiority of something.
- **Design**: Design is the activity where creativity is used for shaping of ideas and concepts and put into use in practical and attractive propositions to the Customer to meet his/her specific needs.
- **FEM techniques**: In mathematics, the finite element method (FEM) is a numerical technique for finding approximate solutions to boundary value problems for differential equations. It uses variational methods (the calculus of variations) to minimize an error function and

produce a stable solution. Analogous to the idea that connecting many tiny straight lines can approximate a larger circle, FEM encompasses all the methods for connecting many simple element equations over many small sub domains, named finite elements, to approximate a more complex equation over a larger domain.

- **Qualification Testing**: A formally defined series of tests by which the functional, environmental, and reliability performance of a component or system may be evaluated in order to satisfy the engineer, contractor, or owner as to its satisfactory design and construction prior to final approval and acceptance
- **Environmental stress screening**: Environmental stress screening (ESS) is the process of exposing a newly manufactured or repaired product or component (typically electronic) to stresses such as thermal cycling and vibration in order to force latent defects to manifest themselves by permanent or catastrophic failure during the screening process. The surviving population, upon completion of screening, can be assumed to have a higher reliability than a similar unscreened population.
- **MTTR**: Mean time to repair (MTTR) is a basic measure of the maintainability of repairable items. It represents the average time required to repair a failed component or device. Expressed mathematically, it is the total corrective maintenance time divided by the total number of corrective maintenance actions during a given period of time. It generally does not include lead time for parts not readily available or other Administrative or Logistic Downtime (ALDT).
- **MTBF**: Mean time between failures (MTBF) is the predicted elapsed time between inherent failures of a system during operation. MTBF can be calculated as the arithmetic mean (average) time between failures of a system. The MTBF is typically part of a model that assumes the failed system is immediately repaired (mean time to repair, or MTTR), as a part of a renewal process. This is in contrast to the mean time to failure (MTTF), which measures average time to failures with the modeling assumption that the failed system is not repaired (infinite repair time).
- **MTBCF**: Usually, mean time between critical failures (MTBCF) is a term used when redundancy exists in a system. It is often used to differentiate system reliability from series mean time between failures (MTBF). Series MTBF, or simply MTBF typically includes all failures without regard to any fault tolerance that may exist, whereas, the "C" in MTBCF indicates that only "critical" failures are counted, i.e., those that will cause the system to not meet specification requirements. That said, MTBF is sometimes used to really mean MTBCF. This is often organization and/or industry dependent.
- **Fixture**: A fixture is a work-holding or support device used in the manufacturing industry. Fixtures are used to securely locate (position in a specific location or orientation) and support the work, ensuring that all parts produced using the fixture will maintain conformity and interchangeability. Using a fixture improves the economy of production by allowing smooth operation and quick transition from part to part, reducing the requirement for skilled labor by simplifying how work pieces are mounted, and increasing conformity across a production run.
- **Vibration**: Vibration is a mechanical phenomenon whereby oscillations occur about an equilibrium point. The oscillations may be periodic such as the motion of a pendulum or random such as the movement of a tire on a gravel road.
- **Shock**: Shock (mechanics), a sudden acceleration or deceleration.
- **EMI**: Electromagnetic interference (or EMI, also called radio-frequency interference or RFI when in radio frequency) is disturbance that affects an electrical circuit due to either electromagnetic induction or electromagnetic radiation emitted from an external source. The disturbance may interrupt, obstruct, or otherwise degrade or limit the effective performance of the circuit. These effects can range from a simple degradation of data to a total loss of data. The source may be any object, artificial or natural, that carries rapidly changing electrical currents, such as an electrical circuit, the Sun or the Northern Lights.
- **EMC**: Electromagnetic compatibility (EMC) is the branch of electrical sciences which studies the unintentional generation, propagation and reception of electromagnetic energy with reference to the unwanted effects (electromagnetic interference, or EMI) that such energy may induce.
- **Salt Spray**: The salt spray test is a standardized test method used to check corrosion resistance of coated samples. Coatings provide corrosion resistance to metallic parts made of steel, zamak or brass. Since coatings can provide a high corrosion resistance through the intended life of the part in use, it is necessary to check corrosion resistance by other means. Salt spray test is an accelerated corrosion test that produces a corrosive attack to the coated samples in order to predict its suitability in use as a protective finish. The appearance of corrosion products (oxides) is evaluated after a period of time. Test duration depends on the corrosion resistance of the coating; the more corrosion resistant the coating is, the longer the period in testing without showing signs of corrosion.
- **Mold Growth**: Mold assessment and mold remediation are techniques used in occupational health: mold assessment is the process of identifying the location and extent of the mold hazard in a structure, and mold remediation is the process of removal and/or cleanup of mold from an indoor environment.
- **RoHS**: The Restriction of Hazardous Substances Directive 2002/95/EC, RoHS, short for Directive on the restriction of the use of certain hazardous substances in electrical and electronic equipment.
- **RoHS Compliance:** The definition and aim of the RoHS directive is quite simple. The RoHS directive aims to restrict certain dangerous substances commonly used in electronic and electronic equipment. Any RoHS compliant component is tested for the presence of Lead (Pb), Cadmium (Cd), Mercury (Hg), Hexavalent chromium (Hex-Cr), Polybrominated biphenyls (PBB), and Polybrominated diphenyl ethers (PBDE). For Cadmium and Hexavalent chromium, there must be less than 0.01%

of the substance by weight at raw homogeneous materials level. For Lead, PBB, and PBDE, there must be no more than 0.1% of the material, when calculated by weight at raw homogeneous materials. Any RoHS compliant component must have 100 ppm or less of mercury and the mercury must not have been intentionally added to the component. In the EU, some military and medical equipment are exempt from RoHS compliance.

- **Sea state**: In oceanography, a sea state is the general condition of the free surface on a large body of water—with respect to wind waves and swell—at a certain location and moment. A sea state is characterized by statistics, including the wave height, period, and power spectrum. The sea state varies with time, as the wind conditions or swells conditions change. The sea state can either be assessed by an experienced observer, like a trained mariner, or through instruments like weather buoys, wave radar or remote sensing satellites.
- **IP**: The IP Code, Ingress Protection Rating, sometimes also interpreted as International Protection Rating, classifies and rates the degree of protection provided against the intrusion of solid objects (including body parts such as hands and fingers), dust, accidental contact, and water in mechanical casings and with electrical enclosures. It is published by the International Electro technical Commission (IEC).
- **SIXSIGMA**: Six Sigma is a set of strategies, techniques, and tools for process improvement. It was developed by Motorola in 1981. Six Sigma became famous when Jack Welch made it central to his successful business strategy at General Electric in 1995, today; it is used in many industrial sectors.
- **Drop Test:** a test of the strength of an object, in which it is dropped under standard conditions or a set weight, is dropped on it from a given height.
- **Grounding**: In electrical engineering, ground or earth (symbol) can refer to the reference point in an electrical circuit from which voltages are measured, a common return path for electric current, or a direct physical connection to the Earth.
- **Zero Halogen**: Low smoke zero halogen or low smoke free of halogen (LSZH or LSOH or LS0H or LSFH or OHLS) is a material classification typically used for cable jacketing in the wire and cable industry. LSZH cable jacketing is composed of thermoplastic or thermo set compounds that emit limited smoke and no halogen when exposed to high sources of heat.
- **E.S.S**: Environmental stress screening (ESS) is the process of exposing a newly manufactured or repaired product or component (typically electronic) to stresses such as thermal cycling and vibration in order to force latent defects to manifest themselves by permanent or catastrophic failure during the screening process. The surviving population, upon completion of screening, can be assumed to have a higher reliability than a similar unscreened population.
- **JSS 55555**: These JSS - Joint Services Specifications are made by and used by defense for quality. JSS 55555 also known as JSS Penta Five is for environmental specifications. You can also find many different numbers like Penta Five which is for other quality specifications.

- **MIL STD 461-E**: MIL-STD-461 is a United States Military Standard that describes how to test equipment for electromagnetic compatibility. Various revisions of MIL-STD-461 have been released. Many military contracts require compliance to MIL-STD-461E. The latest revision (as of 2013) is known as "MIL-STD-461F".
- **Naval Science & Technological Laboratory**: **NSTL**, Visakhapatnam was established on August 20, 1969 to undertake research and development of complete major naval systems (Underwater Mines, Torpedoes, Fire Control Systems, Weapon Launchers, Targets, Decoys, etc) for the Indian Navy to make it self-reliant.
- **Failure analysis**: it is the process of collecting and analyzing data to determine the cause of a failure. It is an important discipline in many branches of manufacturing industry, such as the electronics industry, where it is a vital tool used in the development of new products and for the improvement of existing products. There are many companies which provide services to find the cause of failure in products, devices and in post disaster situations. The failure analysis process relies on collecting failed components for subsequent examination of the cause or causes of failure using a wide array of methods, especially microscopy and spectroscopy. The NDT or non-destructive testing methods are valuable because the failed products are unaffected by analysis, so inspection always starts using these methods.
- **Corrective action and preventive action (CAPA)**: CAPA are improvements to an organization's processes taken to eliminate causes of non-conformities or other undesirable situations. CAPA is a concept within good manufacturing practice (GMP). It focuses on the systematic investigation of the root causes of non-conformities in an attempt to prevent their recurrence (for corrective action) or to prevent occurrence (for preventive action) corrective actions are implemented in response to customer complaints, undesired levels of internal nonconformity, nonconformities identified during an internal audit or adverse or unstable trends in product and process monitoring such as would be identified by SPC. Preventive actions are implemented in response to the identification of potential sources of non-conformity. To ensure that corrective and preventive actions are effective, the systematic investigation of the root causes of failure is pivotal. CAPA is part of the overall quality management system (QMS).
- **Product life cycle**: is a business analysis that attempts to identify a set of common stages in the life of commercial products, in other words the 'Product Life cycle' PLC is used to map the lifespan of the product, i.e. the stages through which a product goes during its lifespan for example, introduction, promotion, growth, maturity and decline.
- **Bathtub Curve**: The bathtub curve is widely used in reliability engineering. It describes a particular form of the hazard function which comprises three parts. The first part is a decreasing failure rate, known as early

failures:
1) The second part is a constant failure rate, known as random failures.
2) The third part is an increasing failure rate, known as wear-out failures.
The name is derived from the cross-sectional shape of a bathtub.

- **Anthropometry**: (Greek anthropos - "man" and metron - "measure"; therefore "measurement of man") refers to the measurement of the human individual. An early tool of physical anthropology, it has been used for identification, for the purposes of understanding human physical variation, in paleoanthropologists and in various attempts to correlate physical with racial and psychological traits.
- **Ergonomics (or human factors):** is the scientific discipline concerned with the understanding of the interactions among humans and other elements of a system, and the profession that applies theoretical principles, data and methods to design in order to optimize human well being and overall system performance.

APPENDICES

1. Environmental Stress Screening (Typical)

Sl. No.	Test	Applicability	Severity
1.1	*Thermal Shock*	*Assembled , wired PCBs /Modules*	*i)For PCBs -40℃……60 minutes +70℃……60 minutes Change over to take place within 03 minutes. Number of cycles 06. Note: Care to be taken while handling PCBs with ESD devices.*
1.2	*Vibration*	*Assembled , wired PCBs /Modules*	*Random Vibration: 20 – 2000Hz, 0.02g2/Hz in X, Y axes, for 10 minutes in each axis*
1.3	*Endurance (Burn-in)*	*The equipment/ system is to be subjected to endurance test post FATS*	*8 hours at room temperature, with equipment ON and at full load.*

2. Environmental Tests (Typical)

	TEST	CONDITION & DESCRIPTION	REMARKS
2.1	*VIBRATION*	*Freq range: 5 to 33Hz, Amplitude ±0.125mm, Constant Displacement, No. of axes: X, Y, Z, Duration: 1hour in each axis, Tests carried out with shock mounts.*	*The equipment should be in switched on condition. Visual inspection and functional check after the test.*
2.2	*HIGH TEMP*	*a) Operation at 50℃±3° for a period of 16 hours. Functional check during last ½ hr. b) Storage at 70℃±3℃ for a period of 16 hours. Functional check at room temp after completion of the test.*	*a) The equipment should be in switched on condition during the test. Functional check in the last ½ hr. b) The equipment should be in switched off condition during the test.*
3 2.3	*DAMP HEAT*	*The temp and relative humidity 40℃±2℃ at 95%RH. Test duration 16 hours. Functional check during last ½ hr.*	*The equipment should be in switched off condition during the test and switched on for functional check during last ½ hr.*
4 2.4	*LOW TEMP*	*Test condition H: - 10℃±3° for a period of 16 hours. Functional check during last ½ hr.*	*The equipment should be in switched off condition during the test and switched on. for functional checks during last ½ hr.*
6 2.5	*DRIP PROOF*	*Duration 15 Minutes*	*The equipment should be in switched ON condition during the test.*
2.6	*MOULD GROWTH*	*Duration 28 days*	*Test will be conducted on sample parts of the equipment*
2.7	*COROSSION (SALT FOG) TEST*	*(To determine the suitability of Eqpt for use and/or storage in salt laden atmosphere)*	*Test will be conducted on sample parts of the equipment*
2.8	*SHOCK TEST*	*Pulse Shape : Half sine wave. Peak Accl : 50g, 11 msec in vertical, 22g, 11 msec in horizontal directions Axis : All 3 axis ,Tests carried out with shock mounts.*	*The equipment should be in switched off condition. Visual inspection and functional check after the test.*

3. EMI/EMC TESTS AS PER MIL STD 461 D/E (Typical)

TABLE IV. Emission and susceptibility requirements.

Requirement	Description
CE101	Conducted Emissions, Power Leads, 30 Hz to 10 kHz
CE102	Conducted Emissions, Power Leads, 10 kHz to 10 MHz
CE106	Conducted Emissions, Antenna Terminal, 10 kHz to 40 GHz
CS101	Conducted Susceptibility, Power Leads, 30 Hz to 150 kHz
CS103	Conducted Susceptibility, Antenna Port, Intermodulation, 15 kHz to 10 GHz
CS104	Conducted Susceptibility, Antenna Port, Rejection of Undesired Signals, 30 Hz to 20 GHz
CS105	Conducted Susceptibility, Antenna Port, Cross-Modulation, 30 Hz to 20 GHz
CS109	Conducted Susceptibility, Structure Current, 60 Hz to 100 kHz
CS114	Conducted Susceptibility, Bulk Cable Injection, 10 kHz to 200 MHz
CS115	Conducted Susceptibility, Bulk Cable Injection, Impulse Excitation
CS116	Conducted Susceptibility, Damped Sinusoidal Transients, Cables and Power Leads, 10 kHz to 100 MHz
RE101	Radiated Emissions, Magnetic Field, 30 Hz to 100 kHz
RE102	Radiated Emissions, Electric Field, 10 kHz to 18 GHz
RE103	Radiated Emissions, Antenna Spurious and Harmonic Outputs, 10 kHz to 40 GHz
RS101	Radiated Susceptibility, Magnetic Field, 30 Hz to 100 kHz
RS103	Radiated Susceptibility, Electric Field, 2 MHz to 40 GHz
RS105	Radiated Susceptibility, Transient Electromagnetic Field

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