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Guideline for the design and production of safe Lithium batteries for camera application

2nd edition

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Battery Association of Japan

Contents

Introduction

In August 1991, which is about six(6) years ago from now, we have published "A guideline for the safety evaluation of Lithium batteries for camera application", for the purpose of preventing further accidents from occurring which were caused by unsafe Lithium batteries used for camera application.

At that time, many fire accidents happened on the market by the cylindrical Lithium batteries which were used in full automatic cameras due to improper design of these Lithium batteries.

Consequently, it was a very important and urgent issue that battery industry as a whole should take necessary measures for the prevention of further accidents from occurring by Lithium batteries and to remove any uneasy feeling on Lithium batteries both by OEM customers and by general consumers.

So far each Lithium battery manufacturer had been separately working for the safety measures, but at that time, we have decided to accumulate necessary expertises on safety of Lithium battery from each manufacturer and to prepare a guideline on the following safety issues.

(1) Design principles for ensuring safety of Lithium batteries.
(2) Quality control items to ensure safety during mass-production of Lithium batteries.
(3) Safety tests and criteria of Lithium batteries.

After the publication of above guideline, number of safety accidents by Lithium batteries for camera application have significantly decreased since necessary expertises for the production of safe Lithium batteries were suitably shared by all battery manufacturers.

From several years ago, fire accidents by unsafe Lithium batteries have gradually increased in the market again.

These Lithium batteries seem to be mainly produced by new foreign Lithium battery manufacturers and they do not apparently seem to properly adopt necessary design principles of safe Lithium batteries which were disclosed in our above guideline.

As a result, we have judged it very important to more widely and popularly disclose necessary expertises on the design and production of safe Lithium batteries more in detail at this time than before.

We have reviewed the contents of our above guideline (1st edition) and come up with 2nd edition this time so that it can more widely and popularly be used than before, by many battery manufacturers and by many camera manufacturers, as well.

During the review of our guideline this time, we tried to harmonize the contents with those of IEC 60086-4, Safety standards of Lithium batteries, as much as possible.

Our basic principles of ensuring safety of Lithium batteries are based on following four measures ((a), (b-1), (b-2), (b-3)), which are explained in detail in Chapter 1-3.

(a)All batteries shipped from each manufacturer to the market should be safe and free from any uncertainty on safety. It means that all batteries with uncertainty on safety should be rejected at the final inspection before shipment by each manufacturer.

(b)When a Lithium battery used in camera becomes unsafe and comes to catch fire, following measures should be taken to avoid any big accident.

(b-1) Fire is stopped inside of the battery.

(b-2) Battery is damaged but the camera is not damaged.

(b-3) Camera is also damaged but it does not lead to an accident of injury or of big fire.

In chapter 4 Safety tests and criteria, we explained the criteria of discrimination between safe batteries and unsafe batteries, based on various safety evaluation tests.

As is the same for such safety evaluation tests, these tests can judge the safety level of each production lot but all production defects from all production lots ("defects of ppm order") cannot be rejected by these tests.

We reasonably assume that it is a task for each battery manufacturer to minimize the number of defects in each production lot ("variation of defects") by its own production engineering technologies and expertises which cannot be specified in detail in design principles or in quality control items.

i.e. This guideline discloses important and basic principles which are necessary to be observed to increase safety level of Lithium batteries but it does not guarantee that all batteries from each manufacturer are safe if the contents of this guideline are observed.

It is reasonable to assume that the relevant battery manufacturers are fully responsible for the defective batteries which were produced by them.

Chapter 1 Background and abstract

From around early years of 1980's, many cameras have come to be provided with electronic features, such as automatic adjustment of light exposure, date memory, electronic shutter, automatic placement of a film roll, automatic winding of a film, and automatic rewinding of a film roll. Portable batteries are used as a power source for the above applications.

Initially, zinc-carbon batteries and alkaline manganese batteries were used as a power source. Later, both higher output power and higher capacity have come to be required than before for advanced type cameras. Consequently majority of present cameras use Lithium batteries. Japanese camera manufacturers have produced and shipped about 36 mln cameras in 1997 from their domestic and overseas factories. These Lithium batteries which are used as a power source of cameras employ spirally wound electrodes so that the battery can provide high output power. Since these batteries use electrodes of very large surface area, battery case and/or camera body may be deformed or even molten when an excessive current flows through these batteries. Since Lithium batteries use metallic Lithium as anode material, which has a relatively low melting point of about 180°C, metallic Lithium may be molten when the battery is excessively overheated and it may lead to fire accidents.

(1) Main conditions in which Lithium batteries are overheated are as follows;

(1.1) When a battery is internally short-circuited.

(1.2) When a battery is abnormally overheated.

(1.3) When an excessive current is provided from outside to flow through a battery or the external circuit is composed to provide an excessive current to flow through a battery.

(1.4) When a charging current of exceeding a certain limit value flows through a battery.

(1.5) When two(2) or more batteries, whose internal resistance or capacity is significantly different from each other, are connected in series and one of these batteries is forcibly discharged.

(2) These Lithium batteries which are now shipped to the market are generally designed to prevent from being overheated at the above conditions ((1.1) - (1.5)). Detail measures against overheating of these batteries are summarized in Fig.1 and brief explanations are as follows;

(2.1) Design

(a) Following measures are taken so that the battery temperature does not increase in above conditions ((1.1) - (1.5)).

(a-1) PTC device is incorporated in the battery.

(a-2) Other measures are taken to prevent internal short-circuiting.

(b) When the battery temperature still increases, inside construction of the battery is destructed by "shut-down" of the separator and the current is ceased to flow.

(c) Battery case is destructed by the operation of safety vent and internal pressure of the battery is decreased to prevent overheating of the battery.

The above three(3) measures and others are explained in detail in Chapter 2.

(2.2) Pilot production

Small amount of batteries which are designed as per (2.1) are produced in a pilot production line. These batteries are examined if they meet necessary design qualities as per (2.1). It should also actually be demonstrated and confirmed with these batteries that all measures as per (2.1) properly work and overheating (accidents) of a battery is prevented.

Details are explained in Chapter 3.

(2.3) Mass production

High amount of batteries which are designed as per (2.1) and whose design qualities are proved to meet as per (2.2) are produced in a mass production line, with suitable production equipment and production engineering technologies to reproduce design qualities as per (2.1).

Number of production defects in a mass production line should be minimized by the proper quality control during production and also these defects should properly be rejected by inspections at various stages before shipment.

It is necessary that each battery manufacturer should elaborate its own expertises to minimize and to reject such defects.

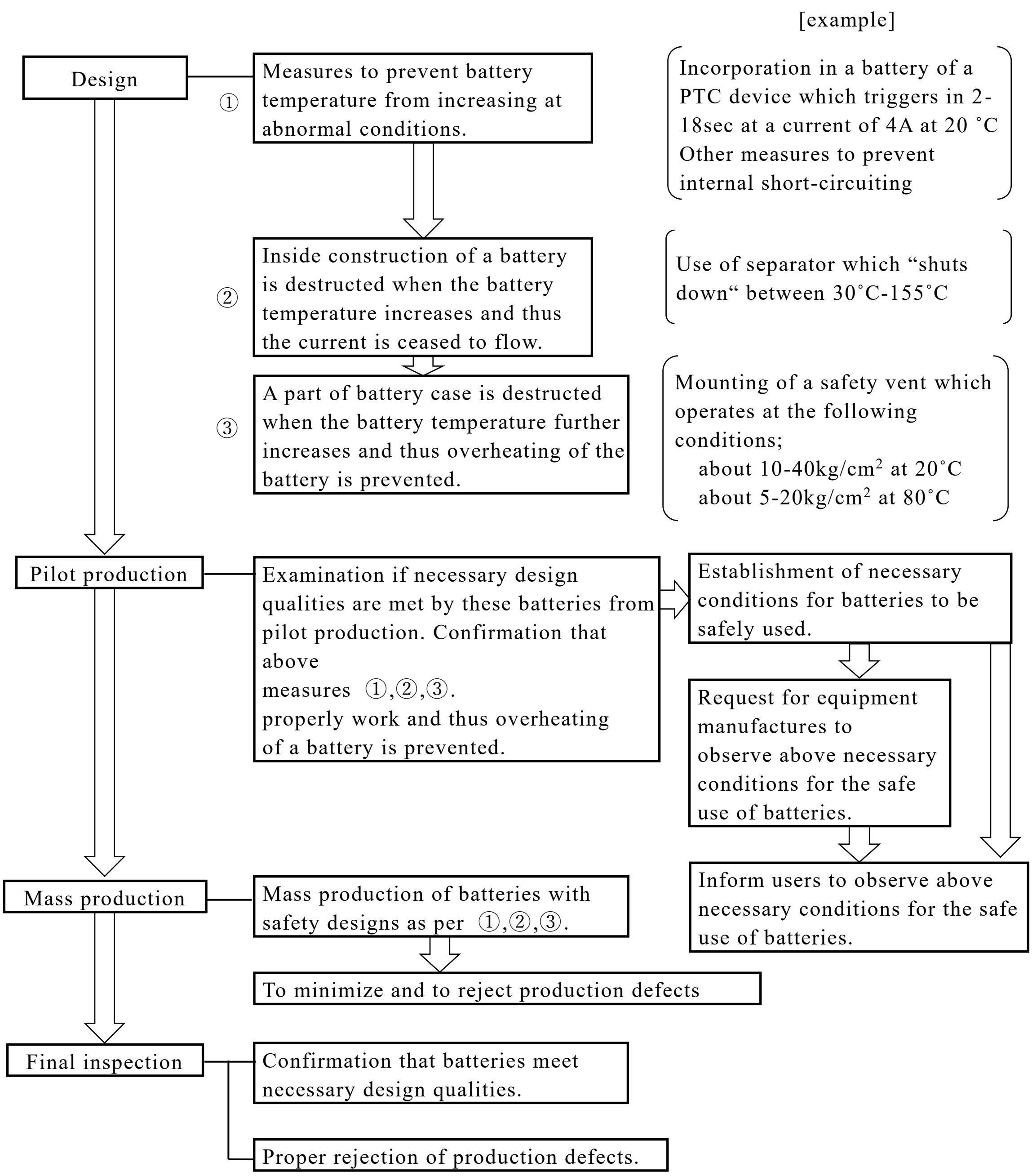
Details are explained in Chapter 3.

(2.4) Final inspection before shipment

These batteries which are mass-produced as per (2.3) are inspected at the final inspection to check if they meet necessary design qualities and then shipped. Each defective battery, as well as defective lots, should also properly be rejected at this inspection. It is necessary that each battery manufacturer should elaborate its own expertises to achieve the above.

Details are explained in Chapter 4.

Fig.1 Flow chart for the design and production of safe Lithium batteries



Chapter 2 Basic design principles for ensuring safety of Lithium batteries

When cylindrical Lithium batteries for camera application are improperly designed, they may cause accidents due to overheating and others. In this chapter, necessary basic design principles for ensuring safety on both single cell Lithium battery and Lithium battery pack are explained. General design principles are explained in (2.1) and these especially related to the prevention of internal short-circuiting are explained in (2.2).

2.1 General design principles

2.1.1 Basic design principles

Lithium battery for camera application should, in principle, be designed as such that it should not overheat and/or explode, its safety vent should not, in principle, operate (*) and significant electrolyte leakage should not occur except when its safety vent operates, at following situations.

(1) When fresh batteries before use are stored.
(2) When a battery is being incorporated in a camera.
(3) When a camera with the battery is actually used to take photos.
(4) When a camera with the battery is exposed to various environmental conditions.
(5) When a battery is being removed from the camera.
(6) When used batteries are removed from cameras and stored before disposal.

* Safety vent should not, in principle, operate. However, when the battery is in abnormal condition and it may overheat and/or explode, the safety vent should be sure to operate and prevent accidents.

Followings are necessary measures which Lithium batteries for camera application should be provided to ensure safety based on the above basic design principles.

2.1.2 Safety design principle of single cell Lithium battery

Safety issues, measures in design for each issue and their explanations are summarized in the following.

2.1.2.1 Internal short-circuiting

a) Measures in design

Measure A: Material and thickness of a separator should properly be selected so that short-circuiting between positive electrode and negative electrode through the separator should be prevented.

Measure B: Width of positive electrode should be designed to be bigger than that of negative electrode. Starting positions of winding of the two(2) electrodes should be displaced between each other so that the edge of positive electrode should not get in touch with negative electrode.

Measure C: Insulators should be placed both at the top and bottom of two(2) electrodes so that wound electrodes are tightly fixed in the battery can and internal short-circuiting due to shock by vibration or drop should be prevented.

Measure D: Lower part of both positive lead and negative lead should be covered with insulation tapes so that internal short-circuiting between the two(2) leads is prevented.

Measure E: Small holes in a separator should be choked ("shut down") when the battery temperature is elevated and thus the internal resistance should be increased. In this way, further current flow should properly be controlled and the battery temperature should not exceed 150℃.

Measure F: Safety vent should properly operate, as follows.

① It should operate at lower pressure at high temperatures than at room temperature.

② When it operates, it should instantaneously open to enough size and eject excessive gases from inside of the battery.

b) Explanations

(1) When a "soft" internal short-circuiting occurs, the self-discharge of a battery increases but it does not lead to unsafe phenomena of a battery. However, when "hard" internal short-circuiting occurs, significant amount of

heat generates in a battery in some cases, and thus the battery may overheat and the safety vent may operate.

(2) One of the reasons why internal short-circuiting occurs is because the positive electrode and the negative electrode get directly in touch with each other through separator. To avoid this, material and thickness of a separator should be selected as described in [Measure A].
When a separator is too thin, internal short-circuiting can easily occur. However, when it is too thick, discharge performance of the battery generally decreases

(3) Other reason is that the edge of positive electrode gets in touch with negative electrode. To avoid this, width of positive electrode should be designed to be bigger than that of negative electrode and starting positions of winding of the two(2) electrodes should be displaced between each other. ([Measure B])

(4) Other reason is that a lead plate of either positive electrode or negative electrode in wound electrodes penetrates through separator and gets in direct touch with the other electrode. It sometimes causes "hard" internal short-circuiting. To avoid this, the following measures have to be taken.

① Wound electrodes should be tightly fixed with the insulators both at the top and bottom of two(2) electrodes so that internal short-circuiting due to shock by vibration or drop is prevented. ([Measure C])
② Lower part of both positive lead and negative lead should be covered with insulation tapes so that internal short-circuiting between the two(2) leads is prevented. It is also effective that the vertical edge of positive electrode is covered with insulation tape. ([Measure D])

(5) When internal short-circuiting actually occurs, it is effective to melt the separator by the generated heat and to choke ("shut down") small holes in the separator. In this way, internal resistance increases and further current flow is controlled. Material of the separator should properly be selected and the

battery should properly be designed so that the separator "shuts down" at appropriate temperature and the battery temperature should not exceed 165℃. ([Measure E])

(6) When internal short-circuiting actually occurs and the battery temperature further increases, the safety vent should operate. ([Measure F])
It should operate at lower pressure at high temperatures than at room temperature, since it is more dangerous at high temperatures. It should also instantaneously open to eject excessive gases from inside of the battery.

2.1.2.2 External short-circuiting

a) Measures in design

Measure A: Terminal construction should be as such that external short-circuiting is difficult to occur.

Measure B: Protective device against excessive current (for example; PTC device) should be incorporated inside the battery to prevent heat generation by an excessive current.

Measure C: Small holes in a separator should be choked ("shut down") when the battery temperature is elevated and thus the internal resistance should be increased. In this way, further current flow should properly be controlled and the battery temperature should not exceed 150℃.

Measure D: Safety vent should properly operate.

b) Explanations

(1) When external short-circuiting occurs, similar phenomena as in the case of internal short-circuiting occur. To avoid this, it is necessary that terminal construction should be as such that external short-circuiting is difficult to occur. For example, terminal should be recessed from external case. ([Measure A])

(2) When external short-circuiting occurs in a battery, it is possible to prevent excessive current from flowing, by incorporating protective device against excessive current (for example; PTC device) inside of the battery. (PTC device

is connected in series with the battery). When excessive current flows through a battery, resistance of PTC significantly increases and thus further flow of excessive current is prevented to avoid overheating of the battery.

[Remarks] It is not possible to prevent excessive current from flowing in case of internal short-circuiting. This is the difference between internal short-circuiting and external short-circuiting.

(3) When a protective device against excessive current inside of the battery operates properly, the battery remains safe even when external short-circuiting occurs. However, when a protective device is defective (or short-circuited), the battery becomes unsafe.
Measures for such cases are the same as those for the case of internal short-circuiting. i.e. Small holes in a separator should be choked ("shut down") ([Measure C]) or safety vent should properly operate. ([Measure D])

2.1.2.3 Discharge

a) Measures in design

Measure A: Protective device against excessive current (for example; PTC device) should be incorporated inside of the battery to prevent heat generation by an excessive current.

Measure B: Small holes in a separator should be choked ("shut down") when the battery temperature is elevated and thus the internal resistance should be increased.
In this way, further current flow should properly be controlled and the battery temperature should not exceed 150℃.

Measure C: Safety vent should properly operate.

b) Explanations

(1) When a battery is discharged during normal camera operations
(taking photo, placing or rewinding a film roll, rewinding and others),
the maximum battery temperature does not exceed about 60℃ and the battery remains safe. However, when a camera becomes defective, it is possible that the battery is overdischarged with abnormal high current. In this case, the

battery is subjected to a similar condition as that at external short-circuiting. Consequently, the same measures as in case of external short-circuiting are requested in design as follows;

[Measure.A]: Incorporation of protective device against excessive current.

[Measure.B]: Choking ("shut down") of small holes in a separator.

[Measure.C]: Operation of a safety vent.

(2) As is the same in the case of external short-circuiting, when a battery is overheated by abnormal discharge, protective device operates and the battery remains safe. However, when a protective device is defective (or short-circuited), [Measure B] and [Measure C] become effective.

2.1.2.4 Drop, vibration and shock

a) Measures in design

Measure A: Insulators should be placed both at the top and bottom of two(2) electrodes so that wound electrodes are tightly fixed in the battery can and internal short-circuiting due to shock by vibration or drop should be prevented.

Measure B: Lower part of both positive lead and negative lead should be covered with insulation tapes so that internal short-circuiting between the two(2) leads is prevented.

b) Explanations

(1) Such physical phenomenon as drop, vibration or shock does not lead chemical substances in a battery into unsafe conditions. However, it is possible that internal short-circuiting may occur due to drop, vibration or shock and the battery becomes unsafe.

(2) Consequently, the same measures as in case of internal short-circuiting are requested as follows;

[Measure.A]: Insulators should be placed both at the top and bottom of two(2) electrodes.

[Measure.B]: Lower part of both positive lead and negative lead should be covered with insulation tapes.

2.1.2.5 Overheating

a) Measures in design

Measure A: Safety vent should be provided to prevent explosion due to the increase of internal pressure when a battery is overheated. Safety vent should be designed in such a way that it should not operate within five(5) hours at 100℃ but it should operate below 165℃.

b) Explanations

Safety vent should be provided to prevent explosion due to the increase of internal pressure when a battery is overheated. When a battery is overheated at 100℃ within five(5) hours, the battery generally remains safe.
Consequently, it is not necessary that the safety vent operates at this condition. However, since a battery generally becomes unsafe after five(5) hours at 100℃, the safety vent should operate.
As the temperature becomes higher, a battery cannot remain safe for long time.
Consequently, the safety vent should operate when the battery temperature reaches at 165℃.

2.1.2.6 Charging by reverse connection

a) Measures in design

Measure A: Battery should be designed so that two(2) negative terminals should not directly contact each other or electric circuit should not be formed when a battery is inserted in a reversed orientation.

Measure B: Safety vent should operate.

b) Explanations

(1) When more than four(4) batteries are connected in series in a circuit and if one~~(1)~~(1) of them is reversely connected, the said one~~(1)~~(1) battery is charged by the rest of batteries.
To avoid this, battery should be designed so that two(2) batteries should not electrically contact each other when one~~(1)~~(1) battery is inserted in a reversed orientation. ([Measure A])

However, if one~~(1)~~(1) battery is charged by the rest of batteries and internal pressure of the said one~~(1)~~(1) battery increases abnormally, it is necessary that the safety vent should operate [Measure B].

(2) When two(2) batteries are connected in series in a circuit and if one~~(1)~~(1) of them is reversely connected, one~~(1)~~(1) battery, whose voltage is lower than the other, is charged by the other battery with higher voltage. However, since voltage difference between the two(2) batteries is relatively small, the said one~~(1)~~(1) battery generally remains safe.

2.1.2.7 Charging by the current of below 10mA

a) Measures in design

Measure A: Materials of both separator and electrolyte should properly be selected so that electrolytic deposition through a separator during charging should be prevented.

Measure B: Safety vent should operate.

b) Explanations

Battery for camera application may possibly be charged by the reverse motive force of a motor. The battery, generally, does not seem to become unsafe by the above charging. Still, it is necessary to take [Measure A]. It is also necessary to take [Measure B] when internal pressure increases abnormally due to above charging.

2.1.2.8 Reversed polarity (No. 1)

When internal resistance* of one~~(1)~~(1) battery in series connection is significantly higher than that of the rest, the said one~~(1)~~(1) battery may be overdischarged into reversed polarity.

* measured at 20℃ by alternative current method (1kHz, 10mA)

a) Measures in design

Measure A: Battery should be designed so that its internal resistance does not exceed about 5 ohm until the battery is discharged to about 75% DOD.

Measure B: Battery should be designed so that little amount of metallic

Lithium remains at the end of discharge.

Measure C: Electrolyte should be as "mild" as possible so that it does not easily catch fire when the battery polarity is reversed.

Measure D: Safety vent should operate when internal pressure of the battery increases abnormally.

b) Explanations

(1) When internal resistance of one~~(1)~~(1) battery in series connection of less than four(4) batteries is significantly higher than that of the rest of batteries, the said one~~(1)~~(1) battery may forcibly be discharged to reversed polarity by the rest of batteries with lower internal resistance and it may overheat.
Example in the case of two(2) batteries in series connection is as follows;
Internal resistance of a normal battery is below 1.0 ohm. If the internal resistance of one of the two(2) batteries increases into 10−50 ohms and these two(2) batteries are continued to be discharged by the current of over 100mA, the battery with higher internal resistance may forcibly be discharged to reversed polarity by the other battery with lower internal resistance and the said battery may generate high amount of heat. However, when the internal resistance significantly increases, the current ceases to flow and thus the battery remains safe. When the internal resistance increases at the end of discharge, the battery also remains safe since remaining capacity is very small.

(2) To avoid this, the internal resistance of a battery should be kept as low as possible by minimizing the contamination with impurities such as water. ([Measure A])
Battery should be designed so that little amount of metallic Lithium remains at the end of discharge. ([Measure B])
Solute in the electrolyte should be as "mild" as possible to keep the battery safe even at reversed polarity. ([Measure C])
Safety vent should operate when internal pressure of the battery increases abnormally due to reversed polarity. ([Measure D])

2.1.2.9 Reversed polarity (No.2)

When discharge capacity of one~~(1)~~(1) battery in series connection is significantly smaller then that of the rest, the said one~~(1)~~(1) battery may be overdischarged into reversed polarity.

a) Measures in design

Measure A: Electrolyte should be as "mild" as possible, so that it does not easily catch fire when the battery polarity is reversed.

Measure B: Battery should be designed so that little amount of metallic Lithium remains at the end of discharge.

Measure C: Safety vent should operate when internal pressure of the battery increases abnormally.

b) Explanations

(1) When more than two(2) batteries but less than four(4) batteries are connected in series, discharge capacity of one~~(1)~~(1) battery may be significantly smaller than that of the rest in following cases;

① Fresh battery and old battery are mixed.
② Batteries from different manufacturers are mixed.
③ Fresh battery and used battery are mixed.

In such cases, the said one~~(1)~~(1) battery with small discharge capacity may forcibly be discharged to reversed polarity by the rest of batteries with large discharge capacity.

(2) To avoid this, it is very important to use "mild" electrolyte such as Lithium tri-fluoro methane sulfonate ($LiCF_3SO_3$). ([Measure A])
Battery should be designed so that little amount of metallic Lithium remains at the end of discharge. ([Measure B])
Safety vent should operate when internal pressure of the battery increases abnormally due to reversed polarity.

2.1.2.10 Low pressure

a) Measures in design

[Measure.A]: Sealing construction should be as such that battery weight should not decrease under low pressure.

b) Explanation

When a camera is used at low pressure, for example at the top of high mountains, chemical materials in a battery does not become dangerous. However, when sealing construction is improper (for example, ununiform sealing, broken gasket), battery weight may decrease and/or electrolyte leakage may occur and thus unsafe phenomena may generate. To avoid this, uniform sealing construction should be ensured with proper die shape, gasket material and gasket shape.

2.1.3 Safety design principles of battery pack made of cylindrical Lithium single cells.

Safety issues, measures in design for each issue and their explanations are summarized in the following.

a) Measures in design

(1) Internal short-circuiting

Measure A: same as [Measure A] of 2.1.2.1 a)
Measure B: same as [Measure B] of 2.1.2.1 a)
Measure C: same as [Measure C] of 2.1.2.1 a)
Measure D: same as [Measure D] of 2.1.2.1 a)
Measure E: same as [Measure E] of 2.1.2.1 a)
Measure F: same as [Measure F] of 2.1.2.1 a)

(2) External short-circuiting

Measure A: same as [Measure A] of 2.1.2.2 a)
Measure B: Protective device against excessive current (for example; PTC device) should be incorporated inside of a battery pack or of a single cell to prevent heat generation by an excessive current.
Measure C: same as [Measure C] of 2.1.2.2 a)
Measure D: same as [Measure D] of 2.1.2.2 a)

(3) Discharge

Measure A: Protective device against excessive current (for example; PTC device) should be incorporated inside of a battery pack or of a single cell to prevent heat generation by an excessive current.

Measure B: same as [Measure B] of 2.1.2.3 a)

Measure C: same as [Measure C] of 2.1.2.3 a)

(4) Drop, vibration and shock

Measure A: same as [Measure A] of 2.1.2.4 a)

Measure B: same as [Measure B] of 2.1.2.4 a)

(5) Overheating

Measure A: same as [Measure A] of 2.1.2.5 a)

(6) Charging by the current of below 10mA

Measure A: same as [Measure A] of 2.1.2.7 a)

Measure B: same as [Measure B] of 2.1.2.7 a)

(7) Reversed polarity (No. 1)

When internal resistance of one~~(1)~~(1) single cell in series connection in the pack is significantly higher than that of the rest, the said single cell may be overdischarged into reversed polarity.

Measure A: same as [Measure A] of 2.1.2.8 a)

Measure B: same as [Measure B] of 2.1.2.8 a)

Measure C: same as [Measure C] of 2.1.2.8 a)

Measure D: same as [Measure D] of 2.1.2.8 a)

(8) Reversed polarity (No.2)

When discharge capacity of one~~(1)~~(1) single cell in series connection in the pack is significantly smaller than that of the rest, the said single cell may be overdischarged into reversed polarity.

Measure A: same as [Measure A] of 2.1.2.9 a)

Measure B: same as [Measure B] of 2.1.2.9 a)

Measure C: same as [Measure C] of 2.1.2.9 a)

(9) Low pressure

[Measure.A]: same as [Measure A] of 2.1.2.10 a)

b) Explanations

(1) As per described in above 2.1.3 a), measures in design are, in principle, the same as these for single cell batteries.

(2) Differences from these for single cell batteries are as follows;

① For 2.1.3 a) (2) External short-circuiting and 2.1.3 a) (2) Discharge, protective device against excessive current (example; PTC device) should be incorporated in each single cell battery. On the other hand, in a battery pack with more than two(2) single cell batteries, protective device against excessive current (example; PTC device) should be incorporated in each single cell battery or connected to the wiring among these single cell batteries. It means that, two(2) protective devices against excessive current (example; PTC devices) are necessary when two(2) single cell batteries are in series connection, but one~~(1)~~(1) protective device against excessive current (example; PTC device) may be enough when two(2) single cell batteries are incorporated in a battery pack.

② When more than two(2) single cell batteries are connected in series, one~~(1)~~(1) of them may be reversely connected and thus it may be charged by the rest. In case of battery pack, single cells are already connected and incorporated in the pack and thus the above problem does not occur.

2.1.4 Additional explanations

a) All battery manufacturers design, produce and inspect their Lithium batteries very carefully to avoid any accidents from occurring based on their full expertises, and thus all these batteries can, in principle, be regarded as safe batteries. However, electrolyte leakage and overheating may sometimes occur when design, production and/or inspection are improperly performed as follows;

(1) Electrolyte leakage;

Electrolyte in a battery comes out from improper sealing of the battery or when safety vent operates in abnormal conditions. Leakage of electrolyte itself does not cause any unsafe phenomena but organic electrolyte which leaked out of the battery may catch fire when fire source is present nearby.

(2) Overheating;

Battery may generate large amount of heat and may overheat under the conditions of 1.1-1.5 of Chapter 1. Usually, when a battery temperature reaches a certain limit value, various safety devices in a battery operate and thus further heat generation and overheating is prevented. However, when design, production and/or inspection are improperly performed, these safety devices may not properly operate and thus battery case and/or camera body may be deformed or molten due to overheating of a battery and fire may occur in extreme cases.

b) Followings are possible causes of overheating.

(1) Single cell battery

① "Hard" internal short-circuiting
② External short-circuiting when protective device against excessive current (example; PTC device) is defective
③ Discharge with very high current* when protective device against excessive current (example; PTC device) is defective
* Value of "very high current" is specified by manufacturers. If not specified, short-circuit current value is applied.
④ Overheating
⑤ Charging (including charging by reverse connection)
⑥ Deformation by pressing
⑦ Drilling
⑧ Operation of safety vent near fire source.

(2) Battery consisting of less than four(4) single cells.

① Same as 2.1.4 b) (1) ①
② Same as 2.1.4 b) (1) ②
③ Same as 2.1.4 b) (1) ③

④ Same as 2.1.4 b) (1) ④
⑤ Same as 2.1.4 b) (1) ⑤
⑥ Same as 2.1.4 b) (1) ⑥
⑦ Same as 2.1.4 b) (1) ⑦
⑧ Same as 2.1.4 b) (1) ⑧
⑨ Forced discharge due to significant difference of internal resistance among single cells.
⑩ Forced discharge due to significant difference of discharge capacity among single cells.

(3) Battery pack
① Same as 2.1.4 b) (1) ①
② Same as 2.1.4 b) (1) ②
③ Same as 2.1.4 b) (1) ③
④ Same as 2.1.4 b) (1) ④
⑤ Same as 2.1.4 b) (1) ⑤
⑥ Same as 2.1.4 b) (1) ⑥
⑦ Same as 2.1.4 b) (1) ⑦
⑧ Same as 2.1.4 b) (1) ⑧
⑨ Same as 2.1.4 b) (1) ⑨
⑩ Same as 2.1.4 b) (1) ⑩

c) Overheating of a battery due to above (b) can be prevented by "measures in design" as per 2.1.2 and 2.1.3.

d) "Deformation by pressing", "Drilling" and "Operation of safety vent near fire source", as per above (b) are not related to these batteries in a camera. Consequently, those items except these three(3) were explained in detail in 2.1.2 and 2.1.3.

2.2 Important design principles for the prevention of internal short-circuiting.

Followings are important design principles of Lithium batteries for camera application to prevent them from internal short-circuiting and thus to ensure safety.

These items which are marked as ◎ should, in principle, be employed. However, these items which are marked as ● may not always be necessary or effective to employ, depending on the basic design of Lithium batteries of each manufacturer. Consequently, it should carefully be studied based on basic design principles of each manufacturer, if these items which are marked as ● should be employed.

2.2.1 Materials and components of a battery.

2.2.1.1 Requirements on separator material.

a) It should have sufficient mechanical strength.

◎ (1) It should not break or tear during winding with electrodes.

◎ (2) It should not break or produce pin-holes when strange particle is mingled and winding is blocked.

b) Short-circuiting should not occur by the penetration of particles through separator.

◎ (1) Small particles of positive mix should not penetrate through separator.

c) Heat resistivity of a separator.

◎ (1) When discharge current of a battery abnormally increases or internal short-circuiting occurs, the separator should "shut down" to cut-off the current and prevent abnormal increase of temperature.

◎ (2) Separator should not shrink and thus should not lose film characteristics due to abnormal overheating of current collector lead during discharge with very high current or internal short-circuiting.

[Remarks] Normally, current collector lead is covered with insulation tape to avoid abnormal overheating.

d) Separator should be thick enough to prevent short-circuiting.
However, suitable thickness should be selected to ensure acceptable discharge performances of a battery.

e) Evaluation criteria of "shut-down" performance of a separator.
(1) Various methods are proposed for the evaluation of "shut-down" performance of a separator but standard method is not defined yet. Some of them are as follows;
① Measurement of the change of internal resistance when a battery is heated up at a constant rate.
② Measurement of the battery temperature when a battery is short-circuited and a current is decreased to a certain level.
(2) Shut down temperature is normally designed to be 130-155℃ with presently available batteries.

2.2.1.2 Safety evaluation criteria of a safety vent.

a) Safety vent operates when internal pressure of a battery abnormally increases during internal short-circuiting and others and ejects gases and/or electrolyte from inside of a battery. In this way, it prevents explosion and other accidents from occurring.

b) It is generally designed to operate at the following conditions in presently available batteries.
(1) 10 – 40kg/cm^2 at 20℃
(2) 5 - 20kg/cm^2 at 80℃

2.2.1.3 Protective device against excessive current

a) When a very high current flows through a battery and the battery temperature increases, its resistance value increases significantly and thus further current is ceased to flow. It is a reversible component.

b) PTC is a typical protective device against excessive current and it is generally designed to trigger in 2-180sec with a current of 4A at 20℃ in presently available batteries. In future, other devices than PTC may also be used for the same purpose.

2.2.1.4 Electrolyte

a) It is preferred to use electrolyte of weak oxidation power for the prevention of possible overheating of a battery at reversed polarity. Lithium trifluoro methane sulfonate ($LiCF_3S0_3$) is a typical solute to be used for electrolyte of weak oxidation power.

b) It is also necessary that electrolyte of environmentally friendly nature should be used.

2.2.2 Production process

2.2.2.1 Production process of positive electrode

◎ (1) Width of positive electrode should be bigger than that of negative electrode (metallic Lithium)

● (2) Lead position of positive electrode and negative electrode should be displaced between each other.

● (3) Both width and length of positive lead should properly be adjusted.

◎ (4) Burr at the cut-off surface of electrodes should be kept under proper tolerance limit.

● (5) Welding position of positive lead should properly be adjusted.

● (6) Vertical edge of positive electrode should be covered with an insulation tape.

● (7) Positive electrode should be put into a separator bag.

2.2.2.2 Production process of negative electrode

◎ (1) Negative lead should be covered with an insulation tape.

◎ (2) Both width and length of negative lead should properly be adjusted.

2.2.2.3 Winding process

◎ (1) Starting position of winding of positive electrode should be in advance of that of both negative electrode and separator.

◎ (2) External diameter of wound electrodes should properly be adjusted.

● (3) When polarity of battery case and electrode at the external circumference is different, the electrode should fully be covered with separator to avoid direct contact with the battery case.

● (4) Positions of positive lead and negative lead should be displaced between each other.

◎ (5) Displacement of wound electrodes should be kept under proper tolerance limit.

2.2.2.4 Assembly process

◎ (1) Insulation plate at the bottom should properly be designed.

◎ (2) Upper insulation ring should properly be designed.

Chapter 3 Quality control items in a production process

It is most important to prevent internal short-circuiting in production processes of cylindrical Lithium batteries for camera application. Typical quality control items in each production process are summarized in the following.

Several of them may not be necessary depending on construction and/or production method of batteries in each manufacturer.

a) Production process of positive electrode

(1) Scatter of the thickness of mix sheet.

(2) Drop and adhesion of mix powder during cut-off and transportation of mix sheet.

(3) Dimension of burr of positive lead.

(4) Welding position of positive lead.

(5) Presence and position of insulation tape which is used to cover positive lead.

(6) Presence and position of insulation tape which is used to cover vertical edge of positive electrode.

b) Production process of negative electrode

(1) Dimension of burr of negative lead.

(2) Presence and position of insulation tape which is used to cover lead section of negative lead.

c) Winding process

(1) Starting position of winding of positive electrode and negative electrode, respectively.

(2) Pressure during winding.

(3) Prevention of blocking of winding by strange particles.

(4) Prevention of displacement of positive electrode, negative electrode and/or separator during winding. (Prevention of bamboo shoot like winding and/or exposure of metallic Lithium.)

(5) External diameter of wound electrodes. (Prevention of loose winding or forcible insertion of wound electrodes in the battery case.)

(6) Prevention of the separator from being excessively folded during winding.

(7) Measurement of the insulation resistance of all wound electrodes after winding and rejection of defects due to internal short-circuiting.

d) Assembly process

(1) Presence of insulation plate at the bottom.
(2) Degree of bending of positive lead and negative lead, respectively.
(3) Presence of upper insulation ring.
(4) Measurement of the insulation resistance of all assembled batteries and rejection of defects due to internal short-circuiting.

e) Finishing process and inspection process before shipment.

(1) Inspection of battery temperature.
(2) Inspection of OCV (open circuit voltage).
(3) Inspection of CCV (closed circuit voltage).
(4) Rejection of defects due to internal short-circuiting by subjecting batteries to vibration, drop or aging.
(5) Inspection of internal construction of batteries (random sample) with transmission X ray.

Chapter 4 Safety tests and criteria

4.1 Safety tests and criteria of cylindrical Lithium single cell battery.

4.1.1 Internal short-circuiting, Crush

4.1.1.1 Internal short-circuiting

a) Test procedure

A test battery* is to be placed on a flat wooden plate. A nail, whose diameter is 2.5 mm and length is 40-70 mm, is to be drilled and penetrated through center of the battery, perpendicular through center of the battery, perpendicular to its longitudinal axis.

* Fresh (undischarged) battery and 50% D.O.D. battery, respectively.
(i.e. Two(2) tests should be conducted)

b) Requirements

No explosion and no fire.

c) Explanation

The aim of this test is to determine the behavior of battery at "hardest" internal short-circuiting. Nail penetration through the battery was adopted to simulate "hardest" internal short-circuiting.

4.1.1.2 Crush

a) Test procedure

A test battery is to be crushed between two(2) flat surfaces. It is to be crushed with its longitudinal axis parallel to the flat surfaces of the crushing apparatus. The force for the crushing is to be approximately 3,000 pounds (13 KN). The force is to be applied by a vise or by a hydraulic ram.

b) Requirements

No explosion and no fire.

c) Explanation

The aim of this test is to determine the behavior of a battery when it is crushed in a waste compactor.

4.1.2 External short-circuiting

4.1.2.1 Test A

a) Test procedure
A test battery is to be externally short-circuited at the following conditions.

(1) -20℃ 24 hrs

(2) +20℃ 24 hrs
(3) +80℃ 5 hrs

b) Requirements
No venting, no fuming, no explosion and no fire.
Battery temperature should not exceed 130℃.

4.1.2.2 Test B

a) Test procedure
A test battery is to be externally short-circuited in a battery case of camera, for 24 hrs at 20℃.

b) Requirements
No venting, no fuming, no explosion, and no fire.
Battery temperature should not exceed 130℃

4.1.2.3 Explanations of Test A and Test B

a) Test periods at -20℃ and +20℃ are specified to be 24 hrs so that to be enough for battery temperature to reduce to original ambient temperature. Normally, it takes 3-4 hrs for battery temperature to reduce to original ambient temperature.

b) Test condition 4.1.2.1 a) (3) +80℃ 5 hrs, is severer than that of 4.1.2.1 a) (1) and 4.1.2.1 a) (2).

c) Any safety problem does not seem to occur when a test battery remains over above time periods, at respective temperatures.

4.1.3 Discharge

a) Test procedure
A test battery is to be discharged at 2 ohm for 24 hrs at 20℃ and 60℃, respectively.

b) Requirements
No electrolyte leakage, no venting, no fuming, no explosion and no fire. Battery temperature should not exceed 100℃

c) Explanation
The aim of this test is to confirm that a battery can properly operate when it is used in a camera.
A pulse discharge of about 1A is assumed to be a typical specification for normal use of camera, and continuous discharge at about 1A is assumed to be a typical specification when a motor continues to operate during blocking of a film.
Consequently, continuous discharge at 2 ohm (corresponding to about 1A) was adopted to simulate above conditions.

4.1.4 Drop, Vibration, Shock, Impact

4.1.4.1 Drop

a) Test procedure
A test battery is to be dropped randomly ten(10) times from 1.9 m (6 feet) onto a concrete floor.

b) Requirements
No venting, no fuming, no explosion and no fire.
Battery temperature should not exceed 45℃.

4.1.4.2 Vibration

a) Test procedure

A test battery is to be subjected to a simple harmonic motion with an amplitude of 0.8 mm (0.03 inch) (1.6 mm total maximum excursion). The frequency of the harmonic motion is to be increased and decreased at a rate of 1 Hz/min between limits of 10 Hz and 55 Hz.
It has to be tested in three(3) mutually perpendicular directions for 90-100 min, respectively.

b) Requirements
No venting, no fuming, no explosion and no fire.
Battery temperature should not exceed 45℃

4.1.4.3 Shock

a) Test procedure
A test battery is to be secured to the testing machine. It is to be subjected a total of three(3) shocks of equal magnitude, which are applied in each of three(3) mutually perpendicular directions. For each shock, the battery is to be accelerated so that in the initial 3 ms, the minimum acceleration is 75 gn, and the peak acceleration is between 125-175 gn (gn : local acceleration due to gravity).

b) Requirements
No venting, no fuming, no explosion and no fire.
Battery temperature should not exceed 45℃.

4.1.4.4 Impact

a) Test procedure
A test battery is to be placed on a flat surface. A 7.9 mm (5/16 inch) diameter bar is to be placed across the center of the battery. A 9.1 kg (20 pound) weight is dropped from a height of 61 cm (2 feet) on to it.

b) Requirements
No venting, no fuming, no explosion and no fire.
Battery temperature should not exceed 45℃.

4.1.5 High temperature storage, Thermal shock, Thermal exposure

4.1.5.1 High temperature storage

a) Test procedure

A test battery is to be exposed to following conditions.

(1) 5 hrs at 100℃, then 8 hrs at 20℃.

(2) 30 hrs at 60℃, then 8 hrs at 20℃.

b) Requirements

No venting, no fuming, no explosion and no fire.

Battery temperature should not exceed 130℃.

4.1.5.2 Thermal shock

a) Test procedure

A test battery is stored for 1 hr in -20℃, moved to a temperature of 60℃ within 5 min and stored for 1 h, then it is moved again to a temperature of -20℃. This cycle is repeated for nine(9) times.

b) Requirements

No venting, no fuming, no explosion and no fire.

Battery temperature should not exceed 100℃.

4.1.5.3 Thermal exposure

a) Test procedure

A test battery is to be placed in an oven. The oven temperature is to be increased at a rate of 5/min until the oven reaches 150℃. The oven is to be maintained at 150℃ for 10 min.

b) Requirements

No explosion and no fire.

4.1.5.4 Explanations of 4.1.5.1-4.1.5.3

The aim of these tests is to determine the thermal stability of a battery at elevated temperatures.

These tests should be conducted by properly adjusting ambient temperatures.

4.1.6 Charging by reverse connection

a) Test procedure

Four(4) batteries are to be connected in series with one~~(1)~~(1) battery (test battery) reversed for 24 hrs at 20℃.

b) Requirements

No overheating, no fuming, no explosion and no fire.

c) Explanation

One~~(1)~~(1) battery may be reversely connected, by mistake, in series connection of more than two(2) batteries. The aim of this test is to determine the behavior of a battery when it is reversely connected in series connection of four(4) batteries, which is used very often in actual applications.

4.1.7 Charging by the current of below 10 mA

a) Test procedure

A test battery is to be charged for 1 hr with a current of 10 mA at 20℃.

b) Requirements

No venting, no fuming, no explosion and no fire.
Battery temperature should not exceed 100℃.

c) Explanation

When a battery is used as a main power source of camera, it may be charged with a charging current due to reverse electromotive force which generates in a motor.
Normally, a prevention circuit of reverse electromotive force is provided and thus the battery is not charged.
The aim of this test is to evaluate the ability of a battery to withstand a small charging current when it is charged by any possibility.

4.1.8 Reversed polarity (No. 1)

When internal resistance of one~~(1)~~(1) battery in series connection of more than two(2) batteries is significantly higher than that of the rest, the said (one) battery may be overdischarged into reversed polarity.

a) Test procedure

A test battery* is to be stored for ten(10) days at 60℃ and to be connected in series with other three(3) batteries* (total of four(4) batteries) and with a resistance of 8.2 ohm. The circuit is to be closed and the four(4) batteries are to be discharged for 24 hrs at 20℃.

* batteries of 25%, 50% and 75% D.O.D., respectively

i.e. Three(3) tests should be conducted.

b) Requirements

No overheating, no fuming, no explosion and no fire.

c) Explanation

When a battery is improperly designed and/or produced, its internal resistance is easy to increase if it is discharged to a certain extent and then stored for a certain period at an elevated temperature.

The aim of this test is to determine the behavior of a test battery which is subjected to the above condition.

8.2 ohm resistance was selected by assuming about 2 ohm resistance for each battery. (See 4.1.3)

4.1.9 Reversed polarity (No.2)

When discharge capacity of one~~(1)~~(1) battery in series connection of more than two(2) batteries is significantly smaller than that of the rest, the said one~~(1)~~(1) battery may be overdischarged into reversed polarity.

a) Test procedure

A test battery* is to be connected in series with three(3) fresh (undischarged) batteries (total of four(4) batteries) and a resistance of 8.2 ohm. The circuit is to be closed and the four(4) batteries are to be discharged for 24 hrs at 20℃.

* battery of 25%, 50% and 75% D.O.D., respectively

i.e. Three(3) tests should be conducted.

b) Requirements

No overheating, no fuming, no explosion and no fire.

c) Explanation

This test assumes a popular case in which four(4) batteries are connected in series. 8.2 ohm resistance was selected by assuming about 2 ohm resistance for each battery. (See 4.1.3)

4.1.10 Low pressure

a) Test procedure

A test battery is to be placed in a vacuum chamber which has a pressure equal to or less than 11.6 kPa for six(6) hrs at an ambient temperature of 20℃.

b) Requirements

No deformation, no electrolyte leakage, no fuming, no explosion and no fire.

c) Explanation

The aim of this test to evaluate the ability of a battery to withstand low ambient pressures. This test simulates an altitude of 15,240 m.

4.1.11 Remarks

(1) Overheating means that the temperature of external surface of a single cell Lithium battery exceeds 150℃.

(2) Fuming means that a smoke emits by partial thermal decomposition of the plastic resin of battery case and/or of camera body.

(3) Unless otherwise stated, an ambient test temperature should be 20±15℃.

(4) Unless otherwise stated, a test battery should be a fresh (undischarged) battery.

(5) For external short-circuiting, the resistance of wiring should be below 0.05 ohm.

4.1.12 Number of test batteries and criteria

The aim of above tests (4.1.1-4.1.10) is to evaluate safety level of Lithium single cell batteries for camera application.

Number of test batteries and test criteria are specified as follows;

(1) Number of test batteries

n = 5 for each test item

[Remarks]

When two(2) or more test conditions (for example : different test temperatures or different D.O.D. of test batteries) are specified for each test, test with n=5 should be conducted at each test condition.

(2) Test criteria

The relevant test lot is to be rejected if one~~(1)~~(1) battery fails the test.

4.2 Safety tests and criteria of cylindrical Lithium battery pack

4.2.1 Internal short-circuiting, Crush

4.2.1.1 Internal short-circuiting

a) Test procedure

Same as 4.1.1.1 a)

b) Requirements

No explosion and no fire

4.2.1.2 Crush

a) Test procedure

Same as 4.1.1.2 a)

b) Requirements

No explosion and no fire

4.2.2 External short-circuiting

4.2.2.1 Test A

a) Test procedure

A test battery pack is to be externally short-circuited at the following conditions.

(1) -20℃, 24 hrs

(1) +20℃, 24 hrs

(2) +80℃, 5 hrs

b) Requirements

No venting, no fuming, no explosion and no fire.
Temperature of a battery pack should not exceed 130℃.

4.2.2.2 Test B

a) Test procedure

A test battery pack is to be externally short-circuited in a battery case of camera for 24 hrs at 20℃.

b) Requirements

No venting, no fuming, no explosion and no fire.
Temperature of a battery pack should not exceed 130℃.

4.2.2.3 Test C

a) Test procedure

A single cell battery for a test battery pack is to be externally short-circuited at the following conditions.

(1) -20℃, 24 hrs
(2) +20℃, 24 hrs
(3) +60℃, 5 hrs

b) Requirements

No explosion and no fire.

4.2.3 Discharge

a) Test procedure

A test battery pack is to be discharged at 4.3 ohm for 24 hrs at 20℃ and 60℃, respectively.

b) Requirements

No electrolyte leakage, no venting, no fuming, no explosion and no fire. Temperature of a battery pack should not exceed 100℃.

4.2.4 Drop, Vibration, Shock, Impact

4.2.4.1 Drop

a) Test procedure
Same as 4.1.4.1 a)

b) Requirements
No venting, no fuming, no explosion and no fire.
Temperature of a battery pack should not exceed 45℃.

4.2.4.2 Vibration

a) Test procedure
Same as 4.1.4.2 a)

b) Requirements
No venting, no fuming, no explosion and no fire.
Temperature of a battery pack should not exceed 45℃

4.2.4.3 Shock

a) Test procedure
Same as 4.1.4.3 a)

b) Requirements
No venting, no fuming, no explosion and no fire.
Temperature of a battery pack should not exceed 45℃.

4.2.4.4 Impact

a) Test procedure
Same as 4.1.4.4 a)

b) Requirements
No venting, no fuming, no explosion and no fire.
Temperature of a battery pack should not exceed 45℃.

4.2.5 High temperature storage, Thermal Shock, Thermal exposure

4.2.5.1 High temperature storage

a) Test procedure
Same as 4.1.5.1 a)

b) Requirements
No venting, no fuming, no explosion and no fire.
Temperature of a battery pack should not exceed 130℃.

4.2.5.2 Thermal shock

a) Test procedure
Same as 4.1.5.2 a)

b) Requirements
No venting, no fuming, no explosion and no fire.
Temperature of a battery pack should not exceed 100℃.

4.2.5.3 Thermal exposure

a) Test procedure
Same as 4.1.5.3 a)

b) Requirements
No explosion and no fire.

4.2.6 Charging by the current of below 10 mA

a) Test procedure
Same as 4.1.7 a)

b) Requirements
No venting, no fuming, no explosion and no fire.
Temperature of a battery pack should not exceed 100℃.

4.2.7 Reversed polarity (No. 1)

When internal resistance of one~~(1)~~(1) battery in series connection of more than two(2) batteries is significantly higher than that of the rest, the said one~~(1)~~(1) battery may be overdischarged into reversed polarity.

a) Test procedure

A test battery (*) is to be stored for ten(10) days at 60℃ and to be connected in series with another battery (*) (total of two(2) batteries) with a protective device against excessive current (example; PTC device) in a battery pack. These two(2) batteries in the battery pack are to be discharged with a resistance of 4.3 ohm for 24 hrs at 20℃.

*: batteries of 25%, 50% and 75% D.O.D., respectively

i.e. Three(3) tests should be conducted.

b) Requirements

No overheating, no fuming, no explosion and no fire.

4.2.8 Reversed polarity (No.2)

When discharge capacity of one~~(1)~~(1) battery in series connection of more than two(2) batteries is significantly smaller than that of the rest, the said one~~(1)~~(1) battery may be overdischarged into reversed polarity.

a) Test procedure

A test battery (*) is to be connected in series with a fresh (undischarged) battery (total of two(2) batteries) with a protective device against excessive current (example; PTC device) in a battery pack. These two(2) batteries in the battery pack are to be discharged with a resistance of 4.3 ohm for 24 hrs at 20℃.

*: battery of 25%, 50% and 75% D.O.D., respectively

i.e. Three(3) tests should be conducted.

b) Requirements

No overheating, no fuming, no explosion and no fire.

4.2.9 Low pressure

a) Test procedure

Same as 4.1.10 a)

b) Requirements

No deformation, no electrolyte leakage, no fuming, no explosion and no fire.

4.2.10 Remarks

(1) Overheating means that the temperature of external surface of a single cell Lithium battery exceeds 150℃.

(2) Fuming means that a smoke emits by partial thermal decomposition of the plastic resin of battery case and/or of camera body.

4.2.11 Number of battery packs for test and criteria

The aim of above tests 4.2.1-4.2.9 is to evaluate safety level of Lithium battery packs for camera application.

Number of battery packs for test and test criteria are specified as follows;

(1) Number of battery packs for test

n = 5 for each test item

[Remarks]

When two(2) or more test conditions (for example, different test temperatures and different D.O.D of test batteries) are specified for each test, test with n = 5 should be conducted at each test condition.

(2) Test criteria

The relevant test lot is to be rejected if one~~(1)~~(1) battery pack fails the test.

4.2.12 Explanations

4.2.12.1 4.2.8 Reversed polarity (No.2);

(1) When single cell batteries are used for camera application, fresh battery and old battery or batteries from different manufacturers may sometimes be mixed together in series connection by end users. In such cases, discharge capacity of each battery may significantly be different among each other and thus it is necessary that a battery of 25%, 50% and 75% D.O.D., respectively, should be tested.

(2) On the contrary, in case of a battery pack, single cell batteries with similar level of discharge capacity are generally selected by pack manufacturers and incorporated in a pack, and thus discharge capacity of each battery in a pack

does not significantly differ, unless it is internally short-circuited in the pack and its capacity has decreased.

Such failure can be prevented by each battery manufacturer with a suitable battery design and proper quality control to reject production defects. Consequently, each battery manufacturer can judge if this test should be conducted based on its own level of quality control. Normally, it is recommended that the test with 25% D.O.D. battery should be conducted and each manufacturer should decide if the other two(2) tests (with 50% D.O.D. battery and 75% D.O.D. battery) should be conducted.

4.2.12.2 External battery case

(1) These battery packs which passed the above safety tests 4.2.1−4.2.9 do not, in general, catch fire. However, when it is heated to 200℃ or a single cell battery in the pack is subjected to "hard" internal short-circuiting, it may catch fire. Consequently, it is recommended to use non-combustible plastic resin for external battery case.

(2) Necessary characteristics which are required for battery case, other than safety, are as follows.

① Heat resistivity
② (Thermal deformation temperature should sufficiently be high.)
③ Resistance against electrolyte solution
④ Shock resistivity
⑤ Environmentally friendly nature

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