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AIRWORTHINESS OF LITHIUM BATTERIES. PART 1 - DEVELOPMENT OF AN AIRWORTHINESS STANDARD

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AIRWORTHINESS OF LITHIUM BATTERIES
PART 1 - DEVELOPMENT OF AN AIRWORTHINESS STANDARD

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ABSTRACT

In the Air element of the Canadian Forces lithium batteries have been used since 1979 in three types of search and rescue beacons: Emergency Locator Transmitter (ELT), Personal Locator Beacon (PLB) and Crash Position Indicator (CPI). While the experience with lithium batteries in aircraft equipment has been limited, the possibility for serious safety hazards was recognized early and steps were taken to establish control over the process whereby lithium batteries were introduced. During that time there have been no operational safety incidents related to lithium batteries. This paper will discuss the approach being taken to develop an airworthiness standard for lithium batteries for use in Canadian military aircraft.

INTRODUCTION

Characteristics of Lithium Batteries

The characteristics of lithium batteries which make them very desirable for use in beacon batteries are long shelf life, good low temperature performance and high specific energy. The light weight and high voltage of the lithium electrode are responsible for the high specific energy. It is the high chemical reactivity of lithium which results in the instantaneous formation of a protective surface film, producing a low rate of self discharge; i. e. good shelf life. The performance of lithium batteries is not uniform, but differs according to the type and is influenced by the properties of the electrolyte and cathode materials, as well as the different design types: active, reserve, thermal, low rate and high capacity to note a few. For example, not all lithium batteries have excellent rate capability at low temperature.

For search and rescue beacon batteries the Li/SO_2 battery type has many of the advantages noted above, yet it has a tolerable voltage delay effect even after several years of storage. It has very good shelf life and excellent low temperature performance, even at reasonably high rates of discharge, superior in this respect to most other types of lithium battery.

Potential Hazards

The potential for hazardous behaviour is one of the main disadvantages of lithium batteries. It was recognized as such early in the use of lithium batteries, and incidently, in Canadian aviation where some of the first ELT incidents occurred in the

1970s. Two properties are responsible for the potential safety hazard; the nature of the contents and the specific energy. The latter is simple in concept; when energy is confined to a small volume there can be danger if it is released in an uncontrolled manner. A measure of this is the energy release of a 10 Ah Li/SO_2 cell that can be as much as the equivalent of 30 g of TNT (Våland and Eriksen, 1982). While it has been shown that in strict technical terms lithium batteries do not explode - they deflagrate, the term explosion is used to characterise the hazardous incidents which occur from time to time. The cell contents which are often highly reactive, toxic, corrosive etc. can harm people and equipment in safety incidents. The consequences of a lithium cell venting are unpleasant; choking fumes, smoke and fire. In aircraft, such incidents can result in the loss of pilot control and may lead to a crash. An ELT battery which vented in a small private airplane in California many years ago was responsible for asphyxiation of the pilot and passengers who were dead before the aircraft hit the ground.

The potential hazard requires careful consideration, respect and attention by all users if the benefits promised by this technology are to be exploited. A reasonable level of safety can be attained through using good operating practices coupled with high quality, reliable products whose safety limitations are known. This undertaking involves the expense of investing in knowledge and experience. It is the concern for safety which mandates the use of standards for lithium batteries to promote awareness of the possible dangers associated with their misuse and abuse, both accidental and intentional.

THE AEROSPACE ENVIRONMENT

Vibration Effects

The aviation environment is special and therefore requires added caution in applying lithium battery technology. The experience of the Canadian Forces with developing a beacon battery for the PLB can provide a useful example. By 1980 there had been a number of improvements in design, materials and manufacturing processes for the Li/SO_2 cell which had largely resolved the safety problems experienced in ELTs in the previous decade. During production of a PLB Li/SO_2 battery in 1985, a series of what appeared to be trivial engineering problems were encountered by the manufacturer. After assurances that all problems had been resolved, the entire lot of beacon batteries was accepted for evaluation. Samples were subjected to a test programme that required environmental conditioning appropriate to avionics: e.g. shock, vibration, exposure to moisture, salt water immersion, etc. When the batteries were discharged after vibration testing, many of them exploded. A laboratory study found that the cell was prone to vibration-induced damage at the cold-welded, lithium electrode tab. The battery package had not been specifically designed to dampen high frequency vibrations. In fact, during testing the battery package displayed resonances which amplified the applied vibrational forces by as much as ten-fold. It became obvious that the problems which had been encountered prior to production were in fact not trivial, but were due to a lack of appreciation for the severity of the vibrational conditions found in aircraft and how they affected the safety of both the cells and the battery.

At that time, Li/SO_2 cells of similar construction were being used in Canadian Forces' ELT batteries. Several batteries that were installed in military aircraft were examined and found to have the same kind of vibration-induced cell defects as the production lot of PLB batteries, i. e. the lithium electrode was torn at the cold-welded connection to the cell casing. This evidence proved that in actual aircraft operations vibrational damage was being inflicted on this particular design of cell. The fault was real and a potential hazard was present. As a safety precaution therefore, all ELT batteries were removed from service in 1985 and replaced by alkaline batteries. The electrochemical mechanism for the lithium sulphur dioxide cell explosions was studied in detail and was presented at the 17th International Power Sources Symposium (Donaldson et al., 1991).

Other Aerospace Conditions

There is more to the aircraft environment than intense mechanical shock and vibration. Equipment containing batteries must be able to survive thermal extremes as well as moisture, salt spray, immersion in water, and the low pressure of high altitude. The battery must survive in the environment and operate, often under conditions that are also severe, all without endangering the crew and aircraft. For example, an ELT battery must be carried for up to thousands of flying hours, survive a crash and then operate. A CPI battery must endure the conditions external to the aircraft, survive the crash and ejection from the aerofoil, land right-side-up and operate for 30 hours at -40°C. This is why aviation lithium batteries must be qualified to a standard that clearly recognizes the complete set of relevant environmental conditions.

A standard that has been in use since 1979 is the United States, Federal Aviation Administration's Technical Standard Order, known as TSO C97. While it is now outdated and was originally intended only for Li/SO_2 batteries, it has been widely used by the aviation industry for several kinds of lithium batteries. It was the main source of reference for developing an airworthiness standard for lithium batteries in the Canadian Forces. Other lithium battery standards have also been consulted: the British Standard (BSI G 239, 1987), the US Army specification for Li/SO_2 batteries (MIL-B-49430C(ER), 1991), and the RTCA special committee SC168 activities in developing a Minimum Operating Performance Standard (MOPS) for lithium batteries (MOPS, 1994).

Other Issues to Consider

There are many issues to be considered by those involved in developing a standard which attempts to give order to the process whereby lithium batteries are introduced. Cell and battery design are critical. It is important to know that there is a statistical variability amongst cells in spite of appearing identical and even being from the same production lot. A plot of the open circuit voltage against cell resistance clearly points to this fact as seen in Figure 1. The data were for Li/MnO_2 cells of the same size but from different manufacturers. The performance results can be expected to differ likewise as will be discussed in Part 2 of this paper (Austin and Farrington, 1995). The plotted data also confirm the fact that often it is not possible to find an interchangeable cell amongst manufacturers, especially if the battery design constraints are tight.

In aircraft equipment applications it is a concern whether a lithium cell should have a vent and if venting can be tolerated and under what circumstances. The need for off-board ventilation for venting gasses in aircraft installations must be considered even if the battery has circuit protection to preclude cell venting. Vibration damage to a cell can be very hazardous as discussed above. The production of cells with design deficiencies, such as the use of lithium cold-welded tabbing may recur, but is clearly a feature that is unsuited for use in high frequency vibration environments. From time to time electrode tabs are used that cannot survive in the highly corrosive, stressed electrochemical environment of the lithium cell. Stress-corrosion and embrittlement may be a problem in certain cell designs (Scully et al., 1991). Some cells have internal electrical fuses, using either the anode or cathode tab or fitted externally under a false end-cap. It is preferred not to have cell level fuses, because they make it impossible to assess the true nature of responses to safety testing. Fuses can be used at the battery level.

There continues to be a fear of lithium batteries in parts of the aviation community; sometimes amounting to paranoia. Some of the anxiety is traceable to the ELT incidents of the 1970s and has been reinforced by the safety events which have taken place since then. Furthermore, the severity of aircraft environmental conditions is not always well understood by users and by equipment and battery manufacturers. Some battery assemblers are not fully conversant with lithium battery technology and are prone to misinterpret information, exaggerate problems, mislead, confuse, etc.. A recent example is the use of shunt diodes for each cell in an ELT battery that consisted of two parallel strings of four cells in series. No blocking diodes were used for the parallel strings and as a consequence the battery exploded in a post office during shipping (Hasvold, 1994). Clearly the assembler misunderstood the essential use of the diode and over-reacted to a perceived safety hazard.

THE APPROACH TO DEVELOPING A STANDARD

In the Canadian Forces the process for qualifying a lithium battery for aviation consists of two steps; a development phase and the qualification, proper. The development phase examines the battery design in light of the environment in which it is to be used. Qualification consists of imposing a test plan to ascertain that the batteries that routinely will be procured by the supply system will in fact be made to the same quality and reliability as those of the development phase.

The approach is to experiment with cells first, then assemble prototype batteries to obtain a data base on performance as well as safety. This process yields a good knowledge of the cell and battery and thereby facilitates the establishment of a qualification test plan for batteries that has been kept as small as possible. The plan is designed to measure only those few elements which are established as critical for acceptable performance and safety.

In the development stage the cell is chosen and its performance and safety are measured. Then prototype batteries are studied to learn as much as possible about their response to abuse and the various stresses as well as to identify those changes in performance that do not scale-up from the cell level. In agreement with TSO C97, importance is given to ascertaining that potting is effective, but does not inhibit the cell vents nor create thermal management problems. Other TSO C97 tests were investigated, and some were rejected as either irrelevant or unrealistic for beacon batteries. Thus batteries were not force discharged into voltage reversal using an electronic power supply. Fuses and diodes were chosen to assure safety and protection of the battery, but mindful of the implications regarding the levels for setting the rate of discharge for electrical abuse tests. The battery drop test was carried out to assure a rugged package design, but it was not called for again in qualification.

Safety Design Criteria

The need for protective devices such as fuses, diodes and thermal fuses has been undertaken with awareness for the special hazards posed by lithium batteries. In search and rescue beacon applications it is intolerable that the failure of a fuse could further risk the life of downed aircrew, therefore PTC (positive temperature coefficient) devices are recommended rather than electrical fuses. Thermal fuses are not considered essential because of the extremely low discharge rates, i. e. typically 50 mA. Blocking diodes are used to protect parallel cell strings against charging and are required for batteries in equipment where the installation is connected to the aircraft dc power bus. The FAA standard requires shunt diodes when five cells or more are connected in series (TSO C97, 1979). This practice is no longer essential for most batteries because of improvements in cell design. The real risk is best assessed by conducting forced discharge testing of cells. A cell which poses a verified safety hazard in this test cannot qualify. Faulty shunt diodes may result in cells becoming depleted during lengthy storage. Such a risk is not acceptable for search and rescue beacon applications where long shelf life is highly desirable. In those battery applications in which high discharge rates and thermal management are factors, thermal fuses would be used.

Battery Performance Requirements

The development of the Crash Position Indicator (CPI) battery will be used as the example in describing the airworthiness testing for development and qualification phases. The CPI is a search and rescue beacon consisting of a radio beacon transmitter which is housed in a moulded fibre-glass shell. It is installed in the aircraft fuselage and is released either by the pilot or automatically via a crash sensing device. The CPI battery is a six-cell, lithium sulphur dioxide battery encapsulated in a rigid foam which is then sealed into the CPI unit. A blocking diode protects against the remote possibility of charging by the aircraft dc power bus, because the CPI also has a rechargeable nickel/cadmium battery to operate the dispenser mechanism. The current model of the CPI battery has a 1/2 A fuse, but a PTC device will be used in future. The beacon transmitter must operate within the temperature range: 55°C to -40°C for at least 30 hours at the lowest temperature. The output must rise above 12 volts within 30 seconds when discharged through a resistive load equal to 330 ohms. This performance must be maintained for at least five years during which time the battery is stored in its packaging at 25°C ± 5°C or installed in aircraft.

QUALIFICATION STANDARD

Safety Qualification Test Plan for Cells

A group of 54 samples is selected from a production lot of cells that are identical to those that will be used for battery assembly. The test plan block diagram is shown in Figure 2. It does not include performance testing since that would have been done beforehand when selecting the cell and developing a performance data base. Ten of the cells are selected for the hermeticity test, the purpose of which is to verify that leakage of SO_2 and other volatile contents will not occur. It is similar to the US Army's specification (MIL-B 49430, 1991) except for the maximum allowed weight loss which is 0.1% of the electrolyte mass. No failures are permitted.

Statistical data include the recording of serial numbers, date of manufacture, mass, open circuit voltage, resistance (ac measurement at 1 kHz). The crush test is done between the electrically insulated jaws of a vice in such a manner as to crush the cell but not interfere with the glass-to-metal seal or the pressure relief vent. To effect crushing, one jaw of the vice is fitted with a 1/4" dowel. Crushing is continued until the emf decreases below 2 volts and/or venting commences or the diameter of a cylindrical cell is reduced by 25%. The intent is to cause an internal short or initiate hydraulic venting and judge the seriousness of the event. There is no vibration, mechanical shock or altitude testing of cells. A reasonable knowledge of cell design and construction is considered sufficient for choosing candidate cells whose design is suited for use in aircraft applications.

Cells are short circuited in the undischarged as well as in the partially discharged state. Often the latter produces more energetic venting, because the original, compact anode surface film has been stripped, then regrown to some extent with an accompanying increase of surface area. The heating test is designed to prove that the vent functions properly at or before 130°C. The thermal shock test is done between extremes of 85° and -65°C which are the limits for avionics installations. Holding times are four hours at the high temperature and 20 hours at the lower, with a one hour maximum permitted for the change from one temperature to the other. Five cycles are conducted. The force over-discharge test is conducted at a rate equivalent to the fuse rating of the battery. The cell is maintained in voltage reversal for the equivalent of 100% of the capacity delivered above 0 volts. The continuity test requires opening cells that were discharged to 2 volts and examining the remains of the anode for isolated, unused portions and parts losing contact with the current collector. The coulombic ratio test is applicable to Li/SO_2 cells.

It is recognized that the cell testing plan requires a large group of cells. However, it is considered that a reasonable statistical basis is necessary to evaluate safety characteristics. The cell test plan attempts to minimize the number of test cells by not requiring testing that is done at the battery level. In this respect it is a compromise between more expensive battery, versus less costly cell testing.

Qualification Test Plan for Batteries

This qualification testing scheme shown in Figure 3 was greatly reduced in size as a result of the knowledge acquired in the battery development phase. The plan contains only those critical elements necessary to assure that the batteries are reliable reproductions of prototypes that were developed. Those critical elements were established beforehand in the development stage. The plan requires only eight batteries, two being kept as spares for the purpose of repeating any dubious results. Discharging is done only at the lowest specified temperature: -40°C, because slight decreases in performance are more easily detected than at higher temperatures. The battery is subjected to a standard military vibration test, based on MIL-STD-202, over the frequency range from 5 Hz to 2000 Hz with a maximum acceleration equal to 10 g. The test is conducted for a duration of three hours in each of the mutually orthogonal axes and is done before the shock test. The mechanical shock test of TSO C97 requires shock impulses equal to 100 g with duration 23 ± 2 milliseconds, applied in each direction successively along the three mutually orthogonal axes of the battery . The test laboratory was not able to achieve better than 85 g for 22 milliseconds. (QETE, 1994). This topic is discussed further in Part 2 of this paper (Austin and Farrington, 1995). In the altitude test the battery is subjected to atmospheric pressure in a vacuum chamber simulating an altitude equal to 15,000 m for a period of six hours. Upon completion of the vibration, shock and altitude tests the open circuit voltage is measured and must be within the normal range which was established in the battery development phase. Leakage, venting or swelling of the cells in the battery, or structural damage to the battery during any phase of the tests constitute failures.

The thermal shock test is the same as that done on the cell level. MIL-STD 202 is followed for the moisture resistance test. The batteries are cycled at 90% to 98% RH between 25°C and 65°C, holding for three hours at 65°C. The temperature is ramped within 2.5 hours. One cycle takes 16 hours; 10 cycles are conducted. Most search and rescue beacons are required to survive a short duration of salt water exposure. The battery is immersed in 3.5% w/w sodium chloride solution for 15 hours with its electrical terminals held out of the bath. After each of these three environmental tests, two batteries are withdrawn from the group and discharged. The test plan assures that at least two batteries are subjected to all the environmental conditions.

CONCLUDING REMARKS

The standard is based on the use of the Li/SO_2 battery system and would have to be modified for other types. It is not intended to stand alone, but needs to have technical expertise available to the military user, otherwise it would have become a long, repetitious, tedious, and consequently a costly exercise. Essentially, safety must be based on an adequate knowledge of lithium battery technology. This reduces risk to low and acceptable levels. A fault which cannot be protected against is a manufacturing defect, but that can be minimized by having a good data base upon which judgement can be made concerning product reliability.

One of the questions remaining is "Where does one draw the line?" In trying to minimize the type and number of qualification tests, it is important to be aware of compromises. How far can one compromise on safety in aerospace applications? Conducting elaborate test plans is expensive by virtue of the equipment and skilled people involved. Changes in cell/battery design - when do they necessitate re-qualification? What kinds and numbers of failures are allowed, and for what tests? How many cells/batteries are needed to assure safety? If one is sure of the technical expertise within the organization, it may be tolerable to permit a few test failures during qualification, knowing that one can keep an eye on things and remedy any risks if they develop later. However, the control for such action is soon lost with changes of personnel, changing structures, down-sizing, the transfer of responsibility from technical experts to supply/procurement organizations, etc. The struggle continues between a host of vested interests: cell manufacturers, battery assemblers, equipment manufacturers, government officials and regulators, airplane manufacturers, etc.

Another concern is the lack of uniformity in technical expertise and knowledge about lithium batteries amongst the parties involved. The standard developed here is for use by those who are knowledgable and experienced in lithium battery technology. A qualification standard that was written for the poorly informed or unconcerned would not meet the needs for good performance and safety of lithium batteries in military aircraft and would be costly in many ways.

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REFERENCES

Austin, P. R. and Farrington, M. D., (1995). "Airworthiness of Lithium Batteries - Part 2: Practical and Regulatory Issues in Aerospace Applications", proceedings 19th International Power Sources Symposium, Brighton, England, April 24-26, 1995.

BSI G 239:, (1987). British Standard Aerospace Series: "Specification for Primary active lithium batteries for use in aircraft",

Donaldson, G. J., Patraboy, T. J., Anderson, J. S. and Whyte, J.C., (1991). "Power Sources **13**", (T. Keily and B. W. Baxter, eds), International Power Sources Symposium Committee, Leatherhead, England, p. 363.

Hasvold, Ø.(1994). private communication, June 1994.

MIL-B-49430C(ER),(1991). Military Specification Batteries, Non-rechargeable, Lithium Sulfur Dioxide, 1 August 1991.

MIL-STD-202,(1980). Tests Methods for Electronic and Electrical Component Parts, Department of Defense, USA.

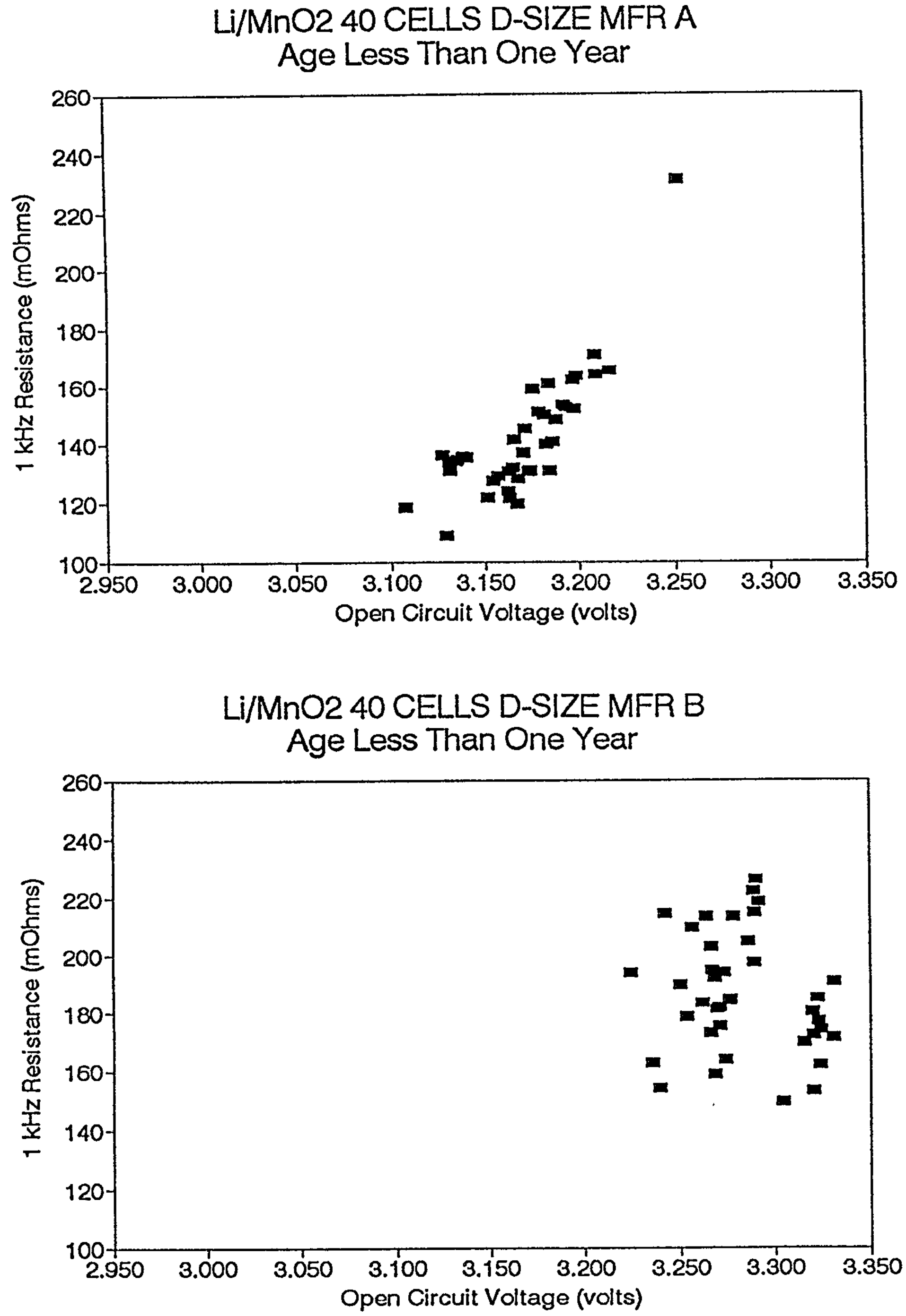
MOPS(1994). Minimum Operational Performance Standards for Lithium Batteries, Revised Final Draft dated June 30, 1994, RTCA Paper No. 258-94/SC168-101.

QETE (1994). "Environmental Testing of Prototype CPI Battery", Quality Engineering Test Establishment, Dept. National Defence, Ottawa, Project No. A025591.

Scully, J. R., Cieslak, W. R. and Bovard, F.S. (1991). J. Electrochem. Soc., **118,** 2229.

TSO C97 (1979). United States of America-Federal Aviation Administration, 14CFR Part 37, "Lithium Sulfur Dioxide Batteries TSO C97: Technical Standard Order Authorization, Published 27 August 1979".

Våland, T and Eriksen, S.(1982). J. Power Sources **7**, 365.



Li/MnO2 40 CELLS D-SIZE MFR A
Age Less Than One Year

Li/MnO2 40 CELLS D-SIZE MFR B
Age Less Than One Year

Figure 1: Graphical representation of open circuit voltage and resistance (at 1 kHz) for Li/MnO_2, D-size cells from two different manufacturers.

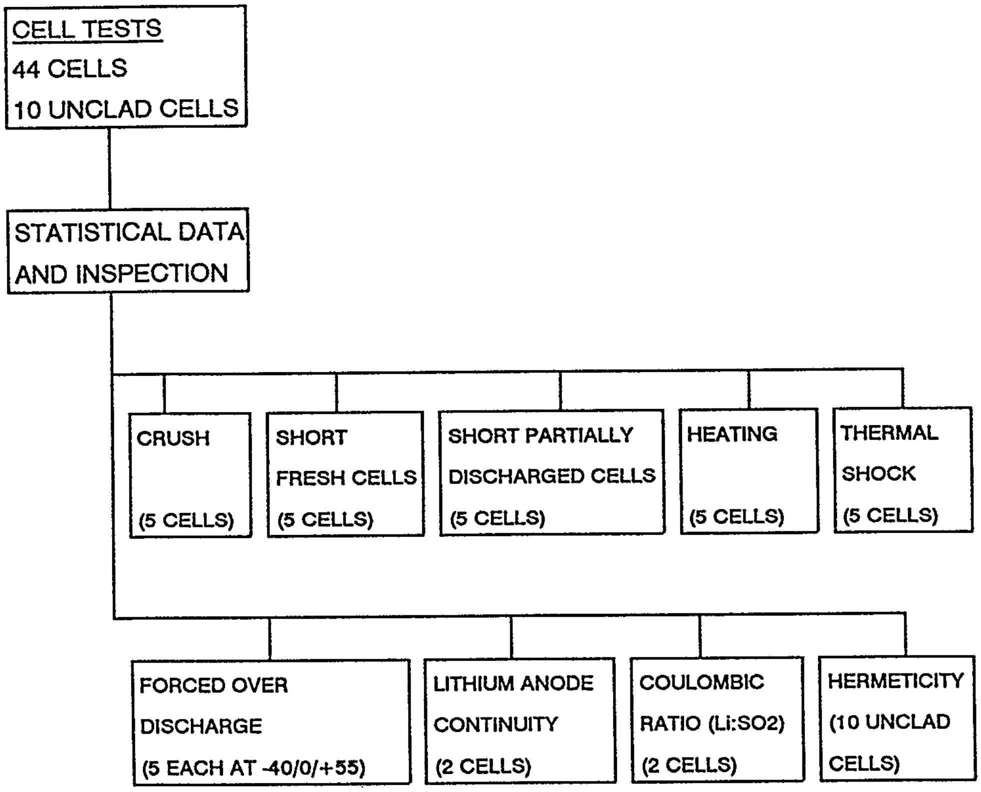


Figure 2: CPI Standard. Safety Qualification Test Plan for Cells.

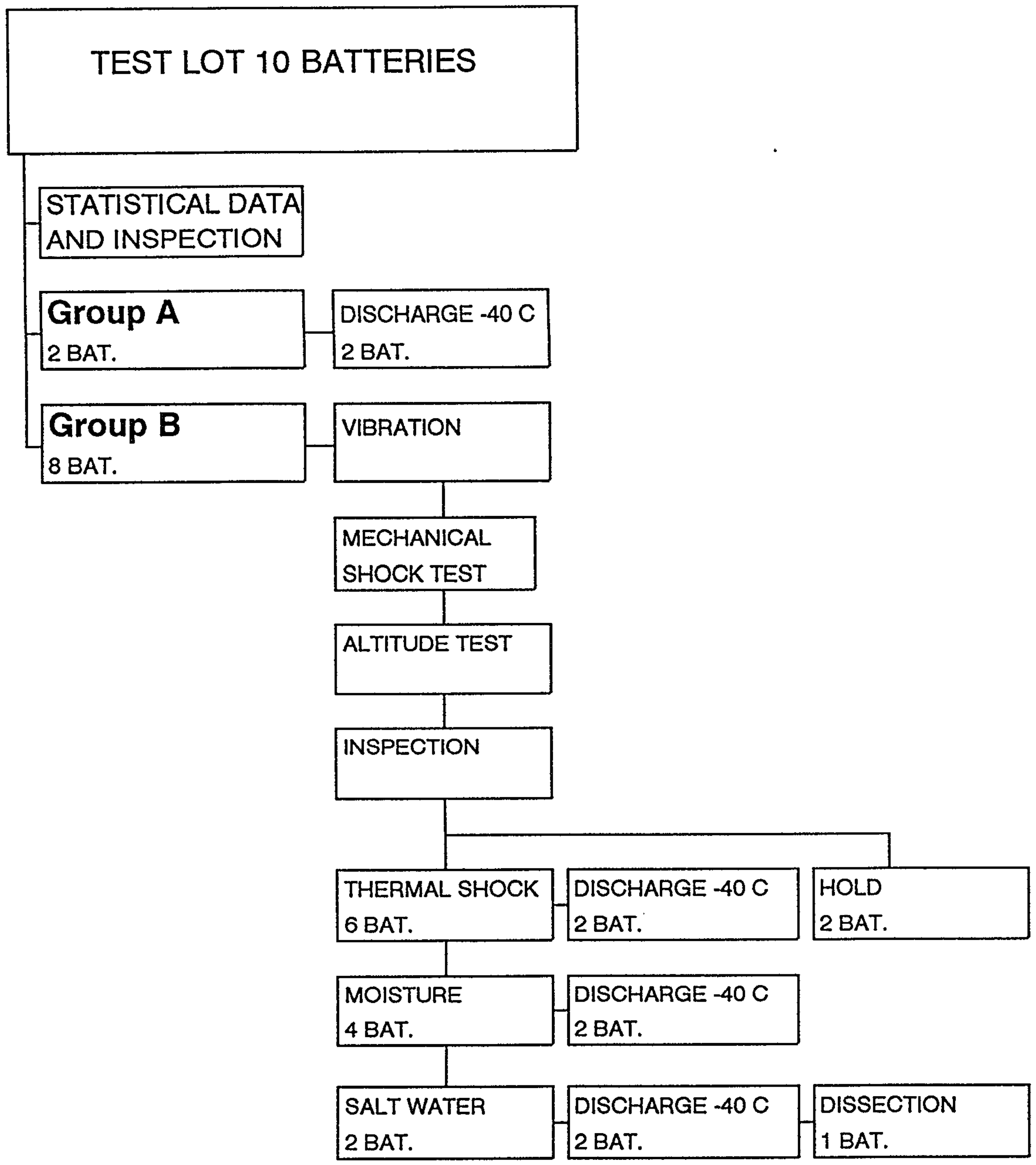


Figure 3: CPI Standard. Qualification Test Plan for Batteries.

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