## Environmental Effects on Mechanical Design

<table>
<thead>
<tr>
<th>Environment</th>
<th>Principal Effects</th>
<th>Corrective Action</th>
<th>Description</th>
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</thead>
<tbody>
<tr>
<td>High Temperature</td>
<td>• Insulation deteriorates&lt;br&gt;• Aging (oxidation)&lt;br&gt;• Softening of materials&lt;br&gt;• Evaporation/drying&lt;br&gt;  - Outgassing&lt;br&gt;  - Reduced viscosity (lubricants)</td>
<td>• Minimize it (thermal design and cooling approach)&lt;br&gt;• Segregate it (mechanical insulation)&lt;br&gt;• Remove it (eliminate heat source in design)</td>
<td>Heat sources include electronic self-heating, friction (mechanical assembly), and ambient temperature.</td>
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<tr>
<td>Low Temperature</td>
<td>• Materials become brittle&lt;br&gt;• Increased viscosity (lubricants)&lt;br&gt;• Ice formation or condensation&lt;br&gt;• High heat loss&lt;br&gt;• Reduced chemical reactions&lt;br&gt;• Stiffening of shock mounts</td>
<td>• Introduce heating&lt;br&gt;• Improve mechanical insulation&lt;br&gt;• Use better materials (parameter/temperature matching)</td>
<td>Low temperatures are typically experienced in uncontrolled environments (temperature, altitude) or inadequately insulated equipment.</td>
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<td>Thermal Cycling</td>
<td>• Materials deformation&lt;br&gt;• Thermal/mechanical fatigue&lt;br&gt;• Creep resulting from a confined constant load&lt;br&gt;• Stress relaxation&lt;br&gt;• Ductile and brittle fractures&lt;br&gt;• Buckling</td>
<td>• Minimize or eliminate the mismatch of thermal expansion coefficients between adjacent materials (materials selection)&lt;br&gt;• Use appropriate mechanical design tolerances</td>
<td>Compatibility of the coefficient of thermal expansion (CTE) of adjacent materials determines susceptibility to thermo-mechanical failure modes.</td>
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<td>Thermal Shock</td>
<td>• Rapid expansion and contraction of equipment can cause:&lt;br&gt;  - Cracks&lt;br&gt;  - Seal failures&lt;br&gt;  - Ruptures&lt;br&gt;  - Parameter changes</td>
<td>• Minimize or eliminate CTE mismatches in adjacent materials&lt;br&gt;• Use appropriate mechanical design tolerances</td>
<td>High temperature gradients can be destructive, and typically result from transition of equipment between two environmental extremes.</td>
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<td>Mechanical Shock</td>
<td>• Interference between parts&lt;br&gt;• Permanent deformation due to overstress</td>
<td>• Use stronger materials (as stiff and light as possible)&lt;br&gt;• Use shock mounts&lt;br&gt;• Superstructure should be stiffer than supporting structure&lt;br&gt;• Use stiff supporting structure if system natural frequency is &gt;35 Hz&lt;br&gt;• Transmit, rather than absorb, energy</td>
<td>The sudden application of force, measured in G’s of acceleration and milliseconds duration. Can be caused by handling, transportation, gunfire, explosion and/or propulsion.</td>
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<td>Vibration</td>
<td>• Intermittent electrical contacts&lt;br&gt;• Touching/shorting of electrical parts&lt;br&gt;• Wire chaffing&lt;br&gt;• Loosening of hardware&lt;br&gt;• Component/material fatigue</td>
<td>• Stiffen mechanical structure&lt;br&gt;• Reduce moments of inertia&lt;br&gt;• Control resonant frequencies (raise or lower to reduce coincidence with equipment natural frequency)</td>
<td>Vibration isolation is the controlled mismatch of a product’s resonant and natural frequencies. It does not usually provide shock isolation. Shock mounts can increase vibration damage.</td>
</tr>
<tr>
<td>Humidity/Moisture</td>
<td>• Loss of electrical insulation (dielectric strength)&lt;br&gt;• Destruction of organic insulation (absorption and expansion)&lt;br&gt;• Corrosion of materials&lt;br&gt;• Acceleration of chemical action/reaction&lt;br&gt;• Aids fungus growth</td>
<td>• Use adequate seals&lt;br&gt;• Select moisture-resistant parts&lt;br&gt;• Use conformal coatings</td>
<td>Moisture coats material surfaces, absorbs sulfur dioxide (SO₂) or other corrosive agents, and attacks material surfaces.</td>
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# Environmental Effects on Mechanical Design (Cont’d)

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| High Altitude/Vacuum | • Induced damage due to pressure differential within a product  
• Evaporation/drying due to outgassing  
• Forms corona (arcing)  
• Generates ozone  
• Reduces electrical breakdown voltages  
• Chemical changes within organic materials (primarily rubber) | • Increase mechanical strength or improve venting  
• Pressurize equipment  
• Improve heat transfer  
• Minimize use of organic materials  
• Properly insulate high voltage components | The primary objectives are to design equipment that can be stored and operated at high ground evaluation points and can survive a rapid decompression without damage to an aircraft or its personnel. |
| Sand and Dust        | • Failure of lubricants  
• Erosion and wear of machine/bearing surfaces  
• Jamming of threaded devices  
• Clogging of orifices  
• Lenses and windows become etched, effecting signal transmission and/or operator visibility  
• Acids are formed if moisture is absorbed  
• Collects at high static potential points, forming ionization paths | • Use air filtering  
• Use hermetic seals  
• Use protective enclosures/coatings | Equipment should resist the penetration of small-particle sand into cracks, crevices, bearings and joints. Equipment should withstand blowing sand (149 to 850mm particle size) without degradation of its performance, effectiveness, reliability or maintainability. |
| Salt Spray/Fog       | • Combines with water to form acidic/alkaline solutions  
• Accelerates corrosion of metals  
• Increases galvanic action of metals | • Use protective coatings  
• Avoid use of dissimilar metals  
• Hermetic seals | Salt is a highly pervasive chemical compound found in the oceans, the atmosphere, ground surfaces, lakes and rivers. All equipment may be exposed to some form of salt during its life cycle. |
| Electromagnetic Radiation | • Equipment may generate electromagnetic interference affecting other equipment (radiated electromagnetic interference (EMI))  
• Equipment performance may be susceptible to electromagnetic interference generated from another source (EMI susceptibility) | • Use EMI shielding and decoupling techniques, i.e., Faraday cage  
• Use proper grounding and bonding techniques (avoid ground loops)  
• Use proper signal filtering, power isolation and conditioners, and frequency allocation and control techniques | Radiation includes radiated and conducted emissions, and can include interference between two equipments, or within one equipment. Radiation can be natural (e.g., lightning) or man-made. |

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**Source:**

**For More Information:**
- RAC Publication, NPS, *Mechanical Applications in Reliability Engineering*. 

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