# Comparison of the Environmental Tests of MIL and IEC Standards for the Betavoltaic Battery

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## 1. Introduction

Recently, new energy sources are being developed for the battery applications. Among them, the radioisotope-based battery is one of the nuclear batteries, which directly convert the power of nuclear radiation into electricity. Among those, the betavoltaic battery is of particular interest due to the prospects for use in microelectromechanical systems [1]. However, there is no standard for measuring the betavoltaic battery environmental performances.

In this study, the comparison between the standards (MIL-STD and IEC standards) for the environmental tests of the betavoltaic battery is shown, which will provide the useful information to the industry. Furthermore, it will be of great help to researchers who apply it to the environmental tests.

## 2. Comparison among the standards

The environmental tests for the battery performance are conducted through standardized methods so that the same results can be obtained even if the location, equipment, tester, process, environmental condition and time are different. The environmental test standards are standardized by international, national, and organizational standards such as IEC, ISO, KS and MIL.

The standardized methods for the environmental tests of the betavoltaic battery are as shown in Table 1.

Table 1. The applicable standard for the betavoltaic battery

| No. | Related standards | Application |
|---|---|---|
| 1 | IEC 60086 series | · Primary battery<br>: No rechargeable |
| 2 | IEC 62133 series | · Secondary battery<br>: Rechargeable through PMIC |
| 3 | MIL-STD-810 | · Primary/secondary battery<br>: low energy sensor, missile and monitoring sensor of military equipment |

IEC standard is applied to all general electrical and electronic equipment, and MIL standard is mainly applied to military equipment.

### *2.1. IEC 60086 series*

IEC 60086 provides fundamental requirements and information on primary cells and batteries. In this sense, IEC 60086-1 [2] is the main component of the IEC 60086 series and forms the basis for the subsequent parts. The main composition of the IEC 60086 series is as follows.

a) Primary battery - IEC 60086-1 and IEC 60086-2 [3] specify primary batteries with respect to dimensions, nomenclature, terminal configurations, markings, test methods, typical performance, safety and environment aspects.
b) Primary battery with aqueous electrolyte for watch battery - 60086-1, IEC 60086-3 [4] and IEC 60086-5 specify primary watch batteries with aqueous electrolyte. IEC 60086-3 specifies dimensions, designations, test methods, and requirements for the primary batteries of watches.
c) Primary lithium battery - IEC 60086-1, IEC 60086-2 and IEC 60086-4 [5] specify primary lithium batteries. IEC 60086-4 specifies tests and requirements for primary lithium batteries to ensure their safe operation under intended use and reasonably foreseeable misuse.
d) Primary battery with aqueous electrolyte - IEC 60086-1, IEC 60086-2 and IEC 60086-5 [6] specify primary batteries with aqueous electrolyte. IEC 60086-5 specifies tests and requirements for primary batteries with aqueous electrolyte to ensure their safe operation under intended use and reasonably foreseeable misuse.

### *2.2 IEC 62133 series*

IEC 62133 series [7]-[8] specifies requirements and tests for the safe operation of portable sealed secondary cells and batteries containing alkaline or non-acid electrolyte under conditions of both intended use and reasonably foreseeable misuse. IEC 62133 series are mainly for the safety requirements of a single battery and battery packs and portable sealed only cell batteries and battery packs containing alkaline or non-acid electrolytes.

IEC 62133 standard includes test and validation of the following items.

a) cell: continuous low-rate charging, vibration, temperature cycling, external short circuit, free drop, shock, thermal misuse, extrusion, low pressure, overcharging, forced discharge, high-rate charge protection function, labeling and packaging, incorrect installation.
b) battery: vibration, high temperature case stress, temperature cycling, external short circuit, free drop, impact, labeling and packaging, overcharge.

### *2.3 MIL-STD-810*

MIL-STD-810 [9] is an equipment test standard by the United States Department of Defense (DoD). It describes detailed test procedures designed to determine how equipment holds up under a variety of conditions-such as temperature, impact, vibration and humidity-the equipment may encounter while being used, transported and stored. The guidance and test methods of the MIL-STD-810 standard are mainly aimed at:

a) Define environmental stress sequences, duration, and levels of life cycles.
b) Develop analysis and test criteria adapted to the equipment and environmental life cycle.
c) To evaluate the performance of the equipment when it is exposed to the life cycle of environmental stresses.
d) Identify deficiencies and defects in equipment design, materials, manufacturing processes, packaging techniques and maintenance methods.

There are 29 main test methods mentioned in the MIL-STD-810 standard, including low pressure(altitude) and high temperature test methods.

### *2.4 Comparison of the environmental test items*

The environmental testing items for the IEC and MIL standards reviewed in the above section are as follows (Table 1).

Table 1. The environmental test items

| Test item | IEC 60086 series | IEC 62133 series | MIL-STD-810 |
|---|---|---|---|
| Low Pressure (Altitude) | ○ | | ○ |
| High Temperature | | | ○ |
| Low Temperature | | | ○ |
| Temperature Shock | | | ○ |
| Contamination by Fluids | | | ○ |
| Solar Radiation (Sunshine) | | | ○ |
| Rain | | | ○ |
| Humidity | | | ○ |
| Fungus | | | ○ |
| Salt Fog | | | ○ |
| Sand and Dust | | | ○ |
| Explosive Atmosphere | | | ○ |
| Immersion | | | ○ |
| Acceleration | | | ○ |
| Vibration | ○ | ○ | ○ |
| Acoustic Noise | | | ○ |
| Shock | ○ | ○ | ○ |
| Pyroshock | | | ○ |
| Acidic Atmosphere | | | ○ |
| Gunfire Shock | | | ○ |
| Combined Environments | | | ○ |
| Icing/Freezing Rain | | | ○ |
| Ballistic Shock | | | ○ |
| Vibro-Acoustic/ Temperature | | | ○ |
| Freeze / Thaw | | | ○ |
| Time Waveform Replication | | | ○ |
| Rail Impact | | | ○ |
| Multi-Exciter Test | | | ○ |
| Mechanical Vibrations of Shipboard Equipment | | | ○ |
| External short circuit | ○ | ○ | |
| Overcharge | ○ | ○ | |
| Impact | ○ | | |
| Crush | ○ | | |
| Forced discharge | ○ | | |
| Abnormal charging | ○ | | |
| Thermal abuse | ○ | | |
| Incorrect installation | ○ | | |
| Overdischarge | ○ | | |
| Case Stress | | ○ | |
| Free Fall | ○ | ○ | |
| Temperature Cycling | ○ | ○ | |

Note:
1. Test items are written in the MIL-STD-810, and if the test configuration of the IEC standard is similar, it is regarded as the same test.
2. The test items of each standard were written based on the battery, not the cells.
3. The test items of IEC 62133 include nickel and lithium systems.

The detailed requirements of the test items of each standard listed in Table 1 are different, and the MIL-STD-810 requires the tailoring guidance (method, procedure, test level and condition) of the life cycle environmental profile (LCEP) for each test item.

In order to determine the environmental test of the betavoltaic battery, the following should be considered.

a) The operational purpose and application of betavoltaic battery
b) The system requirement
c) The natural exposure circumstances
d) Other major considerations

Next, after selecting the proper standard, proceed with the test method specified in the standard. An example of the environmental test facility is shown in Fig. 1.


(a) Altitude chamber


(b) Vibration test



(c) High/low temperature, humidity, low pressure (altitude), temperature shock, salt spray, waterproof and dustproof test, etc


(d) Vibration, shock, impact, drop, durability and head impact test, etc

Fig. 1. The environmental test facility (HCT Co., Ltd.)

## 3. Results and Discussion

In this study, we researched the standards available for environmental test of betavoltaic battery. The representative standards are IEC 60086 series, IEC 62133 series and MIL-STD-810. Next, the environmental test items of the IEC and MIL standard were compared. The environmental tests should be conducted after selecting an appropriate standard in consideration of the purpose and requirements of the betavoltaic battery.

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[2] IEC 60086-1:2021, Primary batteries - Part 1: General.
[3] IEC 60086-2:2021, Primary batteries - Part 2: Physical and electrical specifications.
[4] IEC 60086-3:2021, Primary batteries - Part 3: Watch batteries.
[5] IEC 60086-4:2019, Primary batteries - Part 4: Safety of lithium batteries.
[6] IEC 60086-5:2021, Primary batteries - Part 5: Safety of batteries with aqueous electrolyte.
[7] IEC 62133-1:2017, Secondary cells and batteries containing alkaline or other non-acid electrolytes - Safety requirements for portable sealed secondary cells, and for batteries made from them, for use in portable applications - Part 1: Nickel systems.
[8] IEC 62133-2:2017+AMD1:2021, Secondary cells and batteries containing alkaline or other non-acid electrolytes - Safety requirements for portable sealed secondary cells, and for batteries made from them, for use in portable applications - Part 2: Lithium systems.
[9] MIL-STD-810H, Department of Defense Test Method Standard for Environmental Engineering Considerations and Laboratory Tests, Department of Defense, 2019.