Indian Journal of Engineering & Materials Sciences
Vol. 5, June 1998, pp. 121-123

Influence of environmental factors on component/equipment reliability

S U M Rao
National Physical Laboratory, Dr K S Krishnan Road, New Delhi 110 012, India

Received 1 July 1997; accepted 26 March 1998

Electronic/electrical equipments and materials are expected to function in a variety of climates prevail around the world. Deterioration of system can vary considerably depending on environmental conditions encounter. These factors invariably influence the quality, reliability and life of systems. This paper discusses various effects due to environmental factors on electronic and electrical systems.

Reliability assurance as a specific activity commenced about the year 1955. Its prediction has become essential in the present - day complex electronic/electrical systems which are used in transport, communication, industrial operation, military, medical, entertainment, research etc. The number of reasons[1] could be (a) assessment of the economics of a proposed system (cost of new equipment, spare parts, replacement, scheduled/unscheduled maintenance, downtime, support facility, technical/engineering overheads and penalties of failures), (b) assessment of the operational feasibility of the proposed system and (c) assessment of safety.

Reliability depends on circuit design, manufacturing technique, usage, environmental stresses, failure definition, operator skill and maintenance procedures. With time, the following factors have been recognised as an essential ingredient of reliability program[2-4]:

(i) Devices intended for use where maintenance and replacement are difficult or impossible, expensive and where reliability is imperative.

(ii) Performance of higher component densities in modern electronic systems.

(iii) Modelling failure inter-relationships of systems.

(iv) Obtaining realistic reliability test data for components and interconnections in a sufficient time to be useful.

(v) Effect of widely varying environmental conditions encountered during the useful life of item.

Electronic and electrical equipments and components are expected to function in a variety of climates like tropical/arctic/desert conditions, high altitude, radiation, including transport hazards and mechanical shocks[5]. These factors invariably influence the quality, reliability and life of electronic/electrical systems[6]. In this paper, the general effects of various environmental factors on electronic/electrical systems have been discussed.

Effect of Environmental Factors

The following sub-sections will cover various effects due to any one or a combination of climatic factors[2,3] may have on electronic/electrical equipments and materials.

Temperature - heat

Thermal ageing, oxidation—Loss of electrical quality/change of electrical properties like increase in power factor and decrease of dielectric strength, insulation failure.

Physical expansion—Structural failure, differential expansion of different materials can cause distortion of assemblies, rupturing of seals and wear or binding on moving parts.

Loss or change of viscosity, evaporation—Loss of lubrication properties, structural/mechanical failure (breakage or fracture, seizure).

Softening/melting—Internal temperature of equipment may approach a value where low melting point materials such as greases, protective compounds and waxes become soft or even begin to flow. This may lead to structural failure, physical breakdown or penetration of sealing may lead to internal electrical breakdown.

Chemical decomposition—Decomposition of organic material increases, rubber materials harden. This may change the initial physical or

electrical constants.

The ultimate cause of any of these effects can be physical or chemical change in the material and hence variation in characteristics of component. Excess temperature is perhaps the most destructive environmental factor associated with electronic/electrical components and equipments. Hence development of new stable materials for improved performance of component has been a continuous process.

Temperature cold/arctic condition

Increased viscosity, solidification, physical contraction—Structural failure (breakage or fracture). Mechanical failure due to loss of lubrication properties. Ordinary oils/greases will harden hence special low temperature oils and greases must be used.

Ice formation—Change of electrical properties due to different temperature co-efficients of various component parts such as capacitances, resistances and inductances.

Embrittlement—The effect of this is widespread occurring both in metallic and non-metallic materials. Loss of mechanical strength, cracking and fracture. Physical breakdown of sealing due to shrinkage and cracking leading to electrical breakdown.

Humidity - moisture

Moisture absorption, deposition of damp layers—Swelling, rupture of container and physical breakdown. Water is a good conductor and can act as a low resistance path on the insulation of electronic circuits. It has been observed that an ionized conducting film of water will form on the surface of a dielectric within a few seconds if the RH is 100%. This will lead to insulation breakdown, change of dielectric properties and external electrical failure like tracking, insulation flashover etc. Only a few materials such as silicones, polystyrene and some polymers can stop the formation of a continuous moisture film but have poor resistance to fungal growths.

Corrosion—Structural/mechanical failure. Interference with function, internal electrical failure and change of physical or electrical constants.

Electrolysis—Loss of electrical properties. Increased conductivity of insulators.

Loss of seals/penetration of sealing—Physical breakdown of sealing will lead to loss of electrical quality. A pressure seal must be incorporated in any component which has to be protected from high humidity. Edges of glass fibre material must be sealed to prevent moisture absorption by capillary attraction.

Altitude-high or low air pressure

(a) High Air Pressure :

Structural collapse—Breakage or fracture, external electrical failure like tracking, insulation flashover etc.

Physical breakdown of sealing—Loss of electrical quality like insulation, dissipation factor and electrical breakdown.

(b) Low Air Pressure

Expansion—Fracture of container/insulating materials. Explosive expansion possible.

Low dielectric strength of air—Insulation breakdown and flashover, corona and ozone formation.

Reduced cooling—Overheating and fire risk.

Desert condition

Surface deterioration—The high ambient temperature combined with heat dissipated by the components in the system can develop internal temperature well over 110°C. The UV solar radiation is of a much greater intensity in these regions.

Change of initial physical and electrical properties. The degradation of cable insulation will be considerably accelerated. The use of low melting point waxes should be avoided.

Clogging of parts due to dust or sand—Mechanical failure like seizure, wear or binding on moving parts.

Dehydration—The very low moisture content (<10% RH) of the atmosphere will cause plastics to warp; certain materials will loose tensile strength; and materials embodying paper will disintegrate.

Tropical condition - rain forest

Corrosion—Metals will corrode more rapidly and electrolyte action between dissimilar metals is considerably accelerated.

Distortion of materials—An increase in the absorbed moisture leads to swelling of materials and both electrical and mechanical breakdowns can

occur. Moisture absorbed by insulating material results in lowering of surface and volume resistivities.

Biological activity—One of the endproducts of humidity/deposition of damp layer is growth of fungi. All organic materials are liable to deteriorate owing to the presence of moisture and nutrient causing fungoid growths to form. The presence of mould/fungi/insects can be destructive to electrical and electronic equipments. Such biological activity on the surface of materials will form a low resistance path resulting in loss of electrical quality and causing insulation flashover or breakdown of circuit.

Sea - salty atmosphere

Corrosion—Structural/mechanical failure like breakage, fracture, seizure etc. Physical breakdown of sealing. Change of initial physical or electrical constants.

Deposition of damp layer—External electrical failure like tracking, insulation flashover etc.

Air - wind

Vibration, rocking and excessive movement—Structural failure like breakage or fracture. Physical breakdown of sealing may lead to electrical breakdown or loss of electrical quality.

Transportation/transit hazard

Shock, vibration, bump and drop—Structural collapse, loss of mechanical robustness, breakage, fracture, crack etc. Physical breakdown of sealing. Complete disconnection or intermittent electrical contact.

Contamination

Contamination occupies an important place among the various chemical/physical mechanisms that cause faults in electrical and electronic components. It can be responsible for loss of insulation resistance, warping of insulating materials, development of moulds, short circuits, unwanted/poor or intermittent contacts etc. Electrolytic impurities derived from flux residues and impure supporting materials lead to corrosion in the base of ceramic resistors. Electrochemical and electrolytic corrosion of textile covered wires, connectors due to presence of acids and soluble salts in the coverings. Corrosion by hydrochloric acid released from overheated PVC coverings. Contact corrosion due to formation of black sulphide films on relay contacts in industrial area. Atmospheric pollution produces a tarnish film on the contact surface which increases the initial contact resistance and hence causes heating of the contact, this heating accelerates corrosion.

These hazards must be countered by special care in the selection of resistant materials, sealing of components in containers filled with pure inert gas such as Nitrogen, regulation of environment and maintenance of low humidity, avoidance of gaseous and electrolytic contaminants, avoidance of some of the bimetal couples, encapsulation of parts in suitable synthetic resins, use of stoving paints in equipments, suitable packing material for storage or transit of equipment etc.

Conclusion

Deterioration of equipment and component parts can vary considerably in different regions of the world depending on climates, i.e., the tropical condition, particularly those area known as rain forests in which there are high temperature combined with high humidity; desert area, where the highest temperature occur with wide variation between day and night including airborne dust/sand and the atmosphere has a very low moisture content; the arctic conditions where very low temperature prevails for long periods; biological activities; altitude; salty atmosphere/contamination etc.

It is, therefore, essential that electronic/electrical systems are so designed that they can withstand the natural environmental factors and perform reliably over as wide an area as possible besides having a fairly long life. This is specially true of a vast country like India where extreme and severe conditions prevail in different parts.

References

1 Blanks H S, *Microelectron Reliab*, 12 (1973) 301-319.
2 Jowett C E, *Reliability of electronic components* (ILIFFE Books Ltd., London), 1986.
3 Dummer G W A & Griffin N B, *Environmental testing technique for electronics and materials* (Pergamon Press, Oxford), 1962.
4 Devaney J R, *SAMPE*, 21 (1989) 22-26.
5 Rowse A A, *Microelectron Reliab*, 13 (1974) 175-179.
6 Reynolds F H, *Reliability in electrical and electronic components and systems* (North - Holland, Amsterdam), 1982.